SPECIAL REPORT

Green Chemistry in California: A Framework for Leadership in Chemicals Policy and Innovation

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Prepared for:
The California Senate Environmental Quality Committee
The California Assembly Committee on Environmental Safety and Toxic Materials

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About the California Policy Research Center and This Report

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This report was prepared in response to a January 2004 request for technical assistance in the area of chemicals policy from California State Senator Byron Sher, chair of the Senate Environmental Quality Committee, and Assembly Member John Laird, chair of the Assembly Committee on Environmental Safety and Toxic Materials. The request was prompted by the committees' interest in a California chemicals policy that would address public and environmental health concerns while also building long-term capacity in the design, production, and use of chemicals that are safer for humans and the environment. The committees were also interested in the implications for California of chemicals policy developments occurring in the European Union.

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The views and recommendations expressed are those of the principal author and do not necessarily represent the opinions of the sponsors or funders or the Regents of the University of California.

About the Authors

Michael P. Wilson, the principal author, is an assistant research scientist with the Northern California Center for Occupational and Environmental Health (COEH), School of Public Health, UC Berkeley. The California Legislature established COEH in 1978 (AB 3414) to improve understanding of occupational and environmental health problems in California and work toward their resolution through research, teaching, and service. The Northern California COEH consists of researchers and practitioners at UC Berkeley, UC San Francisco, and UC Davis. Daniel A. Chia and Bryan C. Ehlers conducted research for the report as part of their graduate studies at the Goldman School of Public Policy at UC Berkeley.

About the Advisory Committee

A 13-member Advisory Committee (see following page) provided technical oversight for the report. The full committee was convened one time. Committee members provided individual consultation to the primary author and written comments on three drafts of the report. The report, however, is not a consensus document; final responsibility for the report content rests with the primary author, not with the committee, individually or collectively.

The Advisory Committee

Acknowledgments

The authors extend their appreciation to the members of the Advisory Committee and to Holly Brown-Williams, Al Averbach, John Crapo, Andrés Jiménez, Robert Spear, John Balmes, Steve Shortell, and the many individuals in California, the United States, and the European Union who freely offered their experience and knowledge in chemicals policy.

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Going forward, the chemical industry is faced with a major conundrum—the need to be sustainable (balanced economically, environmentally, and socially in order to not undermine the natural systems on which it depends)—and a lack of a more coordinated effort to generate the science and technology to make it all possible.

Committee on Grand Challenges for Sustainability in the Chemical Industry
The National Academy of Sciences
December 2005[1]

For 25 years, the Golden State has led the nation in programs to save energy; these, in turn, reduce the greenhouse-gas emissions that contribute to global warming. California now uses half as much energy per capita as the nation as a whole, saving the average household $1,000 each year, with total savings now more than $56 billion.

Hal Harvey
Director of Environment Programs
The Hewlett Foundation
February 2006[2]

Executive Summary

By 2050, California's population is expected to grow by about 50%, from 36 to 55 million residents. This expansion will be accompanied by a growing set of social, economic, and environmental problems whose *magnitude* will be determined in large part by the policy decisions California makes now and in coming years. In charting a course to a sustainable future, policymakers will need to guide industrial development in such a way that it fully integrates matters of environmental quality and human health. In practice, if California is to create a future characterized by improving social, environmental, and economic conditions, industrial development will need to *solve*, not exacerbate, the public and environmental health problems facing the state today. To move California in this direction, policymakers need the support of research that links the science of public and environmental health to innovative policy solutions. This report serves that purpose in the area of chemicals policy.

The report makes the case that a modern, comprehensive chemicals policy is essential to placing California on the path to a sustainable future. Problems associated with chemicals are already affecting public and environmental health, business, industry, and government in California. On the current trajectory, the coming years will see these problems broaden and deepen. Correcting these problems will require much more than isolated chemical bans and other piecemeal approaches that currently characterize the Legislature's efforts in this arena. Rather, a comprehensive approach is needed that corrects long-standing federal chemicals policy weaknesses and builds the foundation for new productive capacity in green chemistry—the design, manufacture, and use of chemicals that are safer for biological and ecological systems. This approach to chemicals policy will link economic development in California with improved health and environmental quality, but it will require a long-term commitment to leadership on the part of California policymakers.

We describe initiatives by leading California businesses and the European Union (E.U.) that are already driving interest by industry in cleaner technologies, including green chemistry. Given California's unparalleled capacity for innovation and its scientific, technical, and financial resources, a proactive response to these developments in the form of a modern, comprehensive chemicals policy could position California to become a global leader in green chemistry innovation. The report illustrates that to do so, California will need to adopt a chemicals policy that greatly improves chemical information, regulatory oversight, and support for green chemistry research, development, technical assistance, and education.

Methods

We used four research methods in preparing this report: a literature review, interviews with key informants, participation in chemicals policy meetings, and peer review. Over a two-year period, the primary author held discussions with chemicals policy experts affiliated with academic institutions, scientific bodies, governmental agencies, chemical producers, downstream users of chemicals, entities within the European Union, small and medium-sized enterprises, environmental organizations, and labor organizations. In addition, between April 2003 and February 2006, the primary author participated in 35 meetings and conferences pertaining expressly or in part to chemicals policy matters; he presented the report's key concepts at 17 of these meetings. The report reflects feedback produced throughout this process.

Major Findings

The scale of chemical production is immense and will continue to expand globally.

Every day, the U.S. produces or imports 42 billion pounds of chemicals, 90% of which are created using oil, a non-renewable feedstock. Converted to gallons of water, this volume is the equivalent of 623,000 gasoline tanker trucks (each carrying 8,000 gallons), which would reach from San Francisco to Washington, D.C., and back if placed end-to-end. In the course of a year, this line would circle the earth 86 times at the equator. These chemicals are put to use in innumerable processes and products, and at some point in their life cycle many of them come in contact with people—in the workplace, in homes, and through air, water, food, and waste streams. Eventually, in one form or another, nearly all of them enter the earth's finite ecosystems.

Global chemical production is expected to double every 25 years for the foreseeable future. Between now and 2033, the U.S. EPA expects 600 new hazardous waste sites to appear each month in the U.S. and require cleanup, adding to 77,000 current sites. Efforts at site mitigation are expected to cost about $250 billion. Given the scale, pace, and burden of chemical production, the toxicity and ecotoxicity of chemicals are of great public importance.

Many chemicals that are useful to society are also hazardous to human biology and ecological processes.

There is growing scientific concern over the biological implications of chemical exposures that occur over the human lifespan, particularly during the biologically sensitive period of fetal and child development. Hundreds of chemicals that are released into the environment are accumulating in human tissues; the U.S. EPA found just under 700 such chemicals in a nationwide survey of Americans in 1987. Many of these chemicals enter the developing organ systems of fetuses and infants through the maternal bloodstream and through breast milk. Animal studies indicate that some can interact with and disrupt the development of these systems, such as the endocrine system, at very low doses. Among children, chemical exposures are estimated to contribute to 100% of lead poisoning cases, 10% to 35% of asthma cases, 2% to 10% of certain cancers, and 5% to 20% of neurobehavioral disorders.

Occupational disease continues to exact a tremendous toll in California. Each month, an estimated 1,900 Californians are diagnosed with a preventable, deadly chronic disease that is attributable to chemical exposures in the workplace; another 540 Californians die as a result of a chronic disease linked to chemical exposures in the workplace. The U.S. Occupational Safety and Health Administration (OSHA) has adopted workplace exposure limits for only 193, or about 7%, of the 2,943 chemicals produced or imported in the U.S. at more than one million pounds per year. Immigrants, minorities, and lower-income groups—as workers and as residents—are at particular risk of exposure to hazardous chemicals.

There are extensive deficiencies in the federal regulation of chemicals.

Of all federal environmental statutes, the Toxic Substances Control Act of 1976 (TSCA) is the only law that is intended to enable regulation of chemicals both before and after they enter commerce. However, studies conducted by the National Academy of Sciences (1984), the U.S. General Accounting Office (1994), the Congressional Office of Technology Assessment (1995), Environmental Defense (1997), the U.S. EPA (1998), former EPA officials (2002), and the U.S. Government Accountability Office (2005) have all concluded that TSCA has not served as an effective vehicle for the public, industry, or government to *assess* the hazards of chemicals in commerce or *control* those of greatest concern.

- The TSCA inventory lists 81,600 chemicals that are registered for commerce in the U.S., 8,282 of which are produced or imported at 10,000 pounds or more per year.
- TSCA does not require chemical producers to generate and disclose information on the health and environmental safety of these chemicals—or on the approximately 2,000 new chemicals that enter the market each year. The result is that there is an enormous lack of information on the toxicity and ecotoxicity of chemicals in commercial circulation.
- TSCA places legal and procedural burdens on the EPA that have constrained the agency's capacity to act. Since 1979, the EPA has used its formal rule-making authority to restrict only five chemicals or chemical classes, though the agency reported in 1994 that about 16,000 chemicals in the U.S. were of some concern on account of their structure and volume in commerce.
- TSCA has not provided a vehicle for channeling federal support to research in cleaner chemical technologies, including green chemistry.

Voluntary initiatives on the part of the chemical industry to correct some of these weaknesses are positive but do not make up for TSCA's structural weaknesses. Other federal laws that pertain to chemicals are essentially "end-of-pipe" statutes that do not allow for review of chemicals prior to their introduction into commerce. Together, five major federal statutes apply to only 1,134 chemicals and pollutants. The weaknesses of TSCA and the other federal statutes have produced three fundamental problems in the U.S., which we refer to as the chemical Data Gap, Safety Gap, and Technology Gap.

TSCA's weaknesses are adversely affecting California.

The chemical Data Gap, Safety Gap, and Technology Gap have created a broad set of problems for public and environmental health, industry, business, and government in California.

The Data Gap: Without comprehensive and standardized information on the toxicity and ecotoxicity for most chemicals, it is very difficult even for large firms to identify hazardous chemicals in their supply chains. Along with consumers, workers, and small-business owners, they do not have the right kinds of information to identify safer chemical products. The lack of chemical information weakens the deterrent function of the product liability and workers' compensation systems.

The Safety Gap: Government agencies do not have the information they need to systematically identify and prioritize chemical hazards, nor the legal tools to efficiently mitigate known hazards.

The Technology Gap: The lack of both market and regulatory drivers has dampened motivation on the part of U.S. chemical producers and entrepreneurs to invest in new green chemistry technologies. There has been virtually no government investment in green chemistry research and development.

Meanwhile, evidence of public and environmental health problems related to chemicals continues to accumulate. Each year the California Legislature faces numerous bills related to public concerns over chemicals; on the current trajectory, the number of such bills is likely to grow. Correcting the chemical Data, Safety, and Technology Gaps engendered by TSCA will require a modern, comprehensive approach to chemicals policy in California.

Developments in the European Union and among leading California businesses are driving interest in cleaner technologies, including green chemistry.

Facing a similar set of problems, the European Union is implementing sweeping new chemicals and materials policies that are driving global changes in ways that will favor cleaner technologies, including green chemistry.

- The E.U. *Restriction of Hazardous Substances in Electrical and Electronic Equipment* (RoHS) directive will prohibit the use of lead, cadmium, mercury, certain flame-retardant chemicals, and other toxic materials in electronic and electrical equipment sold in the E.U.
- The *Waste Electrical and Electronic Equipment* (WEEE) directive requires electronics producers to "take-back" their products at the end of their useful life.
- The proposed *Registration, Evaluation and Authorization of Chemicals* (REACH) initiative will require chemical producers to register most chemicals that are widely used and will place restrictions on the use of about 1,400 chemicals of very high concern.

It is becoming clear that cleaner technologies will play an increasingly important role in industrial activity globally—among both developed and developing nations. The E.U. government's policies to motivate investment in cleaner technologies, though difficult for some E.U. producers in the short term, are expected to lead to a long-term E.U. competitive advantage in this arena.

Lacking similar government leadership in the U.S., a number of large U.S. businesses have been working independently to implement strategies for identifying hazardous chemicals in their supply chains and removing those chemicals from their operations. California businesses at the forefront of this effort include Kaiser Permanente, Catholic Healthcare West, Intel, Hewlett-Packard, IBM, Bentley Prince Street, and Apple. These developments signal a growing demand among U.S. businesses for safer chemicals and better chemical information; these efforts, however, are constrained by the Data, Safety, and Technology Gaps. Effective leadership in chemicals policy to close these Gaps is now called for in the U.S.

California needs a modern, comprehensive chemicals policy to address pressing public and environmental health problems and to position itself as a global leader in green chemistry innovation.

These developments have opened an opportunity for California to position itself as a leader in green chemistry science and technology. To do so, California will need to correct the Data, Safety, and Technology Gaps, which have given rise to conditions in the U.S. chemicals market that favor *existing* chemicals and discourage investment by chemical producers in new green chemistry technologies. Large "sunk" investments by industry in existing chemical technologies will make it difficult to transition to an industrial system based on cleaner technology, including green chemistry; this transition, however, will have to be made if California is to respond proactively to developments in the E.U. and address a host of chemical problems affecting public and environmental health, business, industry, and government in the state.

We propose three chemicals policy goals that will move California in this direction:

Close the Data Gap: Ensure that chemical producers generate, distribute, and communicate information on chemical toxicity, ecotoxicity, uses, and other key data.

Close the Safety Gap: Strengthen government tools for identifying, prioritizing, and mitigating chemical hazards.

Close the Technology Gap: Support research, development, technical assistance, entrepreneurial activity, and education in green chemistry science and technology.

Because many policy mechanisms could be employed to reach these goals, we recommend that as a first step the Legislature establish a chemicals policy task force to explore various mechanisms and develop a legislative proposal for a comprehensive policy based on the findings of this report. We recommend that the task force be charged with developing the proposal for the 2007 legislative session.

1. Background

1.1 Methodology

We used four research methods in preparing this report: a literature review, interviews with key informants, participation in chemicals policy meetings, and peer review. Over a two-year period, the primary author held discussions with chemicals policy experts affiliated with academic institutions, scientific bodies, governmental agencies, chemical producers, downstream users of chemicals, entities within the European Union, small and medium-sized enterprises, environmental organizations, and labor organizations. In addition, between April 2003 and February 2006, the primary author participated in 35 meetings and conferences pertaining expressly or in part to chemicals policy matters (listed in Appendix A) and presented the report's key concepts at 17 of these meetings. The report reflects feedback produced throughout this process.

1.2 Scope

For purposes of this report, *chemicals* refers to organic (carbon-based) chemicals, metals, and inorganic chemicals created by humans through chemical processes. The report pertains to chemicals at all points in their life cycle, including (1) feedstock supply chains leading to chemical processing facilities, (2) research, development, design, and manufacture of chemicals and chemical products, and (3) distribution, use, disposal, and recycling of chemicals and chemical products.[3] *Chemical industry* refers to the business and industrial entities involved in the design, production, and distribution of chemicals and chemical products.

The report pertains to chemicals in three market classifications: consumer products, basic chemicals, and specialty chemicals (Figure 1).[A] [6] The report does not address pesticides, pharmaceuticals, cosmetics, or food products.

1.3 Report Overview

For purposes of this report, public policy is defined as a plan of action to guide decision-making that is based on an agreed-upon set of goals. Goals, in turn, are determined by the ways in which problems are defined. A large portion of the report is therefore dedicated to an analysis of chemical problems in the U.S. and California. Following an introduction (Section 2), the report describes the federal regulatory origins of the Data, Safety, and Technology Gaps (Section 3) and the problems these gaps have created for public and environmental health, business, industry, and government in California (Section 4). The report then describes chemicals policy

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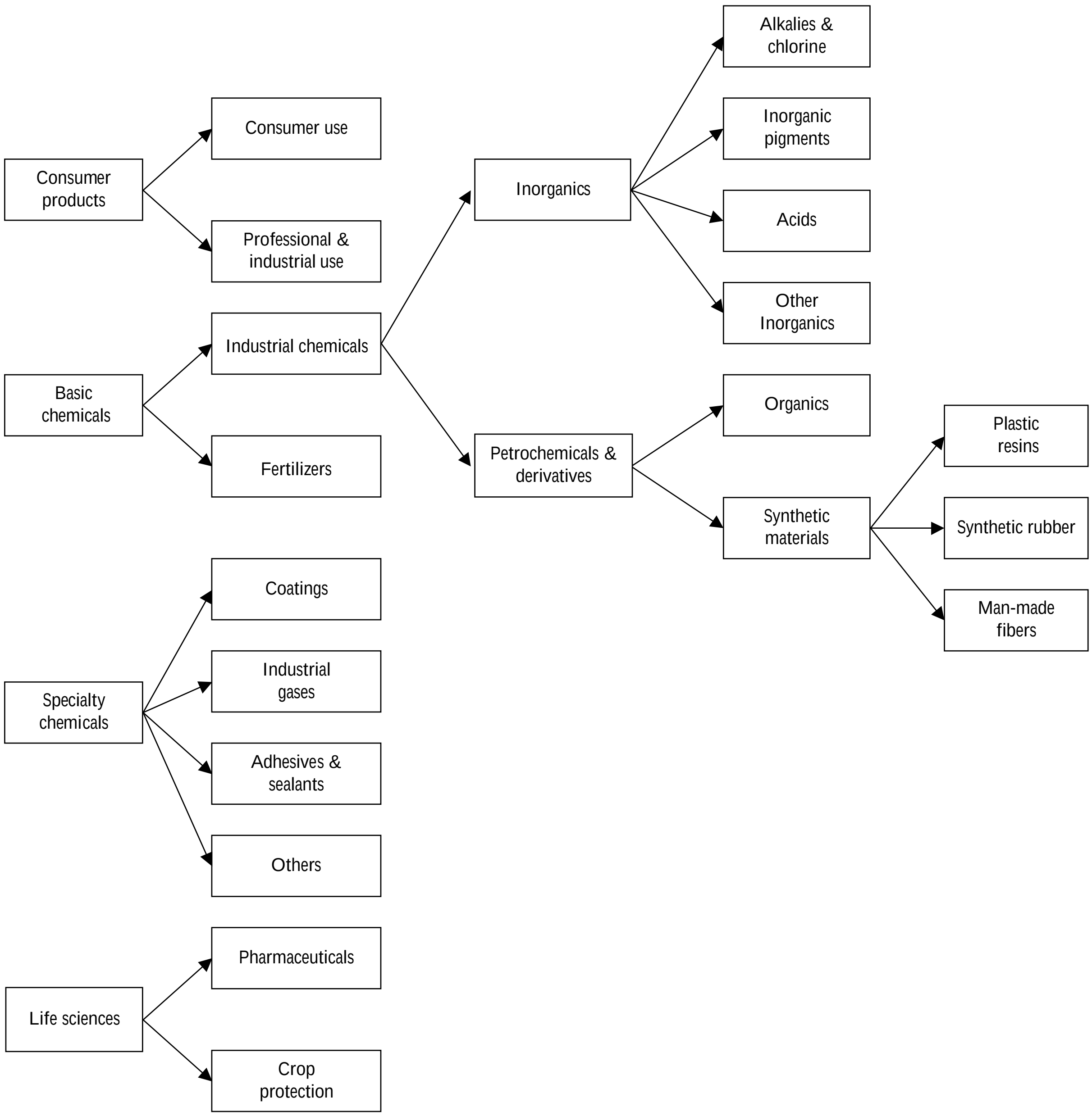
[A] Of the 81,600 chemical substances listed in the inventory of the federal Toxic Substances Control Act (TSCA), 34,000 are discrete chemicals having a definite structure (Class I Substances); 20,000 are complex reaction products, biological materials, and chemical substances having indefinite structures (Class II Substances); and 27,600 are polymers.[4] There are 8,282 chemicals in commercial circulation in the U.S. that are produced or imported at 10,000 pounds or more per year, according to data from TSCA's 2002 Inventory Update Rule (IUR).[5] Of these, over 99% are produced or imported at one million pounds or more per year; these are known as High Production Volume (HPV) chemicals. There are 2,943 HPV chemicals in the U.S. A total of 15.2 trillion pounds of chemicals was produced or imported in the U.S. in 2001, or about 42 billion pounds per day.

Figure 1. The chemical industry's four primary sectors as classified by the American Chemistry Council.



developments occurring in the European Union and efforts by U.S. businesses and non-governmental organizations to "clean" industrial supply chains of hazardous chemicals (Section 5). The report proposes that these developments present a unique opportunity for California to consider a new approach to chemicals policy that addresses public and environmental health problems, supports entrepreneurial activity in green chemistry, and responds proactively to developments in the E.U. The report describes a case study of a reasonably successful, if limited, chemicals policy implemented in Massachusetts in 1989 and discusses its relevance to California (Section 6). The report recommends three overarching goals for a modern, comprehensive chemicals policy in California and explores a number of issues related to each goal (Section 7). The report concludes that a chemicals policy based on these goals is timely and necessary in California, given the state's expanding population, its health and environmental problems, and the pressures of an increasingly competitive global economy (Section 8).

The report is not intended to be an exhaustive study of chemicals policy. It does not present cost-benefit analyses of differing policy approaches, nor does it compare health and environmental risks associated with chemicals against other risks. The development of the report included a cost-benefit analysis of a California chemical reporting system, an analysis of voluntary initiatives by industry, and an analysis of 10 federal and state chemicals policies, but for brevity only the key points of these analyses are summarized in the report.

1.4 Definition of Terms

Adverse health effects: The continuum of health and disease, from early indicators of biochemical disruption (resulting from chemical exposure) to the presence of overt health damage. The definition reflects the fact that health and disease are manifested in degrees, not simply as "either/or."

Bioaccumulative and persistent chemicals: Chemicals that, by virtue of their structure are very slowly metabolized or excreted and therefore increase in concentration in the tissues and fluids of organisms.[7] Some bioaccumulative chemicals are known to exert toxic effects; for most, toxicity is unknown. The exposure pathways for most bioaccumulative chemicals are also unknown. Many bioaccumulative chemicals are resistant to natural degradation processes, such as those induced by sunlight and bacterial activity, and therefore tend to *persist* in the environment. Some persistent chemicals can remain in the atmosphere for decades or centuries (Table A).[8] Chemicals that are bioaccumulative, persistent, and toxic are particularly problematic because they can give rise to toxic effects over a greater period of time and over larger geographic regions.

Biobased material: Chemical products composed wholly, or in significant part, of renewable agricultural, forestry or waste materials.[9] Corn, soybeans, vegetable oils, and wood are currently the main sources used in creating biobased materials (Table B).[10] Some biobased products are processed with other materials, including petrochemicals, to manufacture the final product, while others are derived entirely from plant feedstock. Biobased *processes* utilize enzymatic and other biological mechanisms to generate chemical reactions. A sizeable industry in biobased industrial materials emerged in the U.S. in the 1930s and 1940s.[11]

*Table A. Persistence in the atmosphere of some chlorinated organic molecules.**

Chemical	Atmospheric half-life (yrs)
Tetrachloroethylene	0.3
Dichloromethane	0.4
Dichloroethane	0.4
Chloroform	0.4
Chloromethane	1.0
Dichlorotrifluoroethane (HCFC-22)	1.2
Dichloropentafluoropropane (HCFC-115ca)	1.9
Trichloroethane	3.3
Chlorotetrafluoroethane (HCFC-124)	4.8
Dichloropentafluoropropane (HCFC-225-cb)	5.5
Dichlorofluoroethane (HCFC-141b)	6.2
Dichlorofluoromethane (HCFC-22)	8.3
Bromochlorodifluoromethane	11.1
Chlorodifluoroethane (HCFC-142b)	13.2
Carbon tetrachloride	24.3
Trichlorofluoromethane	31.2
Trichlorotrifluoroethane	58.9
Dichlorodifluoromethane	69.3
Dichlorotetrafluoroethane	152.5
Chloropentafluoroethane	381.2

***** The atmospheric half-life is the time required for a substance to degrade to 37% of its original concentration.

Table B. Common nonfood biobased commercial and consumer products, 2003.

Source	**Chemical products**
Corn	Solvents, pharmaceuticals, adhesives, starch, resins, binders, polymers, cleaners, ethanol
Soybeans	Paints, toiletries, solvents, inks, pharmaceuticals, lubricants, biodiesel fuel, carpet backing, foam insulation.
Vegetable oils	Surfactants in soaps and detergents, pharmaceuticals, inks, paints, resins, cosmetics, fatty acids, lubricants.
Wood	Paper, cellulose for fibers and polymers, resins, binders, adhesives, coatings, paints, inks, fatty acids, road and roofing pitch.

Exposure: Contact between a chemical and a target.[12] Contact takes place at an exposure surface (such as the lungs, skin or digestive tract) over an exposure period.

Exposure assessment: The process of estimating or measuring the magnitude, frequency, and duration of exposure to a chemical, along with the number and characteristics of the population exposed.[13] Ideally, it describes the sources, pathways, routes, and uncertainties in the assessment. Chemicals enter the environment as vapors, gases, liquids, and particles; they do so through intentional and unintentional releases from chemical processes and products; and they enter the body through the lungs (inhalation), the gastrointestinal system (ingestion), and the skin (dermal absorption).[14]

Green chemistry: The design, development, and implementation of chemical processes and manufactured products that are intended to reduce or eliminate substances hazardous to human health and the environment.[15] Green chemistry can be applied in at least three major areas: raw materials, processes, and products. Green chemistry *raw materials* include renewable biobased feedstocks, new chemical building blocks using biobased materials, and the design (or mimicking) of chemicals that exist in nature. Green chemistry manufacturing *processes* use safer solvents or solvent-less systems, alternative reaction pathways, novel catalysts, ultra-thin membrane technologies, and other processes. Some processes harness biological processes (e.g., fermentation) to make chemicals at ambient temperature and pressure.[16-18] Relative to products made through standard chemical processes, green chemistry *products* are less reactive in biological systems; they are less toxic and do not persist in the environment or accumulate in the human body. In 2003, three Nobel prizes were awarded to chemists working in the area of green chemistry.[19]

Twelve principles of green chemistry have been proposed to serve as a guide for measuring progress toward the adoption of green chemistry:[15, 20]

- *Prevent waste:* Design chemical syntheses to prevent waste, leaving no waste to treat or clean up.

- *Design safer chemicals and products:* Design chemical products to be fully effective, yet have little or no toxicity.

- *Design less hazardous chemical syntheses:* Design syntheses to use and generate substances with little or no toxicity to humans and the environment.

- *Use renewable feedstocks:* Use renewable materials and feedstocks. Renewable feedstocks are often made from agricultural products or are the wastes of other processes; depleting feedstocks are made from fossil fuels (petroleum, natural gas, or coal) or are obtained by mining.

- *Use catalysts, not stoichiometric reagents:* Minimize waste by using catalytic reactions. Catalysts are used in small amounts and can carry out a single reaction many times, unlike stoichiometric reagents, which are used in excess and work only once.

- *Avoid chemical derivatives:* Avoid using blocking or protecting groups or any temporary modifications if possible. Derivatives use additional reagents and generate waste.

- *Maximize atom economy:* Design syntheses so that the final product contains the maximum proportion of the starting materials.

- *Use safer solvents and reaction conditions:* Avoid using solvents, separation agents, or other auxiliary chemicals. If these chemicals are necessary, use innocuous chemicals.

- *Increase energy efficiency:* Run chemical reactions at ambient temperature and pressure whenever possible.

- *Design chemicals and products to degrade after use:* Design chemical products to break down to innocuous substances after use so that they do not accumulate in humans or the environment.

- *Analyze in real time to prevent pollution:* Include in-process, real-time monitoring and control during synthesis to minimize or eliminate the formation of byproducts.

- *Minimize the potential for accidents:* Design chemicals and their forms (solid, liquid, or gas) to minimize the potential for chemical accidents, including explosions, fires, and releases to the environment.

Hazard: The inherent property of a chemical having the potential to cause adverse effects when an organism, system, or (sub)population is exposed to that chemical.[13]

Public health: The protection and enhancement of human health and well-being by preserving the integrity of the biological, ecological, and social systems on which human life depend.[21-23]

Risk: The probability of an adverse effect in a person, system or (sub)population caused under specified circumstances by exposure to a chemical.[13] Conceptually, risk has also been defined as a function of hazard and exposure: *Risk = f(hazard,exposure),* where "hazard" is intended to refer to chemical toxicity.[24] Strategies to reduce risk by reducing *exposure* include, for example, preventing escape of chemical emissions from a process, minimizing the volume of chemicals used in a process, setting permissible public and worker exposure limits, using local exhaust ventilation systems, or requiring workers to wear personal protective equipment. These strategies have characterized the great majority of environmental policy activities in the U.S. and California to date. Strategies to reduce risk by reducing *hazards* are oriented toward the *design* of safer chemicals and chemical processes, such as green chemistry.

Sustainability: The condition resulting from industrial processes and products that meet the economic, social, and environmental needs of the present generation without compromising those of future generations.[25] The *Committee on Grand Challenges for Sustainability in the Chemical Industry* of the National Academy of Sciences proposed eight major research objectives "to enable the ongoing transition toward chemical products, processes, and systems that will help achieve the broader goals of sustainability" in the U.S. chemical industry:[26]

- *Green and sustainable chemistry and engineering:* Discover ways to carry out fundamentally new chemical transformations.

- *Life cycle analysis:* Develop tools to compare the total environmental impact of products generated from different processing routes and under different operating conditions through their full life cycle.

- *Toxicology:* Understand the toxicological fate and effect of all chemical inputs and outputs of chemical bond-forming steps and processes.

- *Renewable chemical feedstocks:* Derive chemicals from biomass—including any plant-derived organic matter available on a renewable basis, dedicated energy crops and trees, agricultural food and feed crops, agricultural crop wastes and residues, wood wastes and residues, aquatic plants, animal wastes, municipal wastes, and other waste materials.

- *Renewable fuels:* Lead the way in the development of future fuel alternatives derived from renewable sources such as biomass as well as landfill gas, wind, solar heating, and photovoltaic technology.

- *Energy intensity of chemical processing:* Continue to develop energy-efficient technologies for current and future sources of energy used in commercial processing.

- *Separation, sequestration and utilization of carbon dioxide:* Develop more-effective technology and strategies to manage the resulting carbon dioxide from current and future human activity.

- *Sustainability education:* Improve sustainability science literacy at every level of society—from informal education of consumers, to the practitioners of the field, and the businesses that use and sell these products.

Toxic and ecotoxic: Inherent properties that cause an agent to produce an adverse biological effect. Not all chemicals are toxic or ecotoxic; those that are, are not equally so. Some chemicals can produce death in humans in microgram doses, for example, while others appear to be relatively harmless at doses in excess of several grams (Table C).[27] The toxic effects of chemicals in the human body and in ecosystems can be local or systemic, immediate or delayed, reversible or irreversible, as well as combinations of these attributes.[27] For the great majority of chemicals, the full range of toxic and ecotoxic effects is unknown. The health effects of exposure to chemical *mixtures* are largely unknown; it is well-established, however, that chemical mixtures can amplify or dampen the toxic effects of individual chemicals.[28-30]

*Table C. Examples of the toxicity range for some chemical and biological agents.**

Agent	**LD_{50}, mg/kg**
Ethyl alcohol	10,000
Sodium chloride	4,000
Ferrous sulfate	1,500
Morphine sulfate	900
Phenobarbital sodium	150
Picrotoxin	5
Strychnine sulfate	2
Nicotine	1
d-Tubocurarine	0.5
Hemicholinium-3	0.2
Tetrodotoxin	0.1
Dioxin (TCDD)	0.001
Botulinum toxin	0.00001

*LD_{50} is the dosage (mg/kg body weight) that causes death in 50% of exposed experimental animals. LD_{50} reflects only the acutely lethal dose and does not reflect the spectrum of toxic effects associated with a chemical. Some chemicals may produce cancer or birth defects at doses that produce no evidence of acute toxicity. Note that some chemicals in the table are synthetic and some are naturally occurring, and both types occur at each extreme of toxicity.

2. Introduction

2.1 Green Chemistry Technology Innovation in California

By 2050, California's population is expected to grow by about 50%, from 36 to 55 million residents. This expansion will be accompanied by a growing set of social, economic, and environmental problems; the *magnitude* of these problems, however, will be determined in large part by the kinds of policy decisions California makes now and in coming years. In finding the path to a sustainable future, it will be increasingly important to make decisions that link economic development with measures that support environmental sustainability and human society. A decision-making framework is therefore needed in California that will allow policymakers to guide the transformations of industrial development in ways that simultaneously *solve* health and environmental problems.

This report makes the case that chemicals policy is a key element in California's transition to a sustainable future. Problems associated with society's current approach to chemical design, use, and management represent one of the major challenges of the 21st century, and reorienting this approach will require a long-term commitment to the development of a modern, comprehensive chemicals policy. In California, chemical problems are already affecting public and environmental health, business, industry, and government. On the current trajectory, these problems will broaden and deepen. Altering this course will require a chemicals policy that motivates industrial investment in the design, manufacture, and use of cleaner chemical technologies, known collectively as green chemistry.

Green chemistry represents a primary, long-term solution to many of the chemical problems facing California, and it is a key element of an industrial development strategy that is environmentally, socially, and economically sustainable. Green chemistry *products* are less toxic, they do not accumulate in the body, and they break down more readily in the environment. Green chemistry *processes* use safer materials and less energy and produce less hazardous waste.

As detailed in this report, however, weaknesses in the design and implementation of the federal Toxic Substances Control Act of 1976 (TSCA), together with the narrow scope of other U.S. environmental statutes and a lack of government support for basic research in cleaner technology, have discouraged U.S. chemical producers, product manufacturers, and entrepreneurs from investing in green chemistry on a scale commensurate with the nature of chemical problems facing society. As a consequence, the science of green chemistry remains in its infancy in the U.S., and the U.S. market for green chemistry products has yet to be established. The European Union and other nations, meanwhile, are moving rapidly ahead with chemicals policy changes and public investments in green chemistry science and technology.

To be effective, chemicals policy in California will need to address the weaknesses in federal chemical statutes by implementing improvements in three key areas: chemical information flows, regulatory oversight and investment in green chemistry research and development. A properly conceived chemicals policy will enable California to mobilize its unparalleled capacity for innovation and could position the state to become a global leader in green chemistry science and technology.

2.2 Chemicals: A Key Industry

Over the last 150 years, the U.S. chemical industry has played a key role in the U.S. and global economy. The industry's contributions to economic growth, employment, and improvements in life expectancy, health, and living conditions in Western-style societies are widely acknowledged.[31-34] Chemicals are a basic feedstock to nearly all industrial and productive activity in the U.S., and they appear in thousands of consumer and commercial products. In 2002, the American Chemistry Council (ACC) reported that U.S. businesses purchased $288 billion (Table D) in U.S. chemical products, and industry exports totaled $81 billion—larger than either agriculture or aircraft/aerospace.[35] The ACC reports that the industry contributed directly or indirectly to 5.5 million U.S. jobs, or about 5% of the total U.S. workforce in 2002, and it paid $24.5 billion in federal, state, and local taxes.[35]

Table D. Direct purchases of U.S. chemicals and chemical products in 16 U.S. industry sectors, 2002.

Industry sector	U.S. billions
Health care	106.1
Consumer products	43.1
Rubber and plastic products	35.6
Furnishings, textiles, and apparel	16.4
Services and other	14.6
Agriculture	14.1
Paper and printing	10.0
Construction	10.4
Electrical and electronic equipment	5.4
Motor vehicles	4.6
Nonmetallic mineral products	3.4
Primary metals	3.3
Petroleum refining	3.0
Mining	2.3
Instruments	1.7
All other manufacturing	13.8
Total	**288.0**

In California, the ACC reports that the chemical industry employed about 81,000 people in 2004,[B] and that another 505,000 jobs were produced in the state indirectly by chemical industry activity in California and other states.[36] Together, this produced $28.6 billion in worker earnings and $1.7 billion in state and local tax revenues. The ACC reports that industries for which 10% or more of material inputs is derived from chemicals employ more than 4.3 million Californians (Table E). California consumers and businesses purchase 164 million pounds of chemical products each day, or about 4.5 pounds per capita.[37]

[B] Includes pharmaceuticals and pesticide producers; disaggregated employment information for the four industry sectors illustrated in Figure 1 is not available.

Table E. California employment in industry sectors for which 10% or more of material inputs is derived from chemicals.

Industry	California employment, 2004
Health care	1,179,304
Durable goods	710,892
Construction	683,437
Services	609,038
Nondurable goods	450,517
Agriculture	363,496
Information	263,486
Mining and utilities	54,024
Wholesale	38,776
Total	**4,352,970**

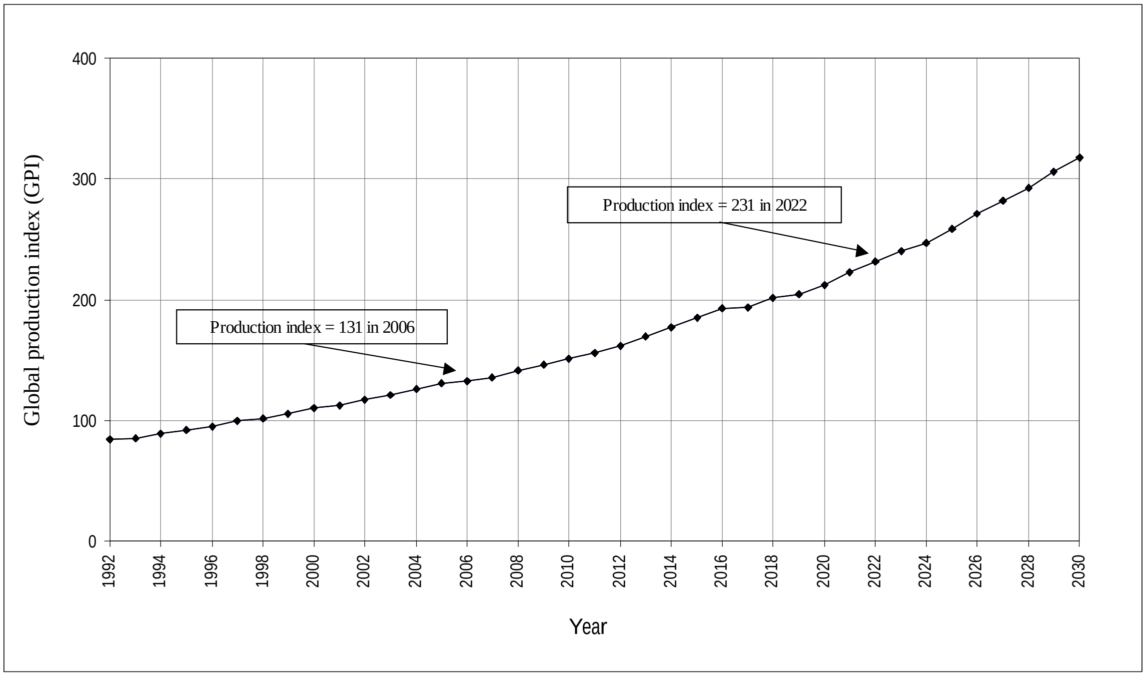
Both directly through its employment and indirectly through its impact on other industries, the chemical industry makes significant contributions to the economic well-being of citizens in the U.S. and California.

The chemical industry is also important because its products are ubiquitous; in roughly the last 50 years, chemicals have come to constitute the primary material base of society. The chemical industry has grown enormously in the last century and will continue to do so in the future, concomitant with expansion in the global consumer economy. In 2001, the U.S. produced or imported 42 billion pounds of chemicals each day,[38] the equivalent (if converted to gallons of water) of about 623,000 gasoline tanker trucks per day, each carrying 8,000 gallons.[C] If placed end-to-end, this number of trucks would extend 6,000 miles from San Francisco to Washington, D.C., and back; in the course of a year, it would circle the earth 86 times at the equator. The equivalent of about 2,700 such trucks are sold each day in California in consumer and commercial products alone.[D]

These chemicals are used in innumerable processes and products, and at some point in their life cycle many of them come in contact with people—in the workplace, in homes and through air, food, water, and waste streams. Eventually, in one form or another, nearly all of them enter the earth's finite ecosystems. On the current trajectory, global chemical production is expected to grow about 3% per year, such that it will double in size every 25 years for the foreseeable future (Figure 2). Given the scale and pace of chemical production, the toxicity and ecotoxicity of chemicals are of great public importance.

[C] An MC-407 gasoline tanker carries about 8,000 gallons of fuel. Estimates in this paragraph are based on the following: (1.52×10^{13} pounds/year)*(0.016 ft^3/lb water)*(7.48 gallons/1 ft^3)*(1 truck/8,000 gallons)*(1 year/365 days) = 623,000 trucks/day. Assuming each truck is 50 feet in length: (1 mile/5280 ft.)*(50 ft./truck)*(623,000 trucks/day)*(365 days/year) = 2,153,000 miles/year. The earth's diameter at the equator = 7,926 miles and its circumference at the equator = $7{,}926\pi$ = 25,000 miles. (2,153,000 miles/25,000 miles) = 86.
[D] For California: (1.64×10^{8} pounds/day)*(0.016 ft^3/1 lb water)*(7.48 gallons/1 ft^3)*(1 truck/8,000 gallons)*(1.11 for 11% population growth from 1997-2004) = 2,723 trucks/day.

*Figure 2. Estimated projection of the global production index (GPI) of chemical production to 2030.** [E]



* 1997 = 100 and production is assumed to follow the trajectory defined by the period 1992–2002.

2.3 Closing the Gaps: The Challenge for Chemicals Policy in California

The size, complexity, economic importance, and rapid growth of the chemical industry have made it very difficult for countries around the world to implement effective chemicals policies. The U.S. is no exception. Of all the federal environmental statutes, the Toxic Substances Control Act (TSCA) of 1976 is the only U.S. law that is intended to enable regulation of chemicals both before and after they enter commerce. It has become clear, however, that TSCA has not provided an effective vehicle for the public, government, or industry to *assess* the hazards of the great majority of chemicals in commerce (the Data Gap), to *control* those that are known to be hazardous to public and environmental health (the Safety Gap), or to stimulate government and industry investment in green chemistry research and development (the

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[E] This estimate was derived using a statistical model in which random samples were drawn from a distribution consisting of 10,000 random samples drawn from values representing the percent change per year in the global chemical production index for the period 1992 to 2002 (range 0.015 to 0.052; mean 0.032; standard deviation 0.015).[39] The model thus assumes continued global production to 2030 at the 1992–2002 rate. This rate is similar to that of previous years. This projection is similar to that of the Organization for Economic Cooperation and Development (OECD), UK Chemicals Industry Association and the American Chemistry Council, which predict an annual growth rate ranging from 0.026 to 0.035 leading up to 2020.[40] Indexed to 1995, the OECD expects non-OECD countries to experience 200% growth in chemical production by 2020 (from 0.5 to 1.5 trillion US$) compared to 75% growth for OECD countries (2.0 to 3.5 trillion US$).

Technology Gap). In California, the problems resulting from these three gaps are affecting public and environmental health, business, industry, government, and chemical producers themselves—especially those seeking to innovate green chemistry. Addressing these problems will require a modern, comprehensive approach to chemicals policy in California.

Other U.S. statutes have not remedied the deficiencies of TSCA and are surprisingly narrow in their scope. Combined, five major U.S. environmental and occupational statutes cover only 1,134 chemicals and pollutants.[41] The U.S. Occupational Safety and Health Administration, for example, has adopted workplace exposure limits for only 193, or about 7%, of the 2,943 chemicals produced or imported at more than one million pounds per year in the U.S.[42]

TSCA's weaknesses have far-reaching effects. Lacking comprehensive and standardized information on toxicity and ecotoxicity for most chemicals, it is very difficult for businesses and industry to choose safer chemicals or to identify and reduce the use of hazardous chemicals in their supply chains. Government agencies do not have the information they need to systematically identify and prioritize chemical hazards, nor the legal tools to efficiently mitigate known hazards. Consumers, workers, and small-business owners do not have the right kinds of information to identify and use safer chemical products. The lack of chemical information weakens the deterrent function of the product liability and workers' compensation systems. The lack of both regulatory and market drivers has dampened motivation on the part of U.S. chemical producers and entrepreneurs to invest in new green chemistry technologies. Meanwhile, evidence of public and environmental health problems related to chemicals continues to accumulate. The California Legislature faces numerous bills each year related to chemical problems, and on the current trajectory, the number of bills is likely to grow.

Leaders in the U.S. chemical industry have responded to these problems with a number of voluntary initiatives, including the *Responsible Care* program (of the ACC), the *High Production Volume* chemical program (ACC), the *Long-Range Research Initiative* (ACC), and the *Responsible Distribution Process* (of the National Association of Chemical Distributors). These efforts have undoubtedly produced improvements in environmental performance by leading firms in the chemical industry, and they will continue to do so. In particular, the HPV program is expected to produce basic screening level data for the great majority of the 2,943 chemicals in the U.S. that are produced or imported at more than one million pounds per year and that currently constitute about 99% of chemicals in commercial circulation, by volume. When combined with basic measures of exposure, these data could provide a useful, if limited, foundation for chemical data reporting in California. On the other hand, it is clear that California cannot rely on voluntary initiatives by industry as the basis for a comprehensive chemicals policy.[F]

[F] We evaluated a number of voluntary initiatives, including the U.S. chemical industry's *High Production Volume (HPV)* program, the *Responsible Care* program, the semiconductor industry's *Semiconductor Equipment and Materials International S2 Standard (SEMI),* California's *Hazardous Waste Source Reduction and Management Review Act* (SB 14),[43] and an analysis of the mining and forestry sectors conducted by the Organization for Economic Cooperation and Development (OECD).[44] We found that while these efforts were generally positive, they were intended to incrementally improve the performance of existing industrial systems, not to transform those systems through technological change, as will be needed for the broad adoption of green chemistry. The *Responsible Care* program, for example, has sought to reduce environmental impacts among participating firms but has avoided confronting the health, environmental and economic problems associated with continued reliance on

On the current trajectory, problems related to the design, use, and regulation of chemicals in California will only expand. Federal regulatory weaknesses have given rise to conditions in the chemicals market that favor *existing* chemicals and discourage investment by chemical producers in green chemistry innovation and technological change. Large "sunk" investments by industry in existing chemical technologies will make it difficult to transition to an industrial system based on cleaner technology, including green chemistry; this transition, however, will have to be made if California is to respond proactively to developments in the E.U. and address a host of chemical problems affecting public and environmental health, business, industry, and government in the state. A California chemicals policy will enable more of the state's businesses to "clean" their supply chains and implement green chemistry technologies, and it could position California to become a global leader in green chemistry technology innovation. The primary challenge of chemicals policy in California will be to motivate producers, distributors, and users of chemicals to invest in green chemistry and other practices that contribute to a developmental path in California that is environmentally, socially, and economically sustainable.

The analysis presented in the report is intended to help policymakers:

- understand the key weaknesses of federal statutes, particularly TSCA, that have given rise to the Data, Safety, and Technology Gaps (Section 3);
- understand the problems the three Gaps have created in California for public and environmental health, business, industry, and government (Section 4);
- recognize the need for a green chemistry technology transition in the chemical industry (Section 4);
- understand the basis for resistance by chemical producers to policies that would induce this transition (Section 4);
- recognize the significance of chemicals policy developments occurring in the European Union and among U.S. businesses and nongovernmental organizations (Section 5);
- recognize the relevance of the Massachusetts Toxics Use Reduction Act to chemicals policy in California (Section 6); and
- craft a chemicals policy that addresses health and environmental problems and motivates industry to invest in green chemistry technologies by closing the Data Gap, the Safety Gap, and the Technology Gap (Section 7).

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petroleum feedstock; *SEMI* induced positive changes in the environmental performance of numerous actors in the semiconductor industry but did not address the problems associated with the use of lead, cadmium, mercury and other hazardous materials in electronics, which are now being addressed by regulations in the European Union. Under SB 14, the California Department of Toxic Substances Control (DTSC) found that 29 of 40 California firms evaluated in 1998 in the Chemicals and Allied Products sector were significantly out of compliance. DTSC concluded "the underlying problem may be that company management lacks commitment to devoting the necessary resources to evaluate source reduction options." Without a robust market or regulatory driver, most firms seek to avoid the disruption and costs that can accompany technological change, even when such changes are necessary for the long-term viability of the industry as a whole. As a result, we found that policies that could induce technological change were largely absent from voluntary initiatives.

3. The Federal Origins of the Data, Safety, and Technology Gaps

3.1 Overview

This section describes the structural weaknesses in federal statutes that have produced a chemical Data Gap, Safety Gap, and Technology Gap in the U.S. The Data Gap refers to the absence of publicly available, standardized, robust information about the hazards and uses of chemicals in commerce, which impedes businesses, industry, government, consumers, and workers from identifying and acting on chemical hazards. The Safety Gap refers to legal and procedural barriers that prevent government agencies from mitigating known hazardous chemicals or preventing the introduction of new ones. The Technology Gap refers to the absence of proactive government efforts to support research, development, education, and technical assistance in green chemistry science and technology. California has not developed remedies to these three chemicals policy gaps.

Of all federal statutes, the federal Toxic Substances Control Act (TSCA) of 1976 (P.L. 94-469) is the only law that is broadly intended to enable regulation of chemicals both before and after they enter commerce.[G] As detailed in this section, weaknesses with TSCA lie at the heart of the Data, Safety, and Technology Gaps. The majority of chemical problems facing public and environmental health, business, industry, and government in California trace their roots to these weaknesses.

Other federal and state laws that pertain to chemicals are essentially "end-of-pipe" statutes that do not allow review of chemicals prior to their introduction into commerce. The section illustrates that the narrow scope and downstream orientation of these statutes prevent them from remedying the weaknesses of TSCA. Conversely, the weaknesses of TSCA have limited the potential effectiveness of these statutes.

3.2 The Toxic Substances Control Act

TSCA's passage in 1976 resulted from widespread concern about the absence of public oversight over the proliferation of chemicals in commerce. At the time, this situation was not unique to the U.S.; internationally, the introduction of tens of thousands of chemicals into the market preceded regulation of any kind.

In enacting TSCA, Congress had three major policy objectives:[45]

- Those who manufacture and process chemical substances and mixtures should develop adequate data with "respect to the effect of chemical substances and mixtures on health and the environment."

[G] The 1996 *Food Quality Protection Act* addresses pesticides used in food production, and the 1997 *Food, Drug and Cosmetic Act* addresses the use of chemicals in food, drugs, and cosmetics. The 1990 federal *Pollution Prevention Act* addresses chemicals at the point of production and use but its applications are strictly voluntary.

- The government should have adequate authority to regulate chemical substances and mixtures that present "an unreasonable risk of injury to health or the environment, and to take action with respect to chemical substances and mixtures which are imminent hazards."

- The government's authority over chemical substances and mixtures should be exercised "in such a manner so as not to impede unduly or create unnecessary economic barriers to technological innovation."

TSCA represented an important step forward in the U.S. in the regulation of chemicals. Prior to its passage, for example, the U.S. had no inventory of chemicals in commercial circulation, and there was no vehicle for a public agency to conduct pre-market evaluation of chemicals. On the other hand, it is clear that TSCA is need of modernization. Studies conducted by the National Academy of Sciences (1984),[46] the U.S. General Accounting Office (1994),[47] the Congressional Office of Technology Assessment (1995),[48] the nongovernmental organization Environmental Defense (1997),[49] the U.S. EPA (1998),[50] the U.S. Government Accountability Office (2005),[51] former EPA officials,[52] and researchers[53] have concluded that TSCA has fallen short of its objectives and has not provided an effective vehicle for the public, industry or government to *assess* the hazards of chemicals in commerce or *control* those of greatest concern. As a consequence, it has not served to motivate industry investment in cleaner technologies, including green chemistry.

These studies point to TSCA's three overarching weaknesses in design and implementation that we have designated the Data Gap, the Safety Gap, and the Technology Gap.

3.2.1 The Data Gap

For the great majority of chemicals in commercial circulation, TSCA has provided EPA with insufficient authority to require the *generation* of information on chemical toxicity and ecotoxicity and the *distribution* of that information to state governments, businesses, industry, and the public. In 1979, at the time TSCA was implemented, there were about 62,000 chemicals in commercial circulation in the U.S.—often described as "1979 existing chemicals."[54] These chemicals were "grandfathered" under TSCA; chemical producers were not required to disclose information on their toxic and ecotoxic properties, and they were generally considered to be "safe." TSCA assigned the EPA responsibility for assessing the risks associated with these chemicals.

TSCA erected a number of barriers that have prevented the EPA from fulfilling this responsibility. Before the EPA is able to require a chemical producer to generate the test data necessary for assessing risks, TSCA requires the agency to show, on a chemical-by-chemical basis, that a chemical either (a) may present an unreasonable risk to human health or the environment, or (b) that the chemical is produced or imported in substantial quantities, *and* enters the environment in substantial quantities, *or* there is or may be significant or substantial human exposure to the chemical. The EPA must also demonstrate that existing health and environmental information about the chemical is insufficient, and that testing by the producer is necessary to fill the information gaps. If the EPA cannot meet these requirements, it cannot act under TSCA to require generation of safety information about a chemical.

This legal burden has created a “logical paralysis” for the EPA: to assess chemical risks, the EPA needs toxicity and exposure data that producers are not required to provide unless the EPA can first show that such a risk may in fact exist. Not surprisingly, this has turned out to be a significant barrier for the EPA. In 1994, the GAO found that the EPA had managed to review the risks of about 1,200 (2%) of the 62,000 “1979 existing chemicals.”[54] The EPA reported to the GAO, however, that about 16,000 (26%) of these chemicals were potentially of concern on account of their production volume and chemical design.[54]

Though the TSCA inventory has grown to 81,600 chemicals, this body of 62,000 “1979 existing chemicals” continues to constitute the great majority of chemicals in commercial circulation in the U.S. (by volume), many of which have reached high levels of use despite very little information about their toxicity or ecotoxicity.[38] Currently, 8,282 chemicals are produced or imported in the U.S. at more than 10,000 pounds per year, and 2,943 are produced or imported at more than one million pounds per year, known as High Production Volume (HPV) chemicals (Table F).[38] Ninety-two percent of HPV chemicals in commercial circulation today consist of “1979 existing chemicals”; only 248 (8%) new chemicals introduced since 1979 have reached HPV status.[38]

*Table F. Distribution of chemicals produced or imported in the U.S. in 2001, as reported under the 2002 TSCA Inventory Update Rule.**

	Distribution of chemicals produced or imported in the U.S.		
	U.S. production & import range, lbs	Number of chemicals in the production range	Percentage of chemicals in the production range
Non-HPV	10K to 500K	4,670	56%
	>500K to 1M	669	8%
HPV	>1M to 10M	1,548	19%
	>10M to 50M	577	7%
	>50M to 100M	153	2%
	>100M to 500M	273	3%
	>500M to 1B	77	9%
	>1B	315	4%
	Total pounds reported	15,208,921,689,779	
	Total HPV pounds	15,207,877,185,511	
	HPV as percent of total	99.99%	

* Chemicals produced or imported at less than 10,000 pounds per year are not subject to reporting under the Inventory Update Rule except under certain conditions, such as an order under Section 5(e). HPV chemicals constitute about 35% of the *number* of chemicals produced or imported at 10,000 pounds or more per year, but over 99% by *volume*, according to Inventory Update Rule reporting data.

Given its constraints under TSCA, the EPA has opted for voluntary approaches to generating chemical toxicity and ecotoxicity data, beginning in 1997 with an effort to gather screening-level data on the HPV chemicals.[55] As of 2003, chemical producers had voluntarily submitted screening-level data for about 90% of these chemicals.[56] [H] Because HPV chemicals account for over 99% of chemicals in commercial circulation in the U.S., these data could provide a foundation for chemical reporting in California, assuming they can be linked to basic measures of exposure (Section 7).

On the other hand, while the HPV program represents an important beginning, it will not provide enough information to support chemical decision-making by businesses, industry, government, and the public. The U.S. EPA has recommended that more extensive toxicity testing would be needed beyond screening-level tests to "adequately assess the hazards of higher-exposure chemicals (e.g., chemicals in consumer products, chemicals to which children may be exposed, high-release TRI chemicals, chemicals with large numbers of exposed workers etc.)."[57] The EPA, however, presently has no systematic efforts under way to obtain more extensive toxicity data on the HPV chemicals or to gather screening-level data on the 5,339 chemicals produced or imported in the range of 10,000 to one million pounds per year.[58]

For the great majority of chemicals in commercial circulation, there is insufficient publicly available information about the toxicological properties and uses that is necessary for determining whether these chemicals are safe for human health and the environment; this can be characterized as a chemical Data Gap.

3.2.2 The Safety Gap

In addition to giving the EPA limited authority for requiring the generation and distribution of chemical information, TSCA makes it very difficult for the EPA to take regulatory *action* on chemicals. To regulate a chemical, TSCA requires EPA to provide "substantial evidence" that (1) the chemical presents or will present an "unreasonable" risk to health and the environment, (2) the benefits of regulation outweigh both the costs to industry of the regulation and the lost economic and social value of the product, and (3) EPA has chosen the least burdensome way to eliminate only the unreasonable risk. In considering regulatory actions, the EPA is required to "consider the environmental, economic, and social impact of any action" it proposes to take.[59]

Faced with this burden of proof, the EPA has been able to use its formal rule-making authority to regulate only five existing chemicals (or chemical classes) since the passage of TSCA in 1979: polychlorinated biphenyls (PCBs), chlorofluorocarbons (CFCs), dioxins, asbestos, and hexavalent chromium.[60] Of these, TSCA itself required regulation of PCBs, and EPA's regulation of asbestos, promulgated after the agency spent 10 years gathering evidence, was overturned in its most significant aspects by the 5th Circuit Court of Appeals, which concluded that EPA had failed to meet its burdens of proof.[52]

TSCA enables the EPA to be somewhat more active under the provisions of the statute that pertain to "new" chemicals introduced since 1979.[I] As noted above, these chemicals comprise

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[H] Since the program's launch in 1997, about 700 additional chemicals have reached HPV status in the U.S. Chemical producers have voluntarily submitted information for about 100 of these, and the industry has announced an "Extended HPV Challenge" to address the remainder.

[I] These provisions also apply to a small number of "existing" chemicals in the original 1979 TSCA inventory for which the EPA has issued Significant New Use Rules.

248 HPV chemicals and a number of other smaller-volume chemicals.[5] Using information submitted by producers on "pre-manufacturing notices" (PMNs), the EPA has acted in various ways to restrict 3,500 (10%) of the 36,600 chemicals that producers proposed to introduce into commercial circulation between 1979 and 2004.[61]

TSCA thus enables EPA to take steps to control *new* chemicals before they are marketed; on the other hand, it only requires that producers submit toxicity testing information that is "in their possession" when they file the PMN; it does not require new testing.[62] This has created a disincentive for producers to conduct toxicity testing. For example, the EPA has reported that 85% of PMNs lack data on chemical health effects, and 67% lack health or environmental data of any kind.[61] In addition, once new chemicals are placed on the TSCA inventory, EPA may regulate them only under the standards and burdens it carries for "1979 existing chemicals." Producers are not required to generate *tiered* health and environmental data on new chemicals as their production volume increases over time, such as the 248 new chemicals that have reached HPV status.

Finally, TSCA contains confidential business information (CBI) provisions that have prevented the EPA from *distributing* the chemical information it obtains through the PMN process and Inventory Update Rule. In 1998, the EPA reported that 65% of information filings submitted under TSCA were claimed by businesses as CBI.[52] The EPA determined that 22% of these claims were invalid.[63] In 2005, the EPA reported that 95% of PMNs contained some information that chemical companies claimed as confidential.[64] California state agencies, businesses, and nongovernmental organizations have no more access to chemical information classified as CBI under TSCA than do private citizens.[52] State agencies in California are therefore currently unable to determine the toxicity, ecotoxicity, identity, volume in commerce, locations of use, or potential routes of exposure of chemicals used in the state (Section 4).

The U.S. EPA has been unable to regulate "1979 existing chemicals" and it has had to rely on limited information and tools to regulate "new chemicals"; this has produced a chemical Safety Gap in the U.S.

3.2.3 The Technology Gap

By not requiring the generation and disclosure of the toxicity of chemicals on the market, and by erecting barriers to chemical regulation, TSCA has given rise to conditions in the market that have favored *existing* chemicals and dampened industry motivation to invest in green chemistry technology innovation (Section 4). In addition, TSCA was not intended as a vehicle for the federal government to support research, development, and education in cleaner chemical technologies, including green chemistry. Although practical developments in green chemistry are occurring among a number of leading U.S. chemical producers,[65-67] government support for green chemistry research in the U.S. is lagging behind initiatives in Japan, Italy, China, and Australia.[68, 69] Together, these conditions may be producing a green chemistry Technology Gap in the U.S. that could have long-term implications for U.S. competitiveness in the chemicals market.

3.3 Federal Pollution Control Statutes

There are a number of federal statutes oriented to chemical pollution and exposure *control*. These statutes have produced improvements in environmental and occupational health performance by industry.[70] The American Chemistry Council, for example, reports that the industry spent $10 billion per year between 1995 and 2002 (about 3% of sales) on efforts to abate air pollution, water pollution, and other pollution (43%); capital costs for pollution abatement (27%); hazardous waste cleanup (16%); and worker health and safety (14%) related to the industry's current choice of chemical technologies.[71]

On the other hand, the narrow scope of federal statutes has prevented them from functioning as a "safety net" against the deficiencies of TSCA. Five major federal statutes regulate emissions or exposure levels for only 1,134 chemicals and pollutants (Table G).[72] Adding, deleting, or otherwise changing listed chemicals requires extensive justification—at public expense—and typically engenders a legal challenge. These statutes have therefore not kept pace with developing scientific knowledge of chemical toxicity that is reflected, for example, in the *Hazardous Substances Data Bank* of the U.S. National Library of Medicine, which contains entries for about 4,800 potentially hazardous chemicals.[73]

*Table G. The number of chemicals listed under five major federal statutes.**

Federal statute	**Number of chemicals listed**
Clean Water Act (CWA)[74]	148
Resource Conservation and Recovery Act (RCRA)[75]	502
Clean Air Act (CAA)[76]	189
Occupational Safety and Health Act (OSH Act)[77]	453
Emergency Planning and Community Right-to-Know Act; the Toxics Release Inventory (EPCRA – TRI)[78]	600

*With overlap, the total number of regulated chemicals is 1,134.

The number of regulated chemicals, as well as the chemicals themselves, varies considerably from statute to statute (Table H). Chemicals that appear in any pair of the five statutes range from only 13% to 29% of the total number.[72] This variability results primarily from the fact that the lists were derived independently for different reasons; some of the statutes are concerned entirely with human health, for example, while others also address ecosystem effects.[79]

Because the scope of the statutes is constrained, they have not served to motivate broad investment by chemical producers in green chemistry technologies. In theory, if they are sufficiently stringent and adaptable to new technology developments, pollution control strategies can motivate investment by industry in new pollution prevention technologies, including green chemistry. For example, a standard that prohibits the discharge of certain hazardous chemicals into wastewater (but leaves industry responsible for developing the means for achieving the standard) can in principle lead to industrial innovations that include green chemistry solutions. Although the federal pollution control statutes have achieved this objective in isolated cases, they have not motivated industry to invest broadly in green chemistry and other cleaner technologies, which has contributed to the Technology Gap.

Table H. Comparison of chemicals listed under the five statutes in Table G.

Comparison	**Number of chemicals listed**
Regulated under all five statutes	49
Regulated under at least four statutes	119
Regulated under three or more statutes	210
Regulated under two or more statutes	371
Regulated under only one of the five statutes	768

3.4 California Pollution Control Statutes

California has established a number of its own efforts to regulate chemicals that appear in air, water, workplaces, and consumer products (Table I). These efforts have led to improved practices in California. Under Proposition 65 (the *Safe Drinking Water and Toxic Enforcement Act* of 1986), for example, California is able to notify the public of certain carcinogenic or reproductive chemical hazards where the state can demonstrate a potential risk of exposure. The state has assigned workplace permissible exposure limits (PELs) to nearly 700 substances, compared to 453 under federal OSHA.[80] Many of California's PELs are more protective of workers than those of federal OSHA. California has developed a number of community-based exposure limits for chemicals and is pursuing innovative strategies to encourage the use of green building materials.[81] Like the federal statutes, however, California's laws capture a very small number of chemicals and pollutants, and updating them is constrained by legal and procedural barriers.

Other chemical regulatory efforts in California that do not involve lists of chemicals include the *Certified Unified Program Agencies* (CUPAs) of 1993 (SB 1082), the *Hazardous Waste Source Reduction and Management Review Act* of 1989 (SB 14), and the *Hazardous Substances Information and Training Act* of 1986. These laws and programs have produced improvements in the management and communication of some chemical hazards; however, with the possible exception of Proposition 65, however, California's environmental laws—like those at the federal level—are too constrained to enable California to effectively identify, prioritize, and mitigate chemical hazards, nor have they served to motivate industry investment in cleaner chemical technologies, including green chemistry.

*Table I. Numbers of chemicals regulated in California under nine programs.**

California statute or program	Number of chemicals listed
Permissible Exposure Limit (workplace) (DOSH)[80]	688
Chronic Reference Exposure Levels (air) (OEHHA)[81]	80
Registry for Report of Carcinogen Use (workplace) (DIR)[82]	30
Maximum Contaminant Levels (water) (DHS)[83]	77
AB 2588 – Air Toxics "Hot Spots" (air) (EPA)[84]	80
Drinking Water Action Levels (water) (DHS)[85]	49
Toxic Air Contaminants (air) (EPA)[86]	24
Proposition 65 Chemicals (consumer products) (EPA)[87]	635
Process Safety Management Chemicals (industry) (DOSH)[88]	138

*DOSH: Division of Occupational Safety and Health
OEHHA: Office of Environmental Health Hazard Assessment
DIR: Department of Industrial Relations
DHS: Department of Health Services
EPA: California Environmental Protection Agency

This orientation in California law has emerged in part from a general presumption among California policymakers that federal law, particularly TSCA, provides the U.S. EPA with sufficient authority to assess the hazards of chemicals in commercial circulation and control those of greatest concern, which is not the case, as described above.

3.5 Lessons Learned from the Current Regulatory Context

The experience under TSCA since 1979 illustrates three key lessons for chemicals policy in California:

First, it illustrates chemicals policy approaches that are ineffective. These include (1) not requiring chemical producers to generate and disclose toxicity and other information sufficient to evaluate the safety of chemicals (the Data Gap); (2) requiring public agencies to produce extensive evidence of harm and economic analyses before they are able to take actions to protect public and environmental health (the Safety Gap); and (3) neglecting the role of information, regulation, and public investment in spurring research and development in new technologies, such as green chemistry (the Technology Gap). Chemicals policy in California will need to correct these weaknesses.

Second, it illustrates policy approaches that are outmoded. With advancements over the last thirty years in the environmental health sciences, it is clear that many chemicals are hazardous to biological systems, sometimes at very low doses, and they are particularly so during fetal and child development (Section 4). While such chemicals might constitute only a subset of chemicals in commercial circulation, the size of this subset is presently unknown—although the evidence suggests it far exceeds the number of chemicals presently listed under federal and state statutes.

The disconnect between a continually evolving body of knowledge in the environmental health sciences and the static nature of the chemical regulatory system is a source of tension in California that could grow in the future. California journalists are reporting on developments in toxicology and regulatory changes in the European Union, and public-health advocates—as well as a growing number of business leaders in California—are aware that the regulatory system is incapable of responding to these developments in a proactive, deliberative way. California will need to develop mechanisms for decision-making and action in chemicals policy that are better able to respond to evolving knowledge in the environmental health sciences and to developments in the chemicals market (Section 7).

Third, it points to policy flaws that prevent proper operation of the market. The work of Nobel prize-winning economist Joseph Stiglitz suggests that the Data Gap has created a "market failure" in the U.S. that prevents the laws of supply and demand from enabling the market to produce what the public really wants.[89] Because the chemicals market lacks robust, easy-to-use information on chemical toxicity, the prices businesses and consumers pay for chemicals may not reflect their true preferences; they may inadvertently be purchasing hazardous chemicals that they might avoid if they had better information. As a consequence, Guth, Dennison, and Sass argue that "the demand for *safer* products is not adequately expressed or realized in the market."[90] These conditions disadvantage producers of safer products, and they give rise to commercial interests that are motivated to protect existing products, including those that are hazardous (Section 4). These interests naturally resist information disclosure policies out of concern that they could undercut the market share of existing chemicals if those chemicals are found to be hazardous. A new approach to chemicals policy is needed in California that better uses information to leverage market forces.

Together, weaknesses in the federal regulation of chemicals have created Data, Safety, and Technology Gaps that have dampened the motivation of industry to innovate safer chemical products and processes, including green chemistry. The commercial interests that have grown up within this "economic space" will present a significant challenge to new chemicals policy efforts in California; on the other hand, as described in the following section, the array of problems these three gaps are causing for public and environmental health, business, industry, and government in California are likely to worsen if left uncorrected.

4. Chemical Problems in California

This section describes chemical problems in California from three perspectives: public and environmental health, business and industry, and government. The section illustrates that many of these problems trace their roots to the Data, Safety, and Technology Gaps that have emerged as a result of federal chemicals policy weaknesses, notably those of TSCA (Section 3). The section is organized as follows:

4.1 Public and Environmental Health
- 4.1.1 Environmental Justice
- 4.1.2 Children
- 4.1.3 Consumers
- 4.1.4 Workers
- 4.1.5 Environment

4.2 Business and Industry
- 4.2.1 Businesses That Use Chemicals
- 4.2.2 Green Chemistry Leaders
- 4.2.3 Chemical Producers

4.3 Government
- 4.3.1 State and Municipal Agencies
- 4.3.2 The Legislature

4.1 Public and Environmental Health

There is growing scientific concern regarding the implications of chemical exposures that occur over the course of the human lifespan—in workplaces and homes and in air, water, food, and waste streams—particularly during the sensitive period of fetal and child development. In considering health effects in relation to chemical exposures, it is important to recognize that, in the great majority of cases, human *disease* results from a combination of environmental, socioeconomic, genetic, and cultural factors, each of which acts over a lifetime.[91-94] Chemical exposures represent one of many environmental factors that can induce disease directly and can also influence the initiation, progression, or recurrence of other disease processes.[95, 96]

On the other hand, there is a substantial body of literature regarding chemically induced diseases among workers and other highly exposed individuals and populations.[97-106] There is growing evidence in animal studies that some chemicals can disrupt biological processes at very low doses. The biological and ecological effects of chemicals are of growing importance given the scale and pace of chemical production globally. In the following subsections we present examples of public and environmental health problems facing California that are related to chemicals; this review, however, is not intended to be a comprehensive examination of these issues.

4.1.1 Environmental Justice

It is well established that certain populations—immigrants, minorities, and lower-income groups—are at heightened risk of exposure to hazardous chemicals and chemically induced disease. The fact that emissions of chemical pollutants tend to be concentrated in lower-income and minority communities in California is well-documented.[107-110] This reflects earlier research in the area of occupational injuries and illnesses, which showed that Latino males were 80% more likely to suffer a disabling illness or injury than white males (68 vs. 38/1,000), while black males were 40% more likely (53/1,000).[111] Latinas were almost 60% (33/1,000) and African American women were 40% (29/1,000) more likely than their white female co-workers in the same industries (21/1,000) to suffer a disabling illness or injury. In communities and in workplaces in California, immigrants, minorities, and lower-income groups are at disproportionately heightened risk of hazardous chemical exposures.

The California Environmental Protection Agency has adopted an Intra-Agency Environmental Justice Strategy that calls for consideration of environmental justice in the "development, adoption, implementation and enforcement of environmental laws, regulations and policies" in California.[112] Environmental justice matters overlie many of the chemical problems described for children, consumers, and workers in this section.

4.1.2 Children

The evidence indicates that (1) children are especially vulnerable to the effects of chemical exposures; (2) children are exposed to chemicals during pregnancy, in breast milk, through consumer products, and through food, air, and water; (3) many of these chemicals have properties that can cause them to disrupt biological processes; and (4) some portion of the chronic pediatric conditions of asthma, certain cancers, and autism are related to chemical exposures.[113-117] It is possible that the long-term effects of chemical exposures during fetal, infant, and child development are under-appreciated. Children and their offspring will carry the greatest burden of chemically induced damage to human and environmental health. Chemicals policy strategies are needed that will enable California to proactively identify, prioritize, and mitigate chemical exposures of concern to children's health, even when the health outcomes resulting from these exposures have not been fully characterized.

Children are uniquely vulnerable to the effects of chemical exposures.

In 1993, the National Academy of Sciences reported that children are uniquely vulnerable to the effects of chemical exposures during all periods of fetal, infant, and child development. This vulnerability is attributable to four key factors, as follows:[118]

- Sensitive physiological processes can be disrupted during the rapid growth and development characteristic of embryonic and fetal life and the first year following birth. Development of the brain, for example, requires the formation and interconnection of billions of neurological cells; development of the endocrine system and reproductive organs is guided by a precisely timed sequence of hormones that exert their effects in the parts-per-trillion range.

- Children's metabolic pathways, especially in fetal life and in the first month after birth, are immature. Among other factors, growth of the blood-brain barrier, which can provide protection against some chemicals, is incomplete during fetal and early child development, such that chemicals are able to move directly from the maternal blood stream into the developing fetal brain.

- Relative to their size, children's intake of air, water, and food is far greater than that of adults. The amount of air a resting infant breathes, for example, is twice that of an adult, normalized by body weight. Children therefore experience disproportionately higher doses of environmental agents, including chemicals.

- Children have more years of future life than adults and thus have more time to develop diseases initiated by exposures early in life. Many chronic diseases, including cancer and neurodegenerative diseases, appear to arise as a result of cellular changes that take place many years before the actual manifestation of the disease. Critical windows of exposure to hazardous chemicals *in utero*, during early child development, and during puberty are more likely to produce chronic disease than similar exposures encountered later.

Chemical exposures take place during fetal development.

For the reasons outlined above, chemical exposures that occur during fetal development are of special concern.[119, 120] There is evidence that many chemicals reach the fetus.[114, 119, 121-128] A 2005 study reported (for the first time) that the maternal urinary concentration of chemicals used as plasticizers in consumer products—known as phthalates—was associated in a statistically significant dose-response relationship with changes in the sexual characteristics of a study group of 134 boys age 2 to 36 months.[129] [J] These changes were consistent with those seen in animal studies and were reported to occur at maternal phthalate metabolite concentrations that were not unusually high compared to the U.S. female population, based on a nationwide sample. While further studies will be needed to validate these findings, the reported effects could represent one outcome in a cascade of other, as yet unidentified, forms of human endocrine disruption by phthalates. Phthalates make up about 87% of the 10.4 billion-pound-per-year world market for plasticizers.[130]

A 2005 report by the Environmental Working Group, a U.S. nongovernmental organization, showed that between 159 and 234 chemicals were present in samples of umbilical cord blood obtained from 10 newborns.[131] Many of these chemicals were reported to be associated with toxic effects in animals or humans, or both.

Among other pathways, fetuses may be exposed to chemicals through parental use of consumer products. A British study of 7,000 families found that women quite commonly used chemical consumer products during pregnancy.[132] The products used (and the percentage of women using them) were disinfectant (87%), bleach (85%), air freshener (68%), window cleaner (61%), carpet

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[J] These were decreased anogenital distance and incomplete descent of the testes, both of which are associated with feminization. Plasticizers are introduced into a wide range of consumer and commercial products to improve flexibility.

cleaner (36%), paint or varnish (33%), turpentine (23%), pesticides and insecticides (21%), paint stripper (6%), and dry cleaning fluid (5%).

Chemical exposures take place during infant and child development.

There is evidence that children who are nursing are exposed to a significant number of chemicals in breast milk, including some that are known to be toxic, including methylene chloride, styrene, perchloroethylene, toluene, trichloroethylene, 1,1,1-trichloroethane, xylene, dioxins, benzene, polychlorinated biphenyls (PCBs), chloroform, polybrominated diphenyl ethers (PBDEs), and others.[133-140] Over the last 30 years, for example, total PBDE levels in breast milk have shown a doubling time of only five years (Figure 3). While the chemical "body burden" of males slowly increases over a lifetime, it appears to be reduced in nursing mothers through transfer out of fat tissue into breast milk.[141] A study of 800 nursing mothers found that first-born children ingested the highest concentration of chemical contaminants in breast milk, and that contaminant levels decreased during lactation, such that younger children received lower doses than older siblings.[135] While it is widely recognized that breast milk provides overall enhancement of infant health and development, the potential effects of even minute amounts of chemical contaminants in breast milk are of concern to pediatricians and child health researchers.[142-144]

Figure 3. Flame retardants and children's health.

Polybrominated diphenyl ethers (PBDEs) are used as flame retardants in consumer products. Because many U.S. states and the federal government require certain products to be flame-resistant, PBDEs have become an important commercial product, with annual global sales of about 70,000 metric tons.[145] Total PBDE levels have increased in human blood, breast milk, and tissues by a factor of about 100 over the last 30 years, with a doubling time of about five years.[145] This same trend is seen in marine mammals throughout the world.

Animal studies have demonstrated a striking array of toxic effects associated with exposure to PBDEs. Single exposures to animals shortly after birth induce permanent impairment of motor behavior in adulthood.[146] Repeated exposures produce neurotoxicity, endocrine disruption (e.g., decreased thyroid hormone levels), immunotoxicity, and other effects.[146-148] Some of the neurotoxic effects of PBDEs appear comparable to those of polychlorinated biphenyls (PCBs), which were finally phased out of use by most countries of the Organization for Economic Cooperation and Development (OECD) in 1989.[148]

Some portion of childhood asthma, certain cancers, and neurodevelopmental disorders is linked to chemical exposures.

Establishing a link between chemical exposures and disease trends is difficult given the set of epidemiological and toxicological tools currently available.[149] Nevertheless, there is evidence that chemical exposures play a role in certain diseases among children in the U.S.[113] Landrigan et al. estimate that chemical exposures in air, food, water, and communities contribute to 100% of lead poisoning, 10% to 35% of asthma, 2% to 10% of certain cancers, and 5% to 20% of neurobehavioral disorders among children.[150] These chronic conditions of multifactorial origin have been termed the "new pediatric morbidity."

The prevalence of asthma among children approximately doubled between 1980 and 1995, from about 4% to 8%.[113] Between 1994 and 1996, asthma caused U.S. children to miss 14 million days of school. The National Academy of Sciences reported in 2000 that, although data are limited, there is evidence suggesting that indoor air pollutants such as volatile organic compounds, plasticizers, nitrogen dioxide, and pesticides may play a role in childhood asthma.[151] A 2005 study of 14,000 children reported a dose-response relationship between childhood wheezing and pre-natal exposure to chemical consumer products.[132]

The prevalence of childhood cancers, including leukemias (acute lymphoblastic and acute myeloid), central nervous system tumors, lymphomas (Hodgkin's lymphoma, non-Hodgkin's lymphoma), thyroid carcinoma, and malignant melanoma, appears to have stabilized since 1990 after steady increases since 1975.[113] In absolute numbers, childhood cancer deaths have declined since 1975, largely due to improvements in treatment.[152]

Between 3% and 8% of infants born each year in the U.S. are—or will be—affected by neurodevelopmental disorders, including autism, mental retardation or attention-deficit/hyperactivity disorder (ADHD).[113] The causes of these disorders are unknown in the great majority of cases. It is well-established, however, that at low levels certain industrial chemicals—such as lead, methylmercury, PCBs, and others—disrupt the developing brain and nervous system.

4.1.3 Consumers

The Data Gap and the Safety Gap are reflected in the fact that there is very little information about chemicals in consumer and commercial products, and there are very few restrictions on the kinds of chemicals that can be used in these products. Some chemicals that are known to be hazardous therefore continue to be used in consumer products; however, for the great majority of chemicals used in millions of pounds of products sold in California, the toxicity and ecotoxicity are unknown. The chemical consumer market is distorted by the fact that there are no criteria—and there is no simple labeling system—that would enable consumers and small-business owners to identify and choose chemical products on the basis of toxicity or ecotoxicity.

Manufacturers are not required to test the safety of chemicals used in consumer products.

Manufacturers of chemical consumer products are not required to evaluate and disclose the toxicity and ecotoxicity of their products before placing them on the market. The California Air Resources Board (ARB) reports that 164 million pounds of chemical consumer and commercial products are sold in California each day (Appendix B).[153, 154] Because chemicals in consumer and commercial products are typically released from their container in close proximity to the user, the likelihood of exposure is high. There is some information in publicly available databases on the safety of individual chemicals in consumer products; for the great majority of chemicals, however, there is little to no information. As noted above, the effects of chemical *mixtures*, which constitute most chemical products, are unknown; it is well-established, however, that chemical mixtures can amplify or dampen the toxic properties of individual chemicals.[28-30]

Most Californians probably believe that chemicals in consumer products are somehow "safety tested" before being placed on store shelves, or before being introduced into the workplace. In a 2002 survey of 800 voters in Washington and Maine, for example, 55% agreed with the statement, "Currently, the government carefully tests chemicals used in all major consumer products to make sure they are safe for people to use." 76% agreed with the statement, "Current regulations require chemical companies to provide information about the health impacts of the chemicals they create."[155] Both statements are false (Section 3).

Consumers are unable to choose safer chemical products.

There is no simple labeling system in California to communicate to consumers that a chemical product contains, for example, "untested," "hazardous," "safer," or "certified green" chemicals. At present, the Data Gap precludes a labeling system of this nature; it is very difficult for manufacturers of chemical products to gather standardized, robust toxicity information on the chemicals they purchase and introduce into their products.[156] Without a simple labeling system for chemical products, however, consumers and business owners cannot make rapid, efficient purchasing choices that reflect their values. This represents a key barrier to the commercial viability of green chemistry consumer products.

There are hazardous chemicals in consumer products.

California's Proposition 65 lists over 600 chemicals that appear in consumer products and are known to cause cancer or harm to reproduction and/or development. Using 1997 data, the California Air Resources Board estimated that about 472,000 pounds of volatile organic compounds (VOCs) are released from consumer and commercial products each day in California.[153] Due to insufficient data on toxicity and chemical usage, however, it is not possible to identify and prioritize the risks associated with hazardous chemicals in consumer products sold in California.

The *Household Products Database* of the National Library of Medicine lists about 2,000 isolated chemical ingredients that are associated with a range of toxic effects and are contained in about 4,000 consumer products.[157] As previously noted, the U.S. EPA reported in 1994 that about

16,000 chemicals in commercial circulation in the U.S. (about 26% of existing chemicals at that time) are potentially of concern to public health on account of their design and volume in commerce (Section 3).[54] The European Environment Commission estimates that about 1,400 "chemicals of very high concern" are produced or imported in the E.U. at significant levels (Section 5). These substances consist of chemicals that are persistent, bioaccumulative, and toxic; chemicals that are "very persistent and very bioaccumulative", irrespective of toxicity; and chemicals that are carcinogenic, mutagenic, or toxic to reproduction.[158, 159]

Many chemicals persist in the environment and accumulate in the human body.

Persistent and bioaccumulative chemicals represent a unique hazard because they can give rise to effects over a greater period of time and over larger distances than other chemicals. Chemicals that are persistent and bioaccumulative *and* toxic are of particular concern in this regard. In 1987, the U.S. EPA reported finding 688 synthetic chemicals and other substances in the adipose tissue of a nationwide sample of Americans.[160] [K] In 2003, the U.S. Centers for Disease Control and Prevention (CDC) looked for, and found, 116 chemicals and other substances in the blood and urine of a representative sample of the U.S. civilian population.[161] In 2005, the CDC added 32 new chemicals to the survey, all of which were subsequently identified in blood and/or urine samples.[162] Other chemicals will likely appear as these lists are expanded.

Chemicals that consist of hydrocarbon molecules attached to one or more atoms of chlorine, bromine or fluorine—known as halogenated molecules—present a unique set of problems because they often exhibit toxicity in addition to persistence and bioaccumulative properties. Combined, several studies have reported the presence of about 200 *chlorinated* hydrocarbons (or organochlorines) in human adipose tissue, breast milk, blood, urine, semen, and exhaled breath.[163-176] Many of these chemicals are associated with toxic effects in animals and/or humans. The American Public Health Association wrote in a 1994 consensus resolution that "Virtually all organochlorines that have been studied exhibit at least one of a range of serious toxic effects, such as endocrine dysfunction, developmental impairment, birth defects, reproductive dysfunction and infertility, immunosuppression and cancer, often at extremely low doses, and many chlorinated organic compounds . . . are recognized as significant workplace hazards."[177]

Brominated hydrocarbons, which have recently appeared in California in cleaning solvents,[178] exert a range of potent toxic effects on the human reproductive, neurological, and other systems.[179-193] Problems associated with the class of flame retardants known as polybrominated diphenyl ethers (PBDEs) are described in Figure 3, above. Among *fluorinated* compounds, perfluorooctane sulphonate (PFOS), which was used in a variety of consumer products for its "non-stick" and water-repellent properties, has appeared in human tissues and in the tissues of birds, fish, and marine mammals around the world.[194-198]

[K] The EPA identified 288 of these substances at the time of the study; the methods were not available at the time to identify the remaining 400.

4.1.4 Workers

Because chemicals and chemical products are essential to nearly all forms of industrial activity, the chemical industry is important to employment and economic growth in California. A study of California employment trends during 1999 to 2002 concluded that the primary drivers of job growth are the expansion of existing firms and the birth of startup companies.[199] During this period, California employers created 450,000 new jobs through payroll expansion, and startup firms created 220,000 jobs. About 11,000 jobs left California, representing about 1.6% of job creation during this period.

Changes in the nature and organization of the workplace in California (e.g., decreased job stability and unionization, greater income inequality, lower rates of health insurance coverage) have heightened the vulnerability of certain groups of workers in the state. Work-related diseases continue to exact a tremendous human and economic toll in California, a portion of which is attributable to chemical exposures.

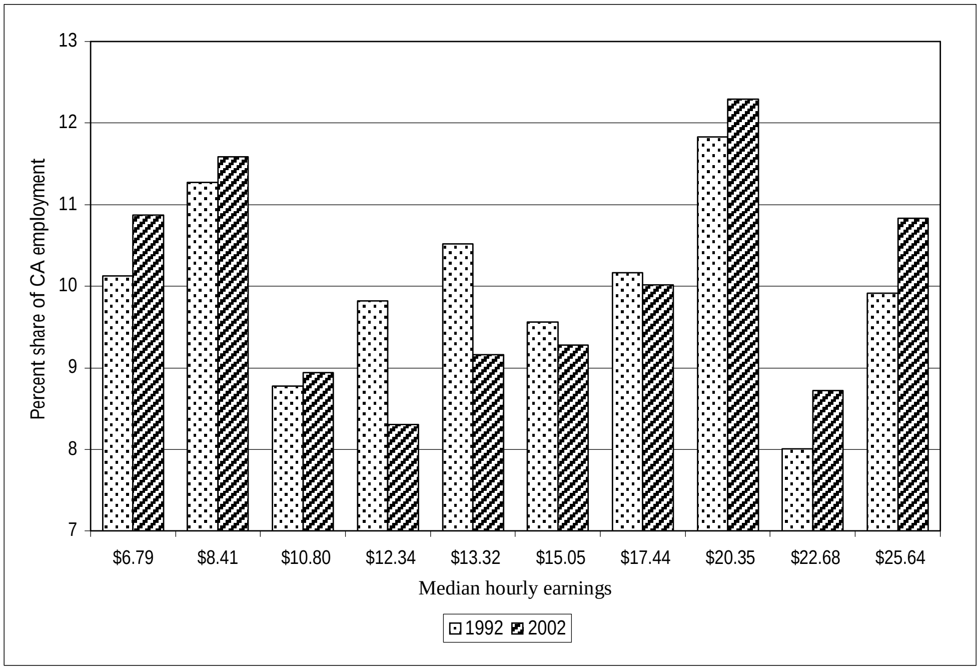
A modern, comprehensive chemicals policy that closes the Data, Safety, and Technology Gaps and motivates industry investment in green chemistry processes and products would begin to address the need for high-quality employment in California as well as the need to protect the health and safety of workers.

There is growing income inequality in California.

Income inequality has grown nearly everywhere in the U.S. in recent decades, but it has been more extreme in California, especially in the Los Angeles metropolitan area.[200] Between the late 1970s and late 1990s, average real (before-tax) income for the poorest 20% of California workers dropped 5.5%, while average real income for the state's wealthiest 20% grew by 37.4%. Average real income of the top 5% of income earners in California grew by 50.4% during this period. Employment in California during the economic expansion from 1992 to 2002 showed growth in the bottom and top ends of the income scale, with declines in middle-income jobs (Figure 4). This growth pattern contrasts with that of California's economic expansion during the 1960s, when new jobs were distributed more evenly across the income spectrum.

Lower-wage jobs offer less economic security and are less likely to offer benefits such as health insurance, paid sick days, paid vacation time, and retirement programs. Because economic status is a key driver of health status in the U.S., growth in income inequality in California represents an emerging public-health problem. A chemicals policy that expands productive capacity in green chemistry would contribute to improved employment opportunities in California.

*Figure 4. Changes in California job growth by median hourly income, 1992 and 2002.**



*In each of the 10 income categories, the income value is the median of the hourly income for six job groups with the largest number of full-time workers in 1992. Growth in the lower-income categories in 2002 occurred among "prime-age" (30 to 55) workers, not in a separate "youth labor market." [200]

Preventable occupational diseases exact a tremendous toll in California.

Workers are at particular risk of chemically related diseases because chemical exposures in the workplace occur at much higher frequency, intensity, and duration than those that occur in the ambient environment. Each year, about 23,000 Californians are diagnosed with a preventable, deadly chronic disease that is attributable to chemical exposures in the workplace (Table J).[201-205][L] About 6,500 Californians die each year as a result of a chronic disease attributable to chemical exposures in the workplace (Table K).[201-205] These figures are the equivalent of 1,900 new cases and 540 new disease-related deaths each month in California.

[L] Estimate does not include nonlethal diseases attributable to workplace chemical exposures, such as neurological diseases and skin diseases. For example, the European Union estimates that about 50% of occupational skin diseases are attributable to chemical exposures.[206]

Table J. Estimated annual new cases of deadly chronic diseases in California that are attributable to workplace chemical exposures, 2004.

Disease classfication	Estimated annual new disease cases in the U.S., 1992.	Estimated annual new disease cases in CA (13%)	Estimated % attributed to occupation	Estimated % attributed to occupational chemical exposures	Estimated % increase in the CA workforce, 1992-2004	Point estimate
Cancer	1,113,100	144,703	6-10%	80-90%	20%	11,808
COPD	1,500,000	195,000	10-20%	20-30%	20%	8,775
Coronary heart disease*	730,000	94,900	5-10%	20-30%	20%	2,135
Cerebrovascular disease*	122,000	15,860	5-10%	20-30%	20%	357
Total						23,075

* Includes only new and recurrent cases of coronary heart disease and cerebrovascular disease among people between ages 25 and 64, inclusive. Source: Leigh, Markowitz, Fahs, and Landrigan. *Costs of Occupational Injuries and Illnesses*, p. 84. University of Michigan, 2000.[207] J. Paul Leigh, University of California, Davis, personal communication, February 6, 2006: California accounts for about 13% of U.S. chronic disease cases; of occupationally related diseases, about 80–90% of cancers, 20–30% of COPD (chronic obstructive pulmonary disease), and 20–30% of coronary heart disease and cerebrovascular disease are attributable to chemical exposures.

Table K. Estimated annual California deaths in selected disease classes that are attributable to workplace chemical exposures, 2004.

Disease classfication	Estimated annual number of deaths in the U.S., 1992.	Estimated annual number of deaths in CA (13%)	Estimated % attributed to occupation	Estimated % attributed to occupational chemical exposures	Estimated % increase in the CA workforce, 1992-2004	Point estimate
Cancer	517,090	67,222	6-10%	80-90%	20%	5,485
COPD	91,541	11,900	10-20%	20-30%	20%	536
Cardiovascular and cerebrovascular disease*	101,846	13,240	5-10%	20-30%	20%	298
Pneumoconioses	1,136	148	100%	100%	20%	177
Nervous system disorders	26,936	3,502	1-3%	40-50%	20%	38
Renal disorders	22,957	2,984	1-3%	40-50%	20%	32
Total						6,566

* Includes only new and recurrent cases of coronary heart disease and cerebrovascular disease among people between ages 25 and 64, inclusive. Source: Leigh, Markowitz, Fahs, and Landrigan. *Costs of Occupational Injuries and Illnesses*, p. 87. University of Michigan, 2000.[207] J. Paul Leigh, University of California, Davis, personal communication, February 6, 2006: California accounts for about 13% of U.S. chronic disease deaths; of occupationally related chronic disease deaths, about 80–90% of cancers, 20–30% of COPD (chronic obstructive pulmonary disease) and cerebrovascular disease, 100% of pneumoconiosis, 1–3% of nervous system disorders, and 1–3% of renal disorders are attributable to chemical exposures.

The total cost of chemically related occupational illnesses and deaths in California is a function not only of medical care and rehabilitation but also of home care, lost wages, effects on the economic security of families, and years of productive life lost.[M] Clearly, the human and financial costs of chemically related diseases are born most immediately by workers. Efforts to prevent occupational disease in California would be greatly enhanced by a comprehensive approach to chemicals policy that closes the Data, Safety, and Technology Gaps.

Numerous factors contribute to the burden of preventable occupational diseases caused by chemical exposures in California.

A number of factors contribute to the continuing burden of occupational disease in California. As a group, these factors make it difficult to estimate the true burden of chemically related occupational disease in the population, and efforts to do so, including in this report, most likely underestimate the true rates.

First, as a consequence of the Data Gap, the full scope of health effects associated with the great majority of chemicals in commercial circulation, even as isolated entities, is unknown (Section 3). Likewise, the effects of chemical mixtures, which account for the great majority of workplace exposures, are unknown, though it is well established that chemical mixtures can dampen or amplify the toxic effects of individual chemicals, as noted above.[28-30]

Second, work-related diseases (including those induced by chemical exposures) are generally under-recognized by workers as well as health-care professionals.[209] The current vehicle for communicating chemical hazard information in the workplace, the Material Safety Data Sheet (MSDS), is inadequate for a variety of reasons.[210-212] Board-certified occupational physicians constitute only about 0.2% of U.S. physicians, and only half of U.S. medical schools require instruction in occupational medicine (and an average of only six hours, at that).[213, 214]

Third, the presence of a labor union in the workplace increases the ability of workers to understand, recognize, and take action to correct workplace hazards, and to ensure proper care and compensation in the event of an injury or disease.[215-218] Unionization has declined to about 10% of workers in the private sector in California, down from 20% in 1983.[219] [N] This has probably produced a decline in vigilance in the private sector with regard to work-related diseases, particularly among low-income, minority, and immigrant workers, who are at greatest risk.[220]

Fourth, there are still wide gaps in government protections for workers. There are permissible exposure limits (PELs) in California for about 700 substances, compared to 8,282 chemicals that

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[M] The $140 billion that has been proposed in the U.S. Senate to compensate workers who were exposed to asbestos illustrates the long-term implications of a weak chemicals policy, particularly with respect to occupational health. As former European Commissioner for the Environment Margot Wallström noted in 2004, “Countries all over the world are paying a high price for failures to address chemical safety. For example, asbestos was once seen as a valuable, versatile material and was used extensively in buildings. Every year people are now dying from exposure to asbestos. It is estimated that, in developed countries alone, 100,000 more people will die. The costs of removing asbestos from building and contaminated sites have been enormous.”[208]

[N] Unionization among public-sector employees was about 58% during this period; public-sector employees, however, constitute only about 16% of total employment in California.[219]

are produced or imported at more than 10,000 pounds per year in the U.S. As previously noted, only 193 PELs (7%) have been established for the 2,943 chemicals in the U.S. that are produced or imported at more than one million pounds per year.[50] Chemicals lacking PELs are not likely to be monitored in the workplace, and the diseases they produce are not likely to be linked to workplace exposures—either by workers or health-care providers. The California Division of Occupational Safety and Health (DOSH) employs only 200 compliance officers to address worker health and safety matters for the state's 16.5 million workers.[221-223] The Hazard Evaluation System and Information Service (HESIS), a public entity charged with anticipating and preventing chemical exposures in California workplaces, consists of only three full-time scientific staff members.

Finally, the Data Gap weakens the deterrent function of the workers' compensation system and the product liability laws.[224] In order to award workers' compensation benefits, a link must be established between the applicant's symptoms, exposure conditions in the workplace, and the specific toxic end-point(s) of a chemical. The same general principle applies to plaintiffs under the product liability laws. This evidentiary burden cannot be met if toxicity data necessary for doing so are inadequate. More broadly, if workers or members of the public are exposed to chemicals that, unknown to society, are in fact toxic, they are not likely to contemplate a legal remedy; damage caused by unrecognized hazards (due to the Data Gap) simply lies where it falls.

4.1.5 Environment

Dispersion of chemicals into the environment has produced a number of major ecological disruptions whose effects continue today. These include, for example, the destruction of stratospheric ozone by chlorofluorocarbons (CFCs), chemical contamination of the Great Lakes, contamination of water supplies by methyl tert-butyl ether (MTBE), disruption of aquatic reproductive activity by tributyltin (TBT) anti-foulants, contamination of foods by perchlorate, and other cases. The number of hazardous waste sites in the U.S. is expected to continue to climb. As noted above, there is ongoing concern about the long-term implications of chemicals that persist in the environment and accumulate in the tissues of animals and humans. On the current trajectory, new instances of chemically induced environmental damage will undoubtedly occur in the future. Today's children and their offspring will carry the heaviest burden of this damage, and they will experience the effects, as yet largely unknown, of persistent and bioaccumulative chemicals.

Environmental damage caused by chemicals can have long-term consequences.

Releases of organochlorines and other chemicals that destroy stratospheric ozone molecules represent a reasonably well-characterized example of the long-term consequences of chemically induced environmental damage—and the difficulties of correcting them.[O] The ozone layer surrounds the earth at an altitude of 10 to 30 miles and absorbs ultraviolet (UV) solar radiation, which protects the earth's surface from wavelengths of light that cause skin cancer, genetic mutations, immune suppression, and burns to the eyes and skin. As early as the 1970s,

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[O] Ozone consists of three oxygen atoms bonded together. Ozone-depleting chemicals that continue to be released include the CFC substitute hydrochlorofluorocarbon (HCFC), halon, methyl bromide and others.

atmospheric scientists recognized that long-lived organochlorine molecules, such as CFCs, could break down ozone molecules, and that industrial releases of organochlorines into the environment could lead to catastrophic damage to the ozone layer. In 1993, the Montreal Protocol was negotiated for the purpose of reducing industrial CFC emissions after evidence indicated that the ozone layer over Antarctica had thinned to about one-third its former concentration.

Despite the Montreal Protocol, damage to health and the ecosystem is expected to continue to unfold over the next 100 years due to past and continuing releases of organochlorines into the atmosphere. The United Nations Environment Programme (UNEP) reports that increased UV radiation reaching the earth's surface during this period will produce a 25% increase in the incidence of nonmelanoma skin cancers, or about 250,000 new cases per year globally. The incidence of melanoma, the more deadly form of skin cancer, will also increase. A 32% increase in UV radiation that damages DNA is expected in northern latitudes.

In December 2005, the National Aeronautics and Space Administration (NASA) announced that recovery of the ozone would not occur until 2065, rather than 2050 as previously estimated, due to continuing releases of ozone-depleting substances by industries around the world, including CFCs, despite the Montreal Protocol.[225]

Between now and 2033, 600 new hazardous waste sites will appear each month in the U.S. and require cleanup.

The number of hazardous waste sites in the U.S. continues to rise. Each year, more than $1 billion is spent on efforts to clean up hazardous waste Superfund sites.[226] Assuming current U.S. regulatory and industrial practices remain the same, the U.S. EPA expects that by 2033, 217,000 new hazardous-waste sites will materialize and require cleanup, on top of 77,000 current sites.[227, 228] The EPA estimates that efforts to cleanup the new sites will cost about $250 billion.

The U.S. Agency for Toxic Substances and Disease Registry (ATSDR) has identified 275 chemicals present at existing "National Priority" hazardous waste sites and has rated those chemicals on the basis of both toxicity and exposure potential.[229] Of the top 50 chemicals on the list, 38 (76%) are "reasonably anticipated" to cause, or are "possibly" or "probably" capable of causing, cancer in humans; 28 (56%) are expected to cause developmental defects in children; and 27 (54%) are suspected of causing acute and/or chronic neurotoxic effects.[230]

4.2 Business and Industry

4.2.1 Businesses That Use Chemicals

California businesses that use chemicals face significant barriers to improving chemical management practices and to adopting green chemistry technologies. These include a lack of standardized, robust information on chemicals in their supply chains (due to the Data Gap); the continued circulation in commerce of chemicals that pose a potential threat to public and environmental health (due to the Safety Gap); a lack of industry and government investment in green chemistry research and development (the Technology Gap); a lack of comprehensive, easy-to-use information on chemical regulatory requirements; and a lack of effective regulatory measures and incentives to improve chemical accounting and management (particularly for small and medium-sized businesses).

Businesses need better information from chemical producers.

The lack of robust, standardized information on the health and environmental safety of chemicals on the market presents a fundamental problem for California businesses that use chemicals. The Data Gap prevents businesses from identifying and using chemical products that are both efficacious and safer, and it exposes businesses to potential liability related to worker, customer, and product safety. It is very difficult for businesses to identify hazardous chemicals in their supply chains and reduce the use of those chemicals in their operations (Figure 5). Health and environmental information supplied by chemical producers, distributors, or consulting firms on Material Safety Data Sheets is often incomplete and can be inconsistent or conflicting even for the same chemical.

The problems created by the Data and Safety Gaps are experienced most acutely by small and medium-sized businesses, which do not have the resources to conduct their own chemical evaluations but have as large a stake in protecting the health of their workers and customers as do large enterprises. Even large companies, however, find it difficult to sustain their own chemical assessment programs, and some have dropped them altogether. Companies of all sizes would benefit from a California chemicals policy that improves the flow of chemical information in the supply chain and enables a state agency to efficiently identify, prioritize, and reduce the commercial circulation of the most hazardous chemicals.

Businesses would benefit from better information and technical assistance regarding chemical regulatory requirements in California.

Some California businesses that use chemicals have expressed frustration in their efforts to gather, comprehend, and conform to chemical regulatory requirements in the state. Businesses that use chemicals can face numerous regulatory requirements that are enforced by local, regional, and state agencies. These agencies are responsible for addressing subsets of chemicals as they appear in different *media*—such as outdoor air, workplace air, surface water, drinking water, solid waste, hazardous waste—and during different *events*—such as routine operations, transportation, storage, minor spills, and emergencies. In general, the regulations governing these differing arenas are not well integrated, and the agencies responsible for enforcing them do not often communicate with each other. As a consequence, some businesses in California experience chemical regulatory requirements as disorganized and confusing.[P]

The frustration on the part of businesses is heightened by two factors. First, while government agencies are responsible for enforcing only those regulations assigned by law to their sector of the chemical universe, businesses often find themselves required to develop and maintain

[P] This set of conditions was improved with the establishment under SB 1082 (19 CCR, Division 2, Article 4) of the Certified Unified Program Agencies (CUPAs), which consist of 82 regional government agencies that are responsible for collecting chemical and other information from businesses that was previously collected under six different programs involving 1,300 local and state agencies.

expertise across the full scope of that universe.[232] Doing so can be costly and time-consuming, particularly for small and medium-sized firms. Second, while California has developed a few business assistance programs that include aspects of chemical management—such as the Consultation Service of the California Division of Occupational Safety and Health[233]—there is no single public entity that is capable of providing comprehensive, easy-to-use information or technical assistance to help businesses understand and meet chemical regulatory requirements.[Q] [234]

Improving the integration and communication of the state's chemical regulatory requirements would benefit businesses and industry throughout the state and would likely lead to closer compliance with existing laws and to improved chemicals management practices generally.

Figure 5. Kaiser Permanente confronts the Data Gap.

> With 30 hospitals and over 430 medical office buildings nationwide, Kaiser Permanente is the largest private provider of health services in the U.S.; it is also the largest private-sector employer in the San Francisco Bay Area. With the support of Chairman and CEO George Halvorson, the Kaiser Environmental Stewardship Council established a new chemicals policy in April 2004 that called for "avoiding the use of carcinogens, mutagens and reproductive toxins and persistent, bioaccumulative and toxic chemicals (PBTs)."[231] It was Kaiser's intent to "achieve this policy for (their) own facilities and to broadcast (their) intent in order to drive innovation in the marketplace." As a purchaser of thousands of chemical substances and materials for which little information was available, Kaiser had operated with considerable uncertainty about the safety of its operations; the new policy sought to remedy this condition.
>
> In implementing the new chemicals policy, Kaiser has faced the lack of chemical information on the market—the Data Gap that traces its roots to deficiencies in the design and implementation of TSCA. At considerable cost, Kaiser has shouldered the responsibility of developing screening tools to assess the toxicity and ecotoxicity of the chemicals and materials it purchases.[231]
>
> The chemical Data Gap has made it difficult for even the Bay Area's largest private-sector employer to identify the properties of chemicals in its supply chain, or to identify and purchase chemicals and materials that are less hazardous to workers, the public, and the environment.

[Q] See, for example, technical assistance provided by the Massachusetts Department of Environmental Protection and the University of Massachusetts, Lowell, Toxics Use Reduction Institute pursuant to the Massachusetts Toxics Use Reduction Act of 1989 (Section 6).

California businesses need greater motivation to account for and reduce their use of hazardous chemicals.

California law requires businesses to comply with various regulatory requirements in the handling of chemicals, but the state has yet to develop a strategy that would motivate businesses to carefully account for and reduce their use of hazardous chemicals. As a consequence, chemical management practices by many California businesses tend to be undisciplined. An evaluation of 300 California companies conducted by the consulting firm 3E made the following findings:[235]

- About a third of the chemicals and chemical products used at the 300 companies were improperly inventoried, were listed but not used, or were used and unaccounted for.
- Chemical toxicity was "massively overlooked." [R]
- There was only about 12% commonality in the chemicals used between firms, even when those firms performed the same function and were owned by the same company.
- Combined, the 300 companies were unaware of the presence of about 55 carcinogenic chemicals and over 200 "extremely hazardous substances" used in chemical products.

The experience in Massachusetts under the Toxics Use Reduction Act of 1989 (Section 6) along with that of California chemical management service providers, shows that businesses are often unaware of the management costs associated with the chemicals they use, which can range from seven to 10 times the purchase cost.[236-238] Chemical accounting systems, such as those required in Massachusetts, motivate businesses to quantify and reduce these costs. Developing these systems, however, take time and money, and the experience in Massachusetts and of 3E suggests that businesses will not invest in these systems without a regulatory driver. The Massachusetts experience also illustrates that technical assistance by a state agency in chemical accounting and management systems is useful, particularly for small and medium-sized businesses.

4.2.2 Green Chemistry Leaders

The Data, Safety, and Technology Gaps represent a barrier to the broad adoption of green chemistry. Due to the lack of robust, standardized toxicity information (the Data Gap), green chemistry leaders find it difficult to differentiate their products in the market; weaknesses in regulatory oversight allow the continued use of hazardous chemicals (the Safety Gap); and there is no substantive public investment in green chemistry research, development, technical assistance, and education (the Technology Gap). Together, these conditions have undermined industry motivation to invest in the technological changes that are necessary for the adoption of green chemistry. This set of conditions broadly characterizes the present status of green chemistry in the U.S. and California.

[R] In light of the Data Gap, this finding most likely understates true conditions in the surveyed firms.

A 2003 study by RAND identified similar barriers to the development and implementation of green chemistry in the U.S.:[239]

- lack of research, technology development, and new process engineering;
- industrial infrastructure problems and integration barriers;
- the size of up-front investments required; and
- lack of coordinated actions by means of regulations, incentives, and government purchasing.

To establish the technical foundation and market viability of green chemistry, California will need to correct these core chemicals policy weaknesses.

The Data Gap makes it very difficult for green chemistry leaders to differentiate their products in the market.

With few exceptions, chemicals and chemical products are differentiated in the market only on the basis of function, price, and performance. The chemicals market is thus unable to select against hazardous chemicals. As a consequence, there is little immediate, compelling *market* advantage to firms that invest time and money in implementing the principles of green chemistry, just as there is very little market disadvantage to firms that gain competitive advantage through the design and manufacture hazardous chemicals. There are no agreed-upon technical criteria or labeling strategies that would allow green chemistry leaders and entrepreneurs to differentiate their products in the market.[S] These market conditions have made it very difficult for both established and new firms to introduce green chemistry products into the market.[240]

Weak regulatory oversight in the chemicals market has dampened industry motivation to invest in green chemistry.

As described below, there is very little regulatory oversight of chemicals in commercial circulation in California. Reflecting the Safety Gap, state agencies are unable to identify, prioritize, and reduce the use of hazardous chemicals in the market. Businesses therefore do not face a regulatory barrier to designing, manufacturing, and using hazardous chemicals and chemical products in California, which weakens the competitive advantage of safer, green chemistry products. Combined with the effects of the Data Gap, these conditions have undermined the commercial success of green chemistry.

The role of regulation in motivating technological change in industry is apparent in changes that have occurred in energy consumption per capita in California compared to the rest of the

[S] The challenges of developing technical criteria for green chemistry products grow as the boundaries of the analysis are extended up the supply chain and through the design and production process. The *California Certified Organic Farmers* (CCOF) label, for example, was based on a fairly narrow set of technical criteria for organically produced foods; it did, however, allow organic growers to differentiate their products in the market. Labeling strategies in the chemicals market are challenging because very few chemicals are sold to end-users; the formulators of chemical products, not chemical producers themselves, play the greatest role with respect to green chemistry product design. In addition, producers and formulators alike often consider green chemistry *processes* to be proprietary.

U.S.[241, 242] Over a period of 25 years, California has adopted some of the strictest energy efficiency requirements in the nation, such that California now uses half as much energy per capita compared to the U.S. as a whole. California's energy efficiency regulations have altered the orientation of the energy market, which, like the chemicals market (with respect to green chemistry), is structured such that it hampers, rather than encourages, energy efficiency.

The important role of regulation in shaping chemicals and materials policy is apparent in changes occurring in the U.S. electronics industry as a result of regulatory developments in the European Union (Section 5). The E.U. directive on the *Restriction of Hazardous Substances in Electrical and Electronic Equipment* (RoHS) will prohibit the use of lead, cadmium, mercury, and other toxic substances in electronic and electrical equipment sold in the E.U. Although the health and environmental effects of these materials have been known for decades—and it has been well known that these materials were dissipating into the environment through electronic waste—most U.S. electronics producers resisted innovating safer materials until they were forced to do so by the RoHS directive. Similarly, the E.U. directive on *Waste Electrical and Electronic Equipment* (WEEE) requires U.S. electronics producers to redesign equipment to facilitate "take-back" at the end of the product's useful life. Most electronics producers resisted similar efforts in California, even though the health and environmental threats of electronic waste (particularly in certain developing countries) have been known for several years.

There is a lack of attention to green chemistry research and education.

Without a functioning market or regulatory driver to motivate chemical producers to invest in green chemistry, and without an explicit government commitment to invest in green chemistry research, U.S. universities have seen little reason to direct attention to green chemistry. The University of Massachusetts offers the only chemistry doctoral program in the U.S. that fully integrates the principles of green chemistry.[243] Moreover, very few U.S. universities require undergraduate or graduate students in chemistry to demonstrate an understanding of toxicology.[244] At the University of California, Berkeley, for example, one of the nation's leading chemistry research and teaching institutions, students earning undergraduate and graduate degrees in the College of Chemistry are not required to undertake coursework in the principles of human and environmental toxicology.

The lack of green chemistry educational and research opportunities at leading U.S. universities represents a key impediment to the technical and commercial success of green chemistry; it is also a potential barrier to the long-term capacity for innovation and growth in the U.S. chemical industry more generally.[245] A sustainable future will not be possible in California if the next generation of chemists has little to no understanding of the basic principles of toxicology.

The broad adoption of green chemistry will require a technological transition in the chemical industry.

As described below, adopting green chemistry practices will require technological change by industry; technological change, however, introduces new costs and uncertainties, both of which are challenging for industry.[246-248] Without a promising market or an effective regulatory driver, most established firms therefore tend to avoid technological change, or they experiment in niche markets with spin-off products that do not pose an economic threat to the company's core processes or markets. As a result, technological innovation is often accomplished by new market actors who have less stake in established technologies. However, because the combined effects of the Data, Safety, and Technology Gaps prevent proper operation of the chemicals market in the U.S., entering the chemicals market as an entrepreneur is extremely difficult.[240, 249, 250] Under present conditions, the broad adoption of green chemistry in the U.S. is unlikely in the near term.

A comprehensive chemicals policy in California that closes the Data, Safety, and Technology Gaps will support green chemistry leaders by enabling proper operation of the market and effective regulation, and by supporting research in green chemistry science and technology.

4.2.3 Chemical Producers

The present position of the U.S. chemical industry with respect to chemicals policy in the U.S. can best be described as a paradox. On one hand, the industry has benefited from the Data and Safety Gaps engendered by TSCA; the industry has not been required to invest substantially in chemical safety testing, and it has not had to contend with a government agency with broad authority to regulate chemicals in the market. Indeed, the American Chemistry Council regularly argues in support of TSCA and advises that changes to the statute are unnecessary.[251] In January 2006, ACC Managing Director Michael Walls noted, "In our opinion, TSCA works and works well."[252]

On the other hand, the weaknesses of TSCA and other federal statutes have dampened the motivation—and perhaps the capacity—of the industry to innovate safer, green chemistry technologies. The websites of the 50 largest U.S. chemical companies all contain a statement of commitment to achieving sustainability goals; at the same time, however, spending on research and development by these companies has decreased or remained flat since about 2000, according to the National Science Foundation.[26, 253] Introducing a new green chemistry product or process has proven to be difficult under the market conditions engendered by TSCA, as previously described. Not surprisingly, the great majority of the chemical processes and chemicals used today have not changed substantially since TSCA was introduced into law nearly 30 years ago (Section 5). Only 248 new chemicals introduced since 1979 have reached High Production Volume (HPV) status, about 8% of the 2,943 HPV chemicals in commercial circulation today (Section 3).[38] [T]

The U.S. chemical industry faces an array of global and domestic pressures.

U.S. chemical producers now face a set of market and policy pressures that they may or may not be capable of meeting, assuming they continue along their current path. Given the industry's role as a feedstock to many industrial and commercial sectors in the U.S., the implications of these challenges for economic growth and employment in California could be significant. These pressures include the following:

- For the first time, the U.S. chemical industry is operating with a global trade deficit.
- North American natural gas costs far exceed those of global competitors.
- The price of non-renewable fossil fuel feedstock rose 50% during 2004–2005.

[T] High Production Volume = produced or imported at one million pounds or more per year.

- Under its current technology choices, the industry faces ongoing regulatory compliance costs.
- Many U.S. states, including California, are pursuing chemical phase-outs and other policies.
- The federal government does not have a strategy to spur innovation in green chemistry.
- The European Union is implementing sweeping new chemicals policy reforms (Section 5).
- A growing number of large U.S. and E.U. businesses are seeking to remove hazardous chemicals from their supply chains (Section 5).
- U.S. nongovernmental organizations are involved in campaigns to change chemical markets and policies (Section 5).

Some of the challenges facing the U.S. chemical industry relate to the pressures of the global economy and to the realities of non-renewable fossil fuels; others signal a demand by the market and the public for safer chemical products and processes, such as green chemistry. Industry leaders recognize that to respond to these challenges, the industry will need to commit itself to a new era of technological change and innovation in which green chemistry will play a significant role. At the same time, the industry's investments in current technologies will likely cause these same leaders to resist policy changes that could bring about a technological transition of this nature. This represents a fundamental dilemma for the U.S. chemical industry and a key challenge for the establishment of a new chemicals policy in California.

For the first time, the U.S. chemical industry is operating with a global trade deficit.

For the first time, the U.S. chemical industry is experiencing a trade deficit (Figure 6).[71] In 2002, the deficit was about $5 billion. This appears to be driven by a widening deficit with the major U.S. chemical trading partner, Western Europe (Figure 7), which highlights the importance of E.U. chemical regulatory initiatives for the U.S. chemical industry and the U.S. economy generally (Section 5).

The U.S. has maintained a trade surplus in chemicals with Asia/Pacific (Figure 8) and with Canada and Mexico (Figure 9). The total value of trade in chemicals between the U.S. and the Middle East, Africa, and Latin America was below $10 billion in total imports and exports for each of these regions during 1992–2002.[71]

The U.S. chemical industry is experiencing a trade surplus in basic chemicals (Figure 10) and consumer products (Figure 11), and a trade deficit in specialty chemicals (Figure 12) and pharmaceuticals/pesticides (Figure 13).

Figure 6.[U] *U.S. global trade in chemicals, 1992–2002.*

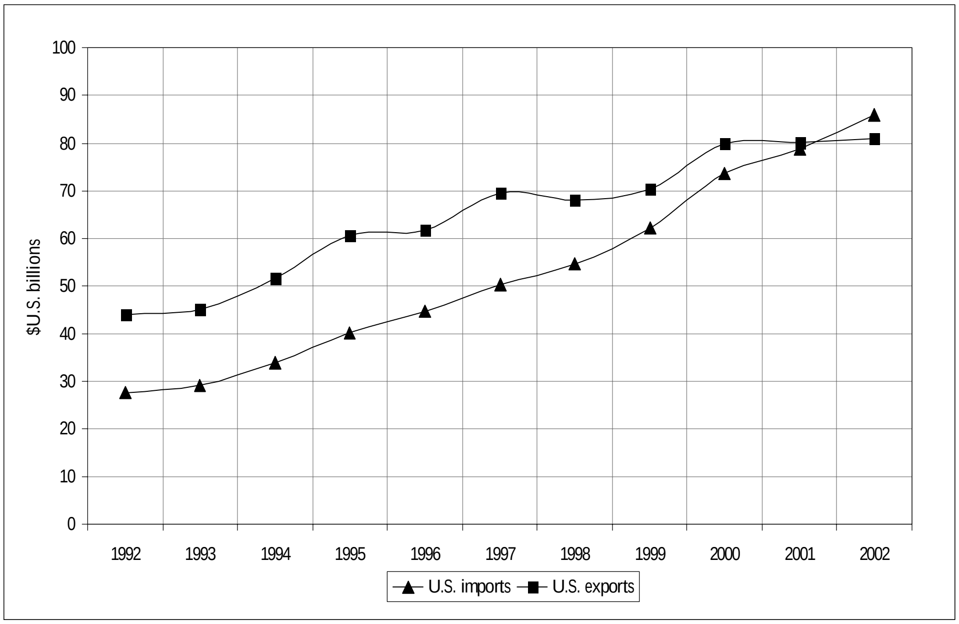
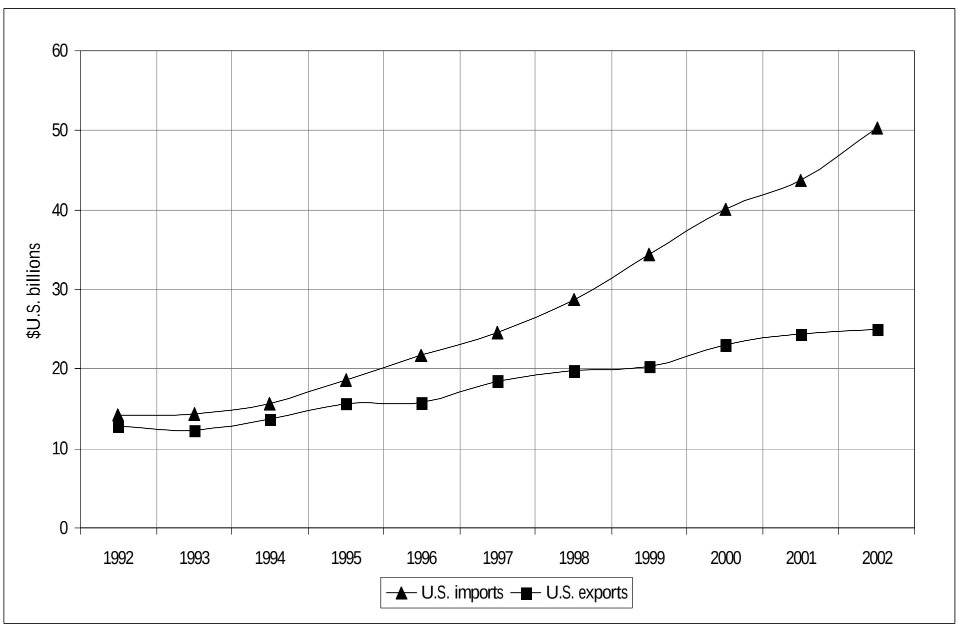


Figure 7.[V] *U.S. trade in chemicals with Western Europe, 1992–2002.*



[U] For Figures 6, 7, 8, and 9, the data reflect totals for basic chemicals, specialty chemicals, life sciences (pharmaceuticals and pesticides), and consumer products.

[V] In 2002, Western European chemical imports accounted for 60% of total U.S. chemical imports. In these data, Western Europe includes the chemical markets of France, Germany, Ireland, Italy, The Netherlands, Switzerland, United Kingdom, and "Other Western European" countries. Countries in Central and Eastern Europe are not included; however, in aggregate the countries of Central and Eastern Europe accounted for only $663 million in U.S. chemical exports (2.6% the level of exports to Western Europe) and $2.3 billion of U.S. chemical imports (4.6% the level of imports from Western Europe) in 2002.

Figure 8. U.S. trade in chemicals with Asia/Pacific, 1992–2002.

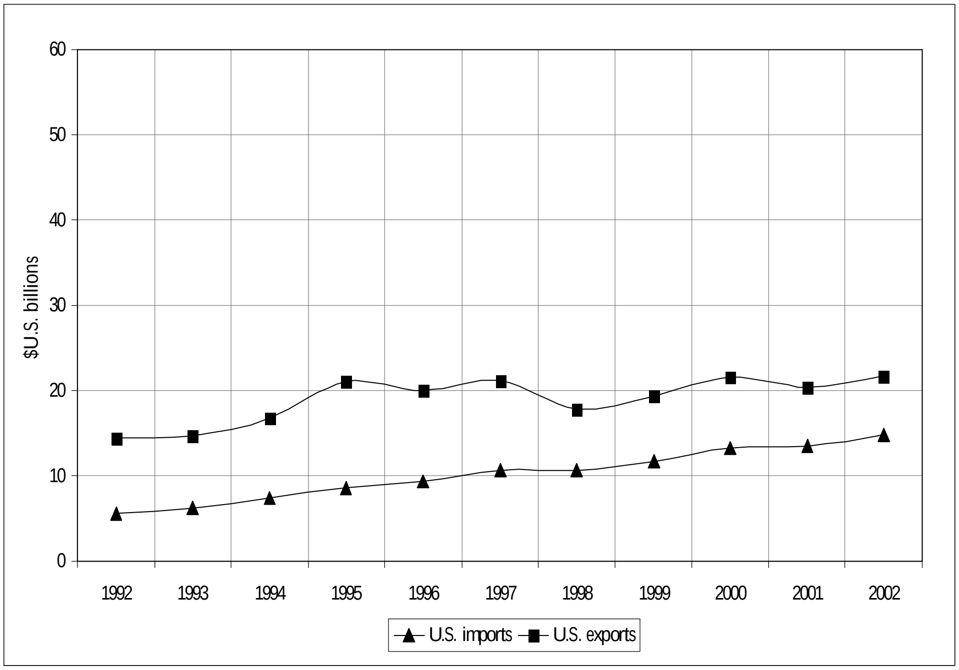


Figure 9. U.S. trade in chemicals with Canada and Mexico, 1992–2002.

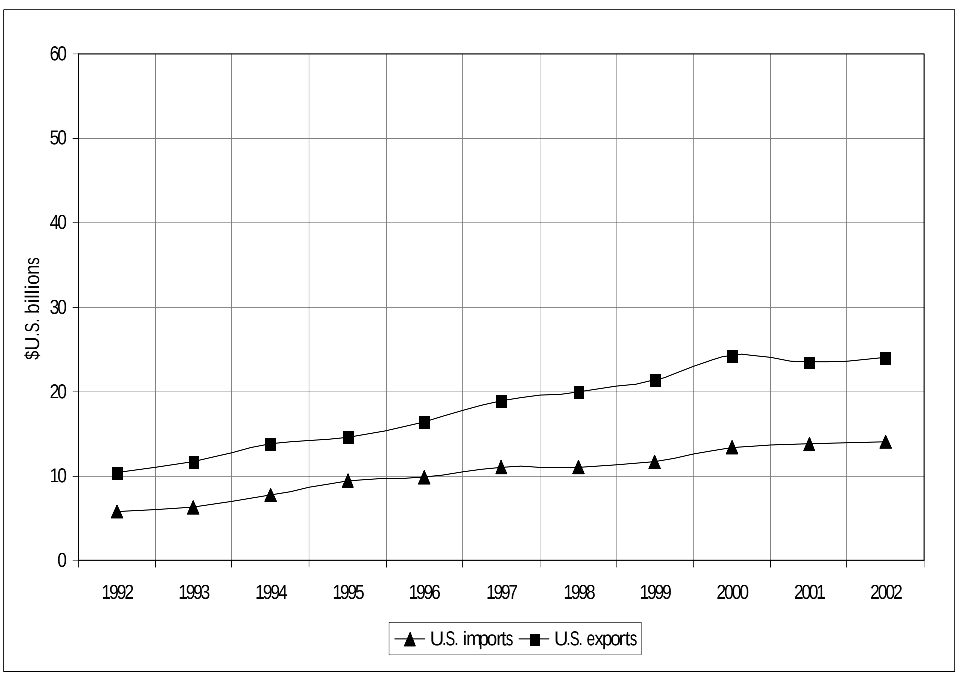


Figure 10.[W] *U.S. global trade in basic chemicals, 1992–2002.*

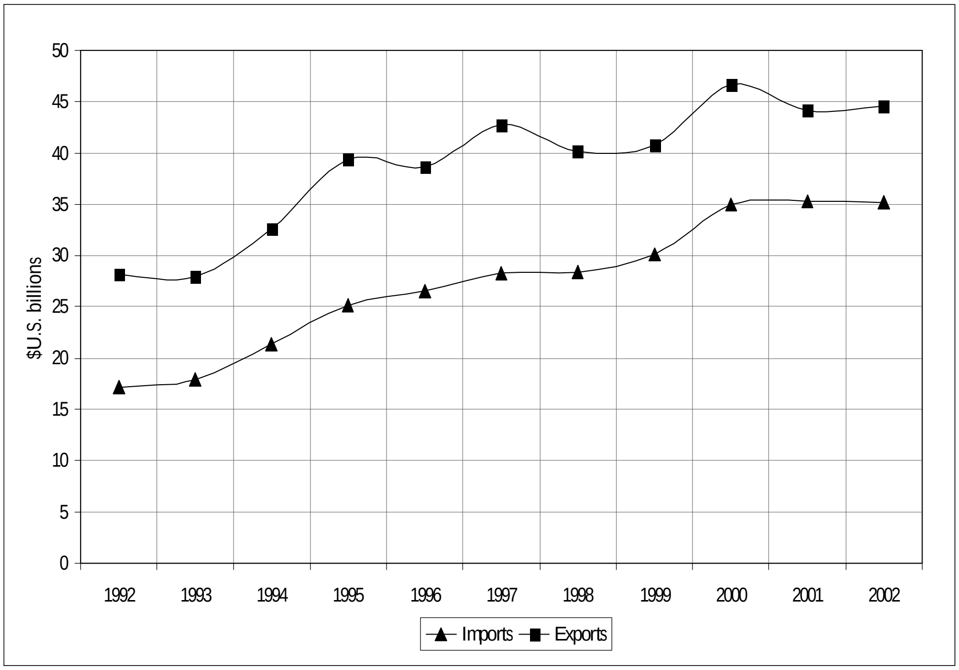
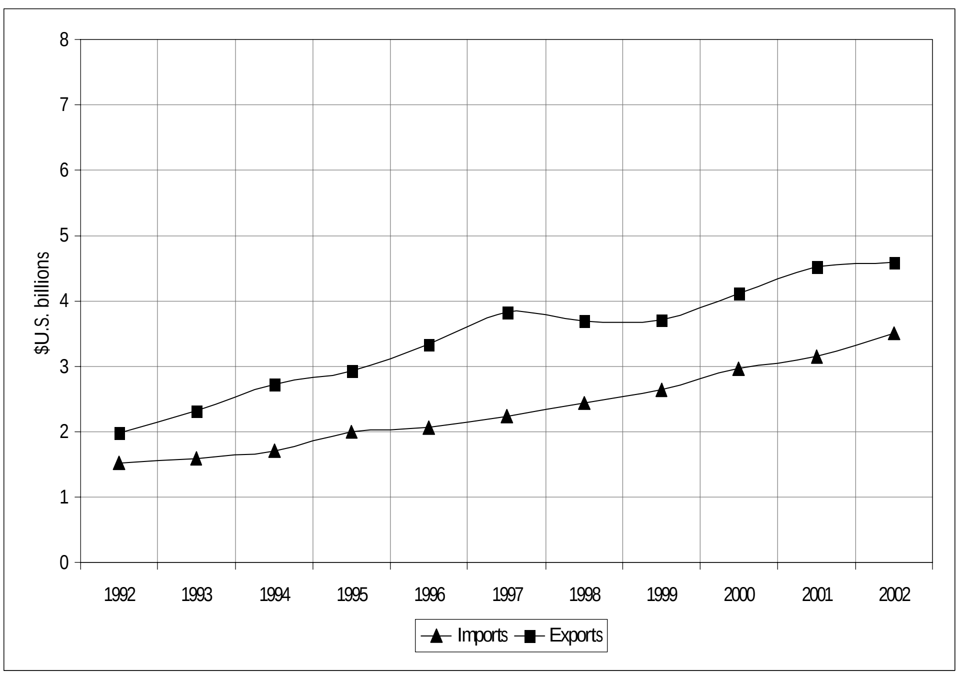


Figure 11. U.S. global trade in consumer products, 1992–2002. (Note scale change.)



[W] Basic chemicals include industrial chemicals (inorganics, bulk petrochemicals and intermediates, petrochemical derivatives and other polymers, surfactants, colorants, printing inks and others) and fertilizers (Figure 1).

Figure 12.[X] *U.S. global trade in specialty chemicals, 1992–2002.*

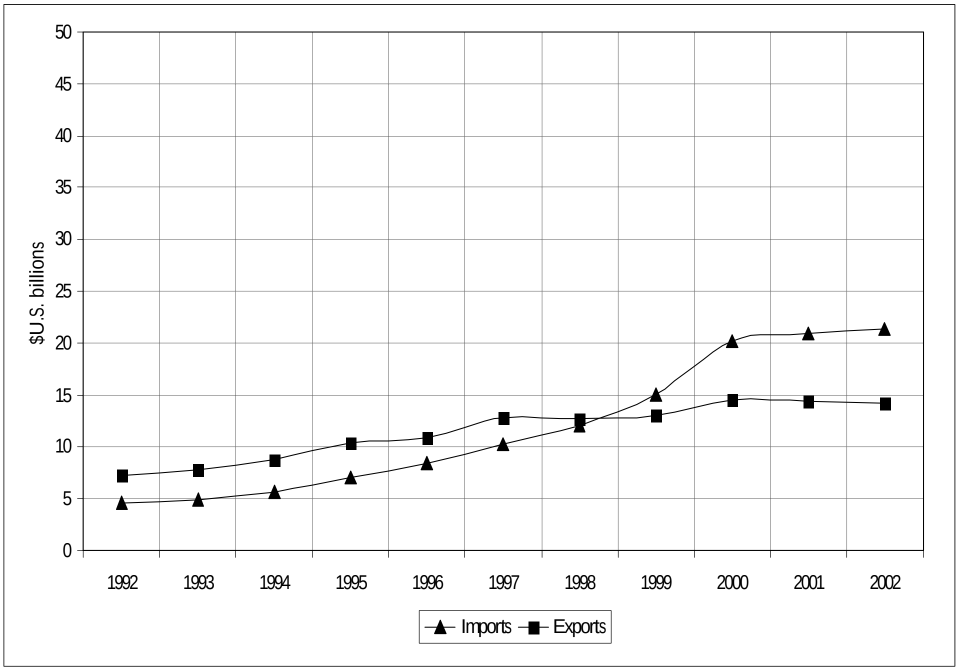
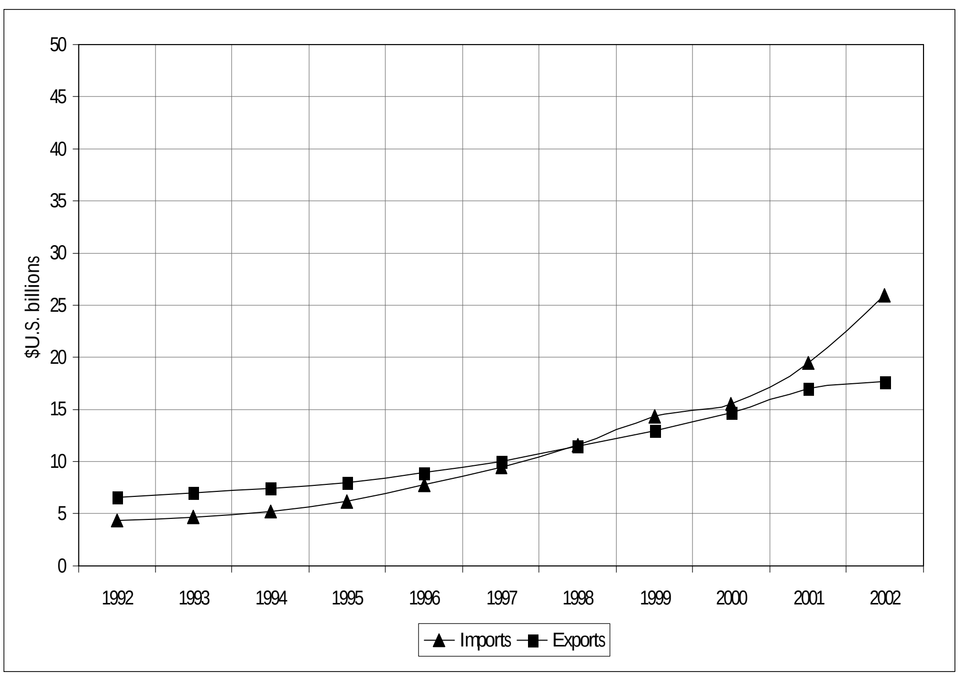


Figure 13.[Y] *U.S. global trade in pharmaceuticals and pesticides, 1992–2002.*



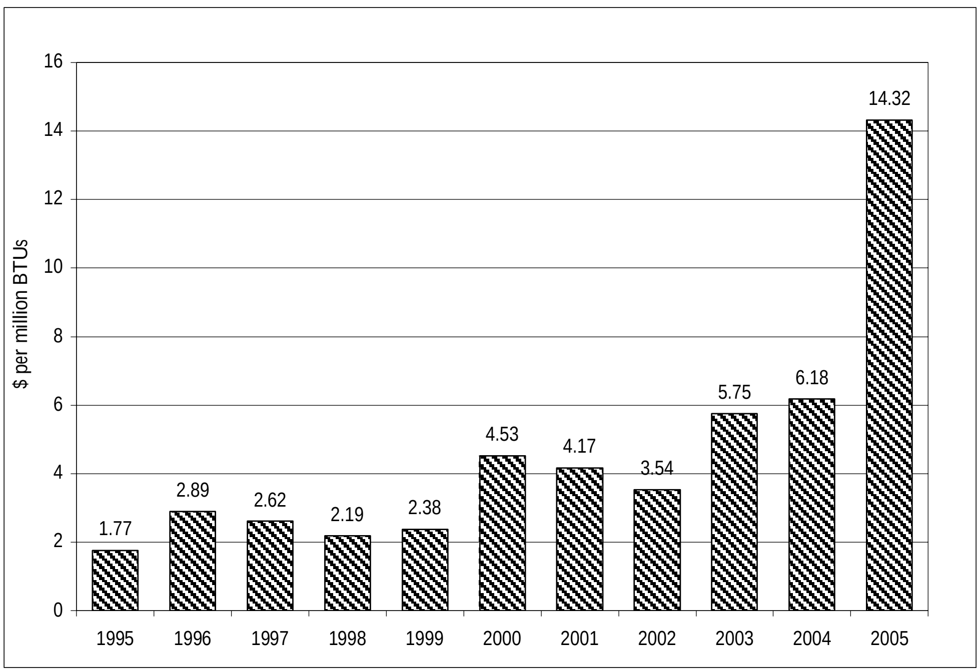
[X] Specialty chemicals include adhesives, catalysts, coatings, electronic chemicals, industrial gases, plastic additives and others.

[Y] These data are dominated by pharmaceuticals. In 2002, U.S. pesticide imports were $0.5 billion and pharmaceutical imports were $25.5 billion; pesticide exports were $1.5 billion and pharmaceutical exports were $16.2 billion.

North American natural gas costs far exceed those of global competitors.

The U.S. chemical industry is the single largest industrial consumer of natural gas in the U.S., accounting for 26% of total consumption for domestic manufacturing.[254] The American Chemistry Council reports that escalating natural gas prices during 2004 and 2005 have sparked an energy crisis in the industry, and that maintaining access to a reliable and affordable supply of energy has become the industry's most important economic issue (Figure 14).[255] Industry analysts note that U.S. electrical utilities are able to pass natural gas price increases onto domestic users, whereas the chemical industry is forced to buy natural gas on a tight North American market and sell its products on a global market, "where they compete with companies whose costs of production, based on natural gas prices, are five times lower."[256] In December 2005, the U.S. Department of Energy reported that after spiking at more than $14 per thousand cubic feet, natural gas prices will return to less than $5 in the long term.[257]

Figure 14. U.S. natural gas prices as reported by the American Chemistry Council, 1995–2005.



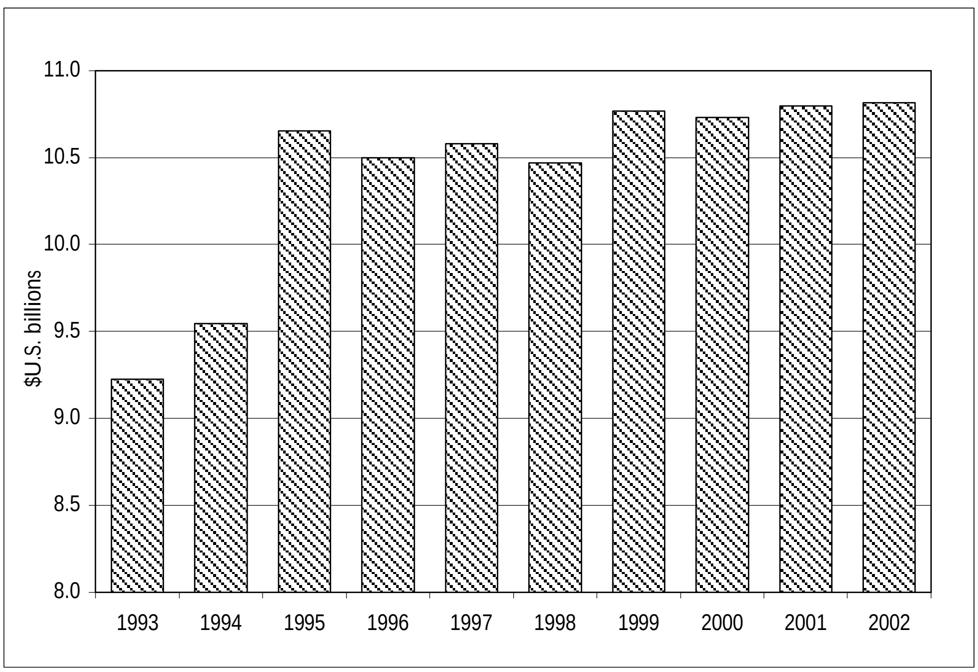
Continued reliance on non-renewable fossil fuel feedstock will be increasingly problematic.

In addition to natural gas prices, the U.S. chemical industry is facing escalating prices and declining availability of fossil-fuel feedstock.[258-260] In 2000, U.S. chemical producers purchased 950 million barrels of oil for organic chemical production, or about 90% of total feedstock.[261, 262] Between June 2004 and July 2005, the price of oil increased from $40 to $60 per barrel.[263] As production of non-renewable fossil fuels peaks, the chemical industry is likely to become increasingly vulnerable to price fluctuations and security of supply concerns.[264, 265] The development of alternatives to fossil fuels, such as biobased materials and processes, is therefore considered to be a key feature in the future of the industry (Section 5).[266] In July 2004, for example, Thomas Connelly, DuPont's chief science and technology officer, noted that "with oil costing as much as $40 a barrel and being a non-renewable resource, there are all kinds of reasons to say that a market for carbon derived from agricultural materials is viable and will improve over time."[267]

Under its current technology choices, the chemical industry faces substantial regulatory compliance costs.

As noted above, the American Chemistry Council reports that the industry spent between $10 and $11 billion per year between 1995 and 2002[Z] on environmental, health, and safety compliance (Figure 15).[71] As previously noted, these costs were associated with efforts to abate air pollution, water pollution, and other pollution (43%); capital costs for pollution abatement (27%); hazardous waste cleanup (16%); and worker health and safety (14%) related to the industry's current chemical technology choices. The ACC reports that these costs amounted to about 3% of sales, with a slight decline from 1993 to 2002.[AA]

*Figure 15. Spending for environmental, health, and safety compliance in the U.S. chemical industry, 1993–2002.**



* For consumer products, basic chemicals and specialty chemicals; excludes pharmaceuticals and pesticides.

[Z] Excludes pharmaceuticals and pesticides.
[AA] The ACC reports that these and other factors have led to marked improvements in environmental and occupational health performance. For example, the ACC notes that while the industry's output increased 26% from 1988 to 2002, emissions of certain substances (as listed under the U.S. Toxics Release Inventory) declined 71%, and the prevalence of occupational illness and injury declined 38%.[71] The largest share of regulatory costs have been devoted to environmental regulatory compliance (59%), followed by various economic (15%), tax (14%) and workplace regulations (12%).[268]

Many U.S. states, including California, are pursuing chemical phase-outs and other policies.

In 2005, the California Legislature deliberated on about 35 bills related to chemicals (see below). During this same period, about 18 U.S. states considered or passed legislation pertaining to chemicals in at least five areas: brominated flame retardants (BFRs), mercury, methyl tert-butyl ether (MTBE), lead, and arsenic in wood products (Figure 16).

Figure 16. Chemicals policy legislation pending or passed in 18 U.S. states, 2005.

	BFR	Mercury	MTBE	Lead	Arsenic
Alaska	■				
California	■	■		■	
Connecticut	■	■	■		
Florida				■	■
Hawaii	■				
Illinois	■	■			■
Maryland	■	■	■		
Michigan	■	■			■
Minnesota	■	■			
Montana	■		■		
New Jersey			■		■
New York	■	■	■		■
North Carolina		■			
Ohio	■	■			
Oregon	■	■			
Rhode Island		■	■		
Vermont		■			
Wisconsin	■	■			

Source: M+R Strategic Services, Bill Wasserman, President. 2120 L Street, NW, Washington, D.C., 20037 (http://www.mrss.com) (accessed March 2, 2006). Used with permission.

Like chemicals policy initiatives occurring among some U.S. businesses, state-based chemical initiatives are a natural reaction to the weaknesses of federal chemicals policies, notably TSCA; they reflect ongoing public concern over the health and environmental effects of chemicals. The number of state-based initiatives is likely to grow in the future as the public becomes more aware of developments in the European Union[269, 270] and of chemical problems in the U.S., such as those related to persistent and bioaccumulative substances[BB] and to children's health.[273]

[BB] The U.S. Centers for Disease Control (CDC)[271] reports that the presence of certain chemicals in the body does not necessarily imply an increased risk of disease or the need for policy action; the E.U., however, is moving in a markedly different direction. The U.K. *Royal Commission on Environmental Pollution*, for example, has recommended that "where synthetic chemicals are found in elevated concentrations in biological fluids such as breast milk and tissues of humans, marine mammals or top predators, regulatory steps be taken to remove them from the market immediately."[272] The E.U. REACH *authorization* process will presumptively remove certain

For many years the chemical industry has recognized the need for green chemistry innovation, but it has not made substantive progress in this arena.

The U.S. chemical industry recognizes that the three pillars of economic, environmental, and social sustainability represent the long-term solution to the many challenges it faces. Industry leaders recognize that to remain viable, the industry must commit itself to a new era of innovation in which green chemistry and other cleaner technologies will need to play a significant role.[31, 265, 274-276]

In its 1996 *Vision 2020* report, the U.S.-based Council for Chemical Research, together with the American Chemical Society, the American Institute of Chemical Engineers, the American Chemistry Council, and the Synthetic Organic Chemical Manufacturers Association, wrote that the vast majority of chemical products are manufactured using technologies developed 40 to 50 years ago and that new technologies are needed that incorporate economical and environmentally safer processes, use less energy, and produce fewer harmful byproducts.[277] *Vision 2020* established goals for the chemical industry of reducing feedstock losses to waste and by-products by 90%, energy intensity by 30%, and emissions and effluents by 30% by the year 2020. The report concluded:[CC]

> While the challenges of sustainability are significant, there are also major opportunities. . . . The chemical industry now has the opportunity to accelerate its development of advanced manufacturing technologies and new chemistry and related technologies that use materials and energy more efficiently. U.S. companies also have an opportunity to build on their current dominance in the relatively new field of environmental technology. Environmental technologies make sustainable development possible by reducing risk, improving process efficiency, and creating products and processes that are environmentally beneficial or benign.

Ten years after *Vision 2020*, the websites of the 50 largest U.S. chemical companies all contain a statement of commitment to achieving sustainability goals, as previously noted, but their spending on research and development has decreased or remained flat since about 2000.[26, 253]

It is not surprising, therefore, that the Committee on Grand Challenges for Sustainability in the Chemical Industry, convened by the National Academy of Sciences, concluded in its December 2005 report that in "going forward, the chemical industry is faced with a major conundrum—the need to be sustainable (balanced economically, environmentally, and socially in order to not undermine the natural systems on which it depends)—and a lack of a more coordinated effort to generate the science and technology to make it all possible."[279] The committee included academic scientists as well as representatives of Dow, PPG Industries, ConocoPhillips, and Agraquest.

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bioaccumulative, persistent and toxic substances from the market, along with "very persistent, very bioaccumulative" substances—regardless of toxicity (Section 5).

[CC] The 1996 *Vision 2020* report was in part the result of a request from the White House Office of Science and Technology Policy for advice from U.S. industry on how the U.S. government could better allocate research and development funds to advance the manufacturing base of the U.S. economy. The report did not use the term "green chemistry," although followup efforts did.[278]

There are indications that green chemistry, including biobased materials, will become increasingly important in the chemicals market.

Given the problems associated with non-renewable fossil fuels, together with developments in the E.U. and efforts by some large U.S. companies to clean their supply chains of hazardous chemicals, it is clear that fundamental changes are occurring in the chemicals market (Section 5). The European Social Investment Forum reported in 2005 that "over the next five to ten years, green chemical innovation could be a significant source of competitive advantage for companies manufacturing chemicals used in consumer products, particularly in markets where brand or product differentiation based on green credentials is a key component of value for the final customer."[266] Great Britain's Crystal-Faraday Partnership[DD] projected that consumer and commercial demand will grow during 2003–2013 for chemical products that are "more environmentally friendly whilst still delivering high performance," and for which there is complete "traceability of all raw materials and ingredients."[280] In California's Silicon Valley, clean technology in energy and chemicals was projected to be one of "ten key trends that are likely to set the direction for technology in 2006."[281]

There are indications that the demand for green chemistry processes and products using biobased materials will increase in the U.S. over the next five to 10 years.[264] In 2000, the National Academy of Sciences evaluated biobased materials in the U.S. and proposed national targets for their adoption (Table L).[282]

Table L. National Academy of Sciences targets for biobased industrial materials, as percent derived from biobased feedstock material.

		National targets	
Biobased product	**2000 level**	**2020 level**	**2090 level**
Liquid fuels	1-2%	10%	50%
Organic chemicals	10%	25%	90%
Materials	90%	95%	99%

The NAS timeline might be conservative.[283] Sales at NatureWorks, a Cargill, Inc. subsidiary that makes rigid-transparent plastics from corn sugars, grew 200% in the first half of 2005 compared to the same period in 2004.[67] NatureWorks Chairwoman Kathleen M. Bader noted that "the early adopters were more influenced by environmental concerns than costs, but now we're competitive with petrochemicals, too."[67] In its October 2005 report, the European Social Investment Forum reported that "the development of alternatives to fossil fuels as a primary input factor to production . . . is a potential source of competitive advantage for chemical companies that are able to make this transition themselves. Leaders in this area will be well positioned to benefit from investment and market opportunities in bio-derived products (e.g. biodiesel) at the expense of laggards, provided stakeholder concerns about genetically modified

[DD] The Crystal-Farraday Partnership is a government-funded consortium of chemical producers and academic researchers in Great Britain. It includes industry participants Proctor and Gamble, GlaxoSmithKline, Protensive and British Petroleum.

organisms (GMOs) can be addressed and required quantities of bio-feedstock can be reliably sourced."[266]

To encourage investment in biobased processes and products, the U.S. Farm Security and Rural Investment Act of 2002 (P.L. 107-171) includes a provision that will require federal agencies (beginning January 2006) to "preferentially purchase" biobased materials—from biodegradable solvents to transmission fluids and synthetic fibers—provided these materials are readily available, efficacious, and cost-effective.[284, 285] [EE]

Investments in current technologies will cause some members of the U.S. chemical industry to resist policy changes that would spur a technological transition to green chemistry.

The U.S. chemical industry has the technical capacity and talent to innovate cleaner technologies, including green chemistry, and a chemicals policy should support, motivate, and compel the industry to do so. Ironically, out of rational self-interest, some members of the industry will likely oppose policies of this nature, despite recognizing that over the long term they would benefit the industry as a whole. This is the fundamental dilemma of an industry that finds itself transitioning from one set of technological and social conditions to another.

The challenges facing the chemical industry will require a deep transition to new technologies, including green chemistry. As the U.S. industrial experience has demonstrated, however, making a transition of this type is inherently disruptive.[246-249] Technology transitions produce winners and losers; companies survive the transition by innovating and re-inventing themselves, or they exit the market. This is the juncture that now appears to be facing the Ford Motor Company, for example.[289-291] [FF] As Ford's case illustrates, a technology transition that occurs in *reaction* to a steady loss of market share can be particularly disruptive. At the same time, for a variety of reasons, industry often finds it difficult on its own to take *proactive* action in the face of imminent changes in the market. The U.S. chemical industry may be beginning to face these conditions in the global chemicals market.

Proactive technology transitions by industry are preferable to reactive transitions.

Technology transitions can occur *reactively* in response to a loss of market share—as the experience of the U.S. auto industry illustrates—and they can be spurred *proactively* through

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[EE] While there are a number of advantages to moving from a petroleum-based to a biobased chemical production system, it is important to note that the health and environmental implications of biobased materials and processes are not yet well understood.[286-288] These include, for example, concerns over worker health effects associated with the production, processing, and use of biobased materials; environmental impacts of agricultural production for the purpose of producing biobased feedstock, such as pesticide and fertilizer use, energy consumption, farm machinery emissions, and soil erosion; and the use of genetically modified organisms (GMOs). The successful development of biobased materials will require linkage to sustainable agricultural and greenwaste practices and a comprehensive, integrated approach to chemicals policy.

[FF] With increases in fuel costs, Ford's 10-year resistance to higher fuel economy standards has now produced a dramatic loss of U.S. market share, which has dropped from about 27% to about 18% over a period of 10 years; U.S. sales of Toyota and Honda vehicles continued to climb during the same period. [289] In the third quarter of 2005, Ford lost $1.2 billion. In 2006, Ford will close 10 of 43 plants and cut 25,000 of 123,000 jobs in North America.

public policy. Industry leaders recognize that technology transitions are inevitable and, in fact, are the driving force of innovation and new growth. Many industry leaders, along with labor and community leaders, also recognize that *proactive* transition strategies provide a margin of protection to the economic security of workers and communities. From the point of view of public health, proactive technology transitions are preferable to reactive transitions, which can be disastrous for workers and communities when they involve an important industry such as the chemical industry. On the current trajectory, however, most U.S. chemical companies will likely continue to rely on existing chemical technologies and products, and some portion of these companies will end up in a reactive transition as they attempt to remain solvent in an increasingly competitive global economy.

By adopting a comprehensive chemicals policy, California would help drive a proactive technology transition in the U.S. chemical industry.

Given the important role of the chemical industry and its products in California, the problems facing the industry warrant a concerted policy response. Just as it continues to provide leadership in policies to promote energy efficiency, California has a unique opportunity to take a leadership role in implementing a chemicals policy that lays the groundwork for a proactive transition in the chemical industry to green chemistry technologies.[241, 242]

The developments described above, however, suggest that the U.S. chemical industry may already be entering the early stages of a reactive transition environment, and that the window for implementing a proactive transition in California could begin to close in the near future.

Most U.S. chemical producers recognize that the future of the industry rests not in a “race to the bottom” with other nations in the production of chemicals that are already on the market, but rather in the technological transition we are describing. Though it could be costly in the short term, this transition will improve the capacity of the industry to compete over the long run on the basis of its contribution and dedication to the three primary dimensions of sustainability—often known as the “triple bottom line” of environmental, social, and economic sustainability. This perspective represents the foundation for a new, comprehensive chemicals policy in California.

4.3 Government

4.3.1 Agencies

As a result of the Data Gap, California state agencies face a fundamental lack of information on the toxicity and distribution of chemicals used in the state, which has prevented them from systematically identifying, prioritizing, and mitigating chemical hazards.

California agencies also face procedural and legal barriers in responding to known chemical hazards; agencies carry the burden of proving that a chemical poses a risk to public health long after it has been introduced into commerce.

In addition to information gaps and regulatory weaknesses, responsibility for chemically related issues in California is distributed among numerous state, regional, and municipal agencies.

There is no single agency equipped to address chemical issues in an integrated, comprehensive manner.

The effectiveness of state agencies is limited by a lack of data on the toxicity and distribution of chemicals.

The Data Gap prevents California agencies from systematically identifying and prioritizing chemical hazards in the state. Agencies are able to gather chemical toxicity information only from publicly available databases and the scientific literature, neither of which is standardized or complete. Agencies are also unable to determine the identity and distribution of chemicals used in the state. A 2002 analysis conducted for the California Department of Health Services found that chemical *use* and *distribution* information from existing state and federal databases, or from voluntary submission by chemical producers, was inadequate for state agencies to characterize chemicals in commercial circulation (Table M).[292] As part of the analysis, only 17 of 96 chemical producers (18%) responded to a voluntary request for chemical distribution information; of these, six (6%) provided the requested information.

The lack of information on the toxicity and distribution of chemicals in California represents a significant barrier to state agencies. At present, agency staff are unable to determine the *identity* of chemicals used in processes and products in California, *where* those chemicals are used, in what *volume*, for what *purpose*, how people may be *exposed* to them, or how *toxic* and *ecotoxic* they might be. They are unable to identify the highest-volume chemicals used in California, for example, or what risks those chemicals might pose to public and environmental health. When new scientific information emerges on a particular chemical, it is not possible for agency scientists to efficiently assess what the information *means* for public health in California; it is therefore difficult for agencies to assess how quickly and to what degree the state should *respond* to the information.[GG]

State agencies face procedural and legal barriers in acting to protect public health from known chemical hazards.

While agencies are limited in their ability to *identify* and *assess* chemical hazards, they are also prevented from taking efficient and timely *action* to mitigate known hazards. With the exception of chemical emergencies, agencies are generally able to take regulatory steps to protect public and environmental health only after a chemical has been introduced into commerce and its adverse effects have become distinct and widely acknowledged. At public expense, this involves a protracted process of (1) gathering sufficient evidence to make a case for harm, (2) meeting scientific standards of proof of harm, (3) building the political will necessary to respond to the evidence of harm, (4) navigating the regulatory hearing process, and (5) responding to legal appeals.[224] To build a case, agencies face the same “logical paralysis” that constrains the U.S.

[GG] Assembly Bill 816 (Lieber) was introduced in the 2005 legislative session as an initial step to address this issue. It would have allowed California’s Hazard Evaluation System and Information Service (HESIS) to respond to new chemical toxicity information by requesting client data from chemical product formulators for the purpose of alerting potentially affected businesses and workers in California.[293] The bill was opposed by the California Chamber of Commerce and vetoed by Governor Schwarzenegger in September 2005.[294]

Table M. State and federal chemical information databases and their key deficiencies.

	Title	Purpose	Key deficiencies
California data sources	California Accidental Release Prevention Program (19 CCR, Division 2, Chapter 4.5)	For local government agencies to obtain chemical information from industry to reduce risks associated with accidental chemical releases.	Data are collected at the local level in 125 different jurisdictions; only 415 chemicals are included in the program.
	Air Toxics Program (AB 2588)	For the state government to obtain emission data from industry on toxic air contaminants for identification of stationary emission sources.	Data are for emissions, not chemical use; database misses imports and chemicals in products; unable to identify facilities by chemical; only 189 chemicals included in the program.
	Site Mitigation and Brownfields Reuse Program Database (CalSites)	For the state government to collect information on areas where hazardous chemicals have been released or might be released.	Database is limited to hazardous waste sites; cannot be sorted by chemical.
	Certified Uniform Program Agencies (CUPAs) (SB 1082) (19 CCR, Division 2, Article 4)	For 82 regional government agencies to collect chemical information from businesses under six programs previously administered by about 1,300 local and state agencies.	With four exceptions, data are collected "on paper" at the regional level in 82 different jurisdictions; data are not uploaded to a statewide database.
	Unidocs Hazardous Materials Online Inventory Project	A voluntary effort of Certified Unified Program Agencies (CUPAs) to build an online database of hazardous materials inventories, risk management plans, and facility maps at industrial sites.	Effort by Counties of San Diego, Los Angeles and Orange, and the City of Palo Alto, to computerize CUPA data; lack of statewide participation.
	Waste Water Pretreatment and Pollution Prevention Plans (Water Code §13263.3)	For the state government to identify discharges of hazardous substances into publicly owned treatment works (POTW) from businesses and to encourage adoption of pollution prevention plans.	Data are collected at hundreds of local POTWs; a small number of chemicals is included in the program.
	Pesticide Use Reporting system (13 CCR 6 *et seq.*)	For the state government to accept pesticide registrations and to evaluate pesticides prior to marketing and application in California.	System is applicable to pesticides only.
Federal data sources	OSHA Integrated Management and Information System (IMIS)	For state and federal government to collect data on facility inspections by OSHA, including air sampling data.	Data are not comprehensive; OSHA inspects only a small fraction of firms in the U.S. and California.
	U.S. EPA Toxics Release Inventory (TRI) (42 U.S.C. 11023); also the Scorecard database of Environmental Defense	For interested parties to track and report the volume of chemical emissions released from some industrial facilities into air, water, and soil, and to waste transferred off-site.	Data are for chemical emissions, not use; misses imports and chemicals in products; covers largest manufacturers in SIC codes 20-39; only about 650 chemicals included in the program.
	CDC National Occupational Exposure Survey (NOES)	For interested parties to characterize the potential for hazardous workplace exposures to chemical, physical, and biological agents in selected U.S. industries.	The database has not been updated since 1983; chemical use data are applicable only to the two-digit SIC code level, covering thousands of facilities in California.

EPA under TSCA (Section 3): to demonstrate that a chemical represents a threat to public health, the agency needs toxicity and exposure data that industry is under no obligation to provide.

Despite these barriers, California has taken a number of steps to address public and environmental health problems related to chemicals (Section 3).

The many agencies with chemical-related responsibilities in California are not well integrated.

Numerous state and regional agencies and boards have responsibility for addressing issues related to chemicals in California (Table N). As previously noted, the responsibilities of these entities are not well integrated, and they do not routinely communicate among themselves, which can be frustrating for businesses that use chemicals.

Table N. A sample of California agencies, districts, and boards responsible for addressing issues related to chemicals.

Agency or Board
Office of Environmental Health Hazard Assessment
Department of Toxic Substances Control
Certified Unified Program Agencies
Environmental Health Investigations Branch
Air Resources Board
Regional Air Quality Management Districts
Integrated Waste Management Board
Water Resources Control Board
Regional Water Quality Control Boards
Occupational Safety and Health Standards Board
Division of Occupational Safety and Health
Occupational Health Branch
Department of Fish and Game
Office of Emergency Services

While the complexity of environmental and occupational health issues requires technical specialization, this *institutional* separation in California has led to a piecemeal approach to chemicals policy in the state. Chemical exposures and releases to the environment occur at numerous points in the life cycle of a chemical—from design, manufacture, and distribution to use, treatment, and disposal. These events, of course, do not recognize the jurisdictional boundaries of government agencies. When an endocrine-disrupting chemical enters commercial circulation, for example, humans can be exposed in the workplace, through the use of finished products, through industrial emissions into air and water, and through the generation of hazardous waste. California's institutional arrangements for managing chemicals are not well suited to the fluid nature of chemical problems that arise throughout chemical life cycles.

4.3.2 The Legislature

In the absence of a chemicals policy, the Legislature will likely face a growing number of chemically related bills in the future.

With TSCA and other environmental laws providing a limited federal role in chemicals management, and with the limited ability of state agencies to generate and gather chemical information and to act on it, the California Legislature has essentially become the "last stop" for public concerns regarding chemicals. About 35 bills pertaining to chemicals were introduced in 2005, most of which addressed a single, rather narrowly defined chemical issue (Figure 17).[295]

Figure 17. Sample of 35 bills related to chemicals introduced in California in 2005.

- AB 121 (Vargas) *Monitoring lead in candy imported or distributed in California.*
- AB 263 (Chan) *Amending law prohibiting sale of PBDEs (polybrominated diphenyl ethers) to include fines.*
- AB 289 (Chan) *Requiring producers to provide analytical test methods for biomarkers of exposure to chemicals.*
- AB 319 (Chan) *Prohibiting manufacture, sale, distribution of phthalates and bisphenol-A in children's products.*
- AB 342 (Baca) *Establishing a perchlorate fee.*
- AB 597 (Montanez) *Revising public participation procedures for cleanup projects.*
- AB 752 (Karnette) *Extending financial responsibility lower then $300 for nontank vessels carrying below a certain threshold of oil.*
- AB 815 (Lieber) *Revising workplace exposure standards for which Office of Environmental Health Hazard Assessment (OEHHA) has published quantitative risk assessments when the existing permissible exposure limit (PEL) is not sufficiently protective.*
- AB 816 (Lieber) *Requiring producers to provide client information to state Hazard Evaluation System and Information Service (HESIS) on request.*
- AB 908 (Chu) *Prohibiting manufacture, sale, distribution of various phthalates.*
- AB 912 (Ridley-Thomas) *Providing tax exemption for loans offered to redevelop certain brown fields.*
- AB 966 (Saldana) *Regulating discharge of mercury from dental offices and requiring use of best available technology to remove mercury from dental wastewater.*
- AB 985 (Dunn) *Requiring DHS to perform testing and to regulate lead in candy.*
- AB 990 (Lieber) *Prohibiting sale of various halogenated solvents, requiring substitutes.*
- AB 1125 (Pavley) *Requiring retailers of household batteries to collect used batteries for recycling, reuse, or proper disposal at no cost to the consumer.*
- AB 1337 (Ruskin) *Providing certain exemptions for rail cars at hazardous waste transfer stations.*

- AB 1342 (Committee on Environmental Safety and Toxic Materials) *Expanding scope of immunity pursuant to California Superfund law.*
- AB 1344 (Committee on Environmental Safety and Toxic Materials) *Streamlining site mitigation procedures.*
- AB 1354 (Baca) *Establishing a primary drinking water standard for perchlorate of 6 parts per billion and establishing cleanup responsibilities.*
- AB 1415 (Pavley) *Prohibiting sale or distribution of mercury switches and relays*
- AB 1681 (Pavley) *Prohibiting lead in children's jewelry.*
- SB 419 (Simitian) *Prohibiting the transportation of ultra-hazardous materials on state highways and railroads.*
- SB 432 (Simitian) *Pertaining to toxic metals in electronic devices and the E.U. Directive 2002/95/EC.*
- SB 484 (Migden) *Requiring disclosure of carcinogenic chemicals in cosmetic products.*
- SB 490 (Lowenthal) *Cooperating with The Netherlands in compiling list of hazardous chemicals.*
- SB 600 (Ortiz) *Establishing a biomonitoring program to monitor the presence of certain chemicals in the population.*
- AB 623 (Aanistad) *Modifying minimum penalties for serious water quality violations.*
- AB 639 (Aghazarian) *Streamlining procedures for issuing ID numbers to hazardous waste generators.*
- SB 838 (Escutia) *Establishing a pollution control technology registry.*
- AB 848 (Berg) *Establishing an Ocean Ecosystem Resource Information System.*
- SB 849 (Escutia) *Supporting environmental health tracking program.*
- SB 982 (Environmental Quality Committee) *Establishing website for receiving reports of hazardous waste violations.*
- SB 989 (Environmental Quality Committee) *Expanding 2004 brownfields immunity legislation in AB 389 (Montanez) Stats.*
- SB 1067 (Kehoe) *Requiring adoption of public health goals regarding trihalomethanes and haloacetic acids in drinking water, and public notification at specific levels.*
- SB 1070 (Kehoe) *Establishing website to report water quality data.*

Most of these bills addressed a contemporary, legitimate chemical problem, but none were designed for the purpose of developing a comprehensive approach to chemicals policy in California. Without such a policy, and given the global expansion of chemical production, it is reasonable to expect that the number of bills devoted to chemical problems facing the California Legislature will continue to grow.

An effective chemicals policy will need to avoid both "paralysis by analysis" and the piecemeal approach that presently characterizes chemical legislative activity in California. By closing the Data, Safety, and Technology Gaps as a strategy to motivate industry investment in green chemistry, a comprehensive approach to chemicals policy will begin to address the underlying health and environmental concerns that are driving the majority of chemical legislative proposals today.

5. Initiatives to Correct the Data, Safety, and Technology Gaps

In addition to the pressures facing the U.S. chemical industry described in Section 4, there are other developments in the chemicals policy arena that are of great relevance to California. As described in this section, these include sweeping new regulatory changes in the European Union, independent initiatives by U.S. and E.U. businesses to “clean” their supply chains of hazardous chemicals, and chemical policy initiatives by U.S. nongovernmental organizations. Though institutionally and strategically distinct, each of these developments is occurring in response to the recognition that regulatory approaches that have grown up with the chemical industry in the U.S. and Europe over the last 30 years are no longer adequately serving the needs of society. Collectively, these developments present California with a unique opportunity to consider a new, comprehensive approach to chemicals policy.[HH]

5.1 The European Union

5.1.1 The European Union is initiating sweeping new chemicals policy reforms.

The position of global leadership in environmental policy that was once held by the U.S. has now shifted to the E.U. In the arena of chemicals and materials policy, the E.U.’s power to enforce its new directives comes not from its ability to levy fines, however, but from the size and wealth of its 25-nation market—and its capacity to restrict access to that market. Its ability to set standards and restrict access on the basis of those standards is affecting U.S. producers, including chemical producers, and it is doing so along the full length of the industrial supply chain.

The proposed REACH initiative (*Registration, Evaluation and Authorization of Chemicals*) is the most important initiative with respect to chemicals.[297] It represents one piece of a fundamental reorientation of chemicals and materials policy in the E.U. that includes directives on *Waste Electrical and Electronic Equipment* (WEEE) and on the *Restriction of Hazardous Substances in Electrical and Electronic Equipment* (RoHS), along with other initiatives pertaining to automobile recycling, cosmetics, and energy use.[298, 299]

The WEEE directive, effective August 2005, requires producers to recover and reuse electrical and electronic waste. It is intended to encourage the use of new materials in electronic products that are easier to handle during recycling and recovery.[299] In July 2006, the RoHS Directive will prohibit the use of certain toxic materials in new electronics products sold in the E.U., including

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[HH] Other important developments we are not covering include the *Child, Worker and Consumer Safe Chemical Act*, introduced in 2005 by Senator Frank Lautenberg (D-NJ) and coauthored by Senator James Jeffords (I-VT); the development of a *Strategic Approach to International Chemicals Management* (SAICM) by the Governing Council of the United Nations Environment Programme; the development of a voluntary *Globally Harmonized System of Classification and Labeling of Chemicals* by the International Labor Organization, the Organization for Economic Cooperation and Development (OECD) and the United Nations Committee of Experts on the Transport of Dangerous Goods; and efforts by the OECD to coordinate more efficient screening methods for 4,100 high-production-volume chemicals.[296] Each of these initiatives is in various states of development and addresses an important aspect of chemicals policy; individually or collectively, however, they do not represent a comprehensive approach to chemicals policy that would correct the Data, Safety, and Technology Gaps.

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lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls, and certain polybrominated diphenyl ethers (PBDEs).[269, 270]

Still undergoing adjustments, the proposed REACH initiative take effect in 2007. In a marked departure from current practice in both the E.U. and U.S., REACH will require chemical producers to *register* and supply basic health and environmental information to an E.U. Chemicals Agency for up to 30,000 chemicals that are already on the market.[300] Of these, 5,000 higher-volume chemicals will undergo more extensive *evaluation*.[301] About 1,400 "chemicals of very high concern" will be presumptively removed from commercial circulation in an *authorization* process in which producers will bear the burden of proof in seeking government approval to use such chemicals.[302] [II]

REACH represents the E.U.'s effort to address long-standing deficiencies in chemical information and regulatory authority that are nearly identical to those of the Data and Safety Gaps in the U.S. engendered by TSCA. For example, the European Commission justified the REACH proposal on the following grounds:[305]

- There is a lack of health, environmental, and other information on the great majority of chemicals in commerce; 99% of chemicals in commercial circulation in the E.U., by volume, lack adequate information on health and environmental effects.
- There is an implicit presumption that chemicals are safe unless proven otherwise by a public entity.
- The ability of public agencies to assess and demonstrate chemical risks has not kept pace with the rate of chemical production; only about 140 of 100,000 existing chemicals in the E.U. have been subject to risk assessments.

The total benefits of REACH are expected to outweigh the costs of implementation over a 30-year period in the form of health and environmental improvements.[306] A study published by the University of Sheffield, United Kingdom, estimated that the incidence of occupationally related asthma, chronic obstructive pulmonary disease (COPD) and dermatitis in the 25 nations of the E.U. per million persons per year is 400, 500 and 400 respectively, and that the proportion of those cases potentially preventable by REACH is 50%, 10%, and 50%, respectively.[206] Based on an E.U. population of 200 million, the number of future cases per year that would be avoided by REACH is 40,000 for asthma, 10,000 for COPD, and 40,000 for dermatitis. The European Commission estimated in 2003 that REACH would prevent about 4,300 occupational cancer cases per year and would save €50 billion ($60 billion)[307] over a 30-year period in total occupational disease cases avoided.[308]

[II] Chemicals subject to *evaluation* are those produced or imported at 1,000 metric tons or more per year, per manufacturer. Chemicals subject to *authorization* ("chemicals of very high concern") consist of chemicals that are carcinogenic (causing cancer), mutagenic (causing changes in the DNA of chromosomes), or toxic to reproduction; chemicals that are persistent, bioaccumulative, and toxic; chemicals that are "very persistent and very bioaccumulative," irrespective of toxicity; and other chemicals considered to be particularly hazardous, such as endocrine-disrupting agents. Chemicals meeting these criteria will be presumptively removed from commerce unless chemical producers can demonstrate that the risks associated with their use are adequately controlled or that their risks are outweighed by their socioeconomic benefits.[303] *Authorization* can also be triggered on the basis of information that becomes apparent during *registration* and *evaluation*.[304]

The American Chemistry Council has opposed the REACH proposal. The ACC has expressed concern that the proposal relies on ambiguous standards of risk, and that it provides inadequate opportunities for producers to appeal decisions rendered by the European authorities on the basis of those standards.[309, 310] The ACC and others have also expressed concern that REACH does not contain adequate provisions for protecting confidential business information, that it could disfavor U.S. products in the E.U. market, and that it will be excessively costly for U.S. producers.[311]

Despite these and other concerns, the fact remains that REACH, like the RoHS and WEEE directives, will become law in the E.U. and will produce global changes in chemical production practices, including in the U.S.[312-315] China, for example, announced plans in 2005 to consider new regulations similar to those of RoHS, WEEE, and REACH.[316, 317]

5.1.2 For California, the pending implementation of REACH raises four key issues.

First, by improving accountability and regulatory oversight in the chemicals market, some observers expect that REACH will improve the commercial viability of cleaner technologies, including green chemistry.[299] Innovest Research Director Marc Brammer noted in 2005 that "There is significant potential for a sea-change in the market for chemicals as knowledge about toxicity expands under the new E.U. REACH directive and similar efforts elsewhere. There is little toxicity data available on many currently commercialized chemicals."[318] The need for green chemistry science and technology innovation could improve in the near term, and California could take steps to attract investment in this sector of the chemical industry (Section 7). As a related case in point, General Electric's CEO Jeffrey Immelt announced in 2005 that GE will devote $1.5 billion annually to clean technology research and development, citing the potential for a U.S. competitive disadvantage with the E.U. in this arena.[319]

Second, REACH presents a unique challenge to California's small and medium-sized chemical producers. To maintain access to the E.U. market, these producers will need to generate toxicity data and other data related to their products, and they will need to navigate the E.U. chain-of-commerce to understand and document how their products are used. California producers that fail to act early in meeting the requirements of REACH could face a loss of market share and profitability during the "catchup" phase, as some have suggested may be occurring with certain electronics companies in response to the RoHS directive.[69, 269] California firms that market products in the E.U. would benefit from information on the technical aspects of REACH. Manufacturers of chemical products would benefit from information on alternatives to riskier chemicals that are likely to fall under the REACH authorization process, for example. California could take steps now to assist its businesses in meeting REACH requirements.

Third, REACH represents an opportunity for a California state agency to gather information on the physical attributes and basic toxicological properties of many chemicals in commercial circulation. Some of this information on the set of 30,000 chemicals registered under REACH could become available to California as REACH is implemented. For this information to be most useful, however, California will need to gather data on the *distribution* of chemicals sold in the state. California could take steps to communicate with the European Chemical Agency regarding the nature of chemical information that could become available under REACH.

Finally, while RoHS, WEEE, and REACH are expected to drive innovation in safer materials and chemicals, it is also conceivable that some producers will seek to market "non- E.U.-compliant" electronic products and chemicals in countries where regulatory oversight is weak, such as in the U.S., particularly during transition periods. The German chemical company BASF, for example, will continue to produce and sell monoester di[2-ethylhexyl] phthalate (DEHP) in the U.S. even though it will be permanently banned in the E.U. for use in toys in 2006.[130] BASF will discontinue production of DEHP and its raw material, 2-ethylhexanol, in the E.U., where it will introduce a substitute whose safety, according to the company, "is beyond all question." California should take steps to ensure that producers do not shift sales of potentially hazardous "non-E.U. compliant" chemicals to California, particularly the 1,400 chemicals that could be presumptively removed from commercial circulation under the REACH authorization process. This will require a comprehensive chemicals policy in California.

5.2 U.S. and E.U. Businesses

5.2.1 U.S. and E.U. businesses are seeking to "clean" hazardous chemicals and materials from their supply chains.

As a result of the Data and Safety Gaps, U.S. businesses operate under conditions of considerable uncertainty regarding the chemicals they purchase and use (Section 4). The potential for liability resulting from these uncertainties, along with the costs of handling known hazardous chemicals and other concerns, is causing some large U.S. and E.U. companies to develop screening tools to remove hazardous chemicals and materials from their supply chains.

As previously noted, Kaiser Permanente, the largest private health-care provider in the U.S. and the largest private-sector employer in the San Francisco Bay Area, recently implemented a procurement policy for chemicals and materials for its 30 hospitals and 430 medical office buildings nationwide that calls for "avoiding the use of carcinogens, mutagens and reproductive toxins and persistent, bioaccumulative and toxic chemicals"(Figure 5).[320] The Consorta Group is the primary group purchasing agent for Kaiser and other health-care organizations in the U.S. and handles an annual purchase volume of $4.1 billion. Consorta has adopted a purchasing policy to screen-out hazardous chemicals and materials by requiring manufacturers to produce data on the toxicity and ecotoxicity of their products.[156]

Firms with operations in California that are adopting chemical and material screening programs include Kaiser Permanente, Catholic Healthcare West,[321] Intel,[322] Hewlett-Packard,[323] Bentley Prince Street,[324] IBM,[325] and Apple.[326] In November 2005, for example, Catholic Healthcare West awarded a five-year, $70 million contract to Braun Medical Inc. for the supply of polyvinyl chloride (PVC)/di-2-ethylhexyl phthalate (DEHP)-free intravenous (IV) bags, solutions, and tubing to the system's 40 hospitals in California, Arizona, and Nevada.[321] Other U.S. and E.U. companies working to "clean" their supply chains and produce safer products include Herman Miller, Shaw Carpets, Coastwide Labs, S.C. Johnson, Samsung, Sony, Fujitsu, Nike, Marks and Spencer, and Boots Group PLC.[296, 327]

These efforts signal a demand in the U.S. market for better chemical information and safer materials; they have been constrained, however, by the lack of robust, standardized chemical information in the market (the Data Gap). By improving chemical information flows (Section 7), California would enhance the ability of businesses to implement chemical and material screening strategies—along with more extensive green chemistry practices—and to market their products as such. Better information would "lower the threshold" for other business sectors in California to follow the efforts of Kaiser and other leaders noted above in conducting audits to clean their supply chains of hazardous chemicals and materials.

5.3 U.S. Nongovernmental Organizations

5.3.1 U.S. nongovernmental organizations are involved in campaigns to change chemical markets and policies.

U.S. environmental and public-health groups have launched initiatives to encourage businesses to transition to safer chemicals, and they have developed recommendations to guide chemicals policy changes in the U.S. Health Care Without Harm (HCWH) has been one of the most successful organizations to date in motivating key players in a large business sector, the health-care industry, to identify hazardous products in their supply chain and replace them with products that are both efficacious and safer. HCWH now consists of over 400 organizations in 52 countries "working to protect health by reducing pollution in the health care industry."[328] The coalition includes Kaiser Permanente, Catholic Health Care West, and the Consorta Group, among others. The campaign is particularly important because it affects an industry sector that accounted for 37% of all purchases of chemical products in the U.S. in 2002 (Table D).

In 2005, U.S. environmental and health groups drafted a set of guiding principles for chemical policy reform in the U.S. that has now been endorsed by over 60 organizations.[329] The principles, known as the *Louisville Charter*, include six key elements:

- Require safer chemical substitutes and solutions.
- Phase-out persistent, bioaccumulative, or highly toxic chemicals.
- Give the public and workers the full right to know and to participate in chemical policy decision-making.
- Act on early warnings of harm.
- Require comprehensive safety data for all chemicals.
- Take immediate action to protect communities and workers.

Meeting these goals in California will require a comprehensive chemicals policy that closes the Data, Safety, and Technology Gaps (Section 7).

In February 2006, a first-time gathering of 85 U.S. environmental and public-health advocates in Washington, D.C., focused on the concept of green chemistry as an essential element to addressing public and environmental health problems related to chemical design, use, and regulation in the U.S.[330] The meeting included representatives of HCWH, the Natural Resources Defense Council, the World Wildlife Fund, the Environmental Working Group, and Greenpeace, as well as numerous local and regional organizations.

6. Case Study: The Massachusetts Toxics Use Reduction Act of 1989

6.1 Background

We evaluated six state and four federal chemicals policies to determine whether and to what extent they represent models that address the Data, Safety, and Technology Gaps engendered by TSCA.

The state policies were:

- the California Safe Drinking Water and Toxic Enforcement Act (Proposition 65),
- the California Pollution Prevention Act (SB 14),
- the California Birth Defect Prevention Act (SB 950),
- the Massachusetts Toxics Use Reduction Act,
- the New Jersey Worker and Community Right-to-Know Act, and
- the New Jersey Pollution Prevention Act.

The federal policies were:

- the Federal Insecticide, Fungicide, Rodenticide Act,
- the Food Quality Protection Act,
- the Hazard Communication Standard of the Occupational Safety and Health Act, and
- the permissible exposure limits established under the Occupational Safety and Health Act.

We performed the evaluation using three questions:

- Does the policy address the Data Gap by ensuring that producers generate and distribute robust, standardized information on chemical toxicity, ecotoxicity, and other key data?
- Does the policy address the Safety Gap by improving the regulatory authority and flexibility of government to act to protect public and environmental health from known chemical hazards?
- Does the policy address the Technology Gap by directly or indirectly supporting green chemistry research and development?

Based on this analysis, we concluded that the Massachusetts Toxics Use Reduction Act (TURA) of 1989, though limited, is a model that is relevant to the development of a comprehensive chemicals policy in California. TURA is unique among U.S. environmental statutes in that it requires firms to report their *use* of hazardous chemicals, rather than their *releases* of chemical pollutants, and it requires firms to evaluate their operations and plan for process improvements. It is the only statute that includes an institute—funded with fees assessed against the use of a list of particularly hazardous chemicals—to provide ongoing technical assistance, training, and research for Massachusetts businesses in toxics use reduction strategies. Together, these approaches have motivated continual innovation by firms in strategies to reduce their use of hazardous chemicals. TURA takes a few steps toward correcting the Data, Safety, and Technology Gaps. We believe California can learn from (and build on) the 16 years of experience by government and industry in Massachusetts under TURA.

6.2 Gains Under TURA

6.2.1 To reduce emissions of hazardous chemicals, TURA requires industry to carefully evaluate its chemical inputs and processes.

TURA aims to "sustain, safeguard and promote the competitive advantage of Massachusetts businesses, large and small, while advancing innovation in toxics use reduction and management." Toxics use reduction is defined under TURA as "in-plant changes in production processes or raw materials that reduce, avoid, or eliminate the use of toxic or hazardous substances or the generation of hazardous byproducts per unit of product, so as to reduce risks to the health of workers, consumers or the environment, without shifting risks between workers, consumers, or parts of the environment."[331] TURA defines hazardous chemicals as those listed under Section 313 of the Emergency Planning and Community Right-to Know Act (EPCRA), commonly known as the Toxics Release Inventory (TRI), and those listed under Sections 104(14) and 102 of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), known as the Superfund.

TURA established six toxics use reduction techniques: input substitution, product reformulation, production unit redesign or modification, production unit modernization, improved operations and maintenance, and in-process recycling, reuse, or extended use of production materials. Out-of-process recycling was not included as a toxics use reduction strategy. Green chemistry would play a role primarily in "input substitution" and "product reformulation."

6.2.2 TURA takes steps to close the Data, Safety, and Technology Gaps.

TURA has taken initial steps toward closing the chemical Data, Safety, and Technology Gaps.

To close the Data Gap, TURA requires firms to account for, evaluate, and disclose their use of listed hazardous chemicals. This has allowed Massachusetts to identify the most prevalent hazardous chemicals used by large producers in the state. Because the TRI and CERCLA chemicals are assumed to constitute a public and environmental health threat, additional toxicity data is not required under TURA.

To close the Safety Gap, TURA makes the assumption that chemicals listed under the TRI and CERCLA are inherently hazardous and their use in processes should be steadily reduced or eliminated; TURA does not rely on quantitative risk assessments for individual chemicals as the basis for decision-making and action. On the other hand, it does not *mandate* implementation of toxics use reduction plans by firms, nor does it enable government to prioritize chemical hazards and take action to reduce those of greatest concern.

To close the Technology Gap, TURA assigns fees and reporting requirements to the use of listed chemicals, thereby disadvantaging them in the market and encouraging the use of nominally safer substitutes. It encourages continual learning and innovation in industry by requiring regular evaluation of chemical inputs and processes and by providing technical assistance, training, education, and research in toxics use reduction strategies.

6.2.3 TURA provides industry with technical assistance in developing and implementing toxics use reduction plans.

To assist industry in meeting the requirements of TURA, the Act established the Toxics Use Reduction Institute (TURI) at the University of Massachusetts at Lowell to provide technical assistance, training, education, and research in toxics use reduction strategies. TURI trains toxics use reduction planners, who are then certified to practice in industry by the Massachusetts Department of Environmental Protection.

TURA also funds the state Office of Technical Assistance within the Department of Environmental Protection to provide technical assistance to industry. Between 1989 and 2004, the Office of Technical Assistance conducted over 1,400 site visits to about 600 firms in support of toxics use reduction activities.[236] During the same period, the Office of Technical Assistance sponsored over 200 toxics use reduction conferences, workshops, and other events for Massachusetts firms.

6.2.4 TURA has produced marked improvements in environmental performance by Massachusetts firms.

The initial objective of TURA was to reduce the use of listed hazardous chemicals in Massachusetts by 50% by 1997, with a baseline year of 1987. This goal was met in 1998 and then surpassed in 1999, adjusted for a 45% increase in production.[332]

A 2000 study based on 35 case studies and interviews with plant personnel found that between 1990 and 1997 Massachusetts companies decreased their volume of toxic chemical byproduct by 40%, indexed to production. In almost half the cases analyzed, improved worker health and safety was cited as a benefit of the toxics use reduction projects.[333] Solvents were eliminated or reduced in 63% of cases. About half of the companies profiled introduced water-based chemicals in the place of more volatile ones, and acids and caustics were reduced or eliminated in about 20% of the cases. Following implementation of TURA, Massachusetts firms outperformed virtually every other manufacturing state in the country on releases of substances under the TRI.[236]

An analysis of the effects of TURA showed that even though only one in 10 firms initially viewed TURA as positive, the mandatory planning, reporting, and continual learning process it requires of firms has led to an atmosphere of innovation in Massachusetts that has caused even reluctant firms to improve their environmental performance.[236] TURA has forced firms to better understand their chemical processes (and costs) and has pointed them to options for toxics use reduction through case studies, training, and examples from leading firms. A survey of Massachusetts firms showed significant improvements in involvement by firms in six measures of environmental performance before and after passage of TURA (Table O).[236]

Table O. Involvement of Massachusetts firms in six environmental performance areas before and after TURA.

Activity	Percentage of respondents 'very involved' in activity	
	Before TURA	After TURA
Tracking quantities of wastes generated	49%	89%
Tracking quantities of chemicals used	48%	90%
Establishing a corporate or facility environmental team	24%	68%
Setting goals for waste reduction	24%	73%
Reviewing changes in production processes for their environmental, health and safety impact	30%	76%
Allocating environmental costs to processes or products	21%	52%

6.3 TURA's Limitations

6.3.1 TURA is limited in important ways.

Despite the improvements it has brought about in Massachusetts, TURA is limited in important ways. Its does not apply to firms that manufacture or process less than 25,000 pounds of listed chemicals per year, or that *use* less than 10,000 pounds of listed chemicals per year, or that have fewer than 10 employees. In aggregate, however, small and medium-sized firms can generate significant chemical problems throughout the chemical lifecycle. Chemical exposures among workers may also be magnified among smaller firms that lack the resources to recognize, evaluate, and control exposures. Some chemicals may be hazardous even in small quantities. Importantly, the TURA list of hazardous chemicals reflects the state of knowledge prevailing in the 1980s and does not account for improved scientific understanding of chemical hazards. TURA is therefore constrained in the scope of exposures and health risks it targets.

Nor does TURA include regulatory tools to compel recalcitrant firms to implement their toxics use reduction plans. The lack of a regulatory "hammer" may be allowing some companies to gain a competitive advantage in Massachusetts through poor environmental performance. There has been little public participation in TURA activities and limited public disclosure of information on toxic use reduction performance by companies. The law does not link fiscal incentives such as grants or tax credits to industry research and development in toxics use reduction, and it employs only weak fiscal tools to discourage the use of listed hazardous chemicals. TURA has not resulted in the development of criteria for identifying and promoting green chemistry technologies.

Perhaps most importantly, TURA is intended primarily to address industrial *processes*. The law does not oblige manufacturers, retailers, or suppliers to evaluate the toxicity and ecotoxicity of chemicals used in intermediate or final consumer and commercial *products*, or to disclose this information to consumers, workers, businesses, and industry. It does not require business and industrial buyers of chemicals to evaluate the toxicity and ecotoxicity of the chemicals they use, including those introduced into consumer and commercial products. It therefore does not support U.S. firms that are attempting to "clean" their supply chains (Section 5).

6.4 TURA and California Chemicals Policy

6.4.1 TURA offers lessons for chemicals policy in California.

Despite its weaknesses, TURA represents a chemicals policy approach that appears to motivate innovation by industry, as reported by O'Rourke and Lee in 2004:[236]

> TURA makes clear that regulation can and should promote industry self-monitoring and exploration of process improvements. Regulatory implementation should be supported through new mechanisms of transparency, accountability and learning, rather than rigid technology-based standards. Perhaps most importantly, the history of TURA shows that regulations need to transform the attitudes of managers, and then support their efforts at change. Regulations can provide some "commands" to motivate action, and some assistance to guide explorations. TURA's basic requirements of reporting and planning can motivate creative thinking, exploration, experimentation and "surprises." TURA represents the potential for what could be termed a sort of "command-and-innovation" regulation.[236]

With modernizing and adaptation to California's circumstances, TURA represents a potential model for some aspects of a comprehensive chemicals policy.

6.4.2 A TURA-like approach could be strengthened in California in a number of ways:

- Establish a system for chemical reporting, screening, evaluation, and priority-setting as the basis for toxics use reduction planning in California, rather than relying on pre-existing lists of hazardous chemicals.
- Ensure that the scope of the regulation includes small and medium-sized firms.
- Require chemical producers, suppliers, and product manufacturers to review their products for chemical toxicity and ecotoxicity and distribute this information in standardized form to end users.
- Expand technical assistance and training programs to meet the needs of a larger set of businesses and industry, particularly for small and medium-sized firms.
- Incorporate green chemistry more explicitly into the technical assistance, research, education, and training aspects of the regulation.
- Structure the regulation so that it better motivates innovation and use of green chemistry processes and products.
- Establish mandatory toxics use reduction targets and schedules based on lowest-, low-, medium-, high-, and highest-priority chemicals.
- Improve public participation in decision-making regarding design, implementation, and updating of the regulation.
- Improve public disclosure of the performance of firms in meeting toxics use reduction targets.
- Ensure full integration of worker health and safety in toxics use reduction strategies.

- Include mechanisms for mandatory implementation of toxics use reduction strategies for priority chemicals, including product bans and phase-outs where appropriate.
- Efficiently update the regulation in response to new information that surfaces in the process of chemical reporting, screening, evaluation, and monitoring.
- Efficiently update lists of targeted hazardous chemicals based on developing environmental health knowledge.

7. Recommendations

Problems cannot be solved at the same level of awareness that created them.
—Albert Einstein[334]

Section 4 illustrates that many of the chemical problems facing public and environmental health, businesses and industry, government, and the chemical industry itself trace their roots to weaknesses in TSCA and other federal statutes that have produced the Data, Safety, and Technology Gaps. Addressing these weaknesses represents the logical framework for chemicals policy goals in California:

Close the Data Gap. Ensure that chemical producers generate, distribute, and communicate information on chemical toxicity, ecotoxicity, uses, and other key data.

Close the Safety Gap. Strengthen government tools for identifying, prioritizing, and mitigating chemical hazards.

Close the Technology Gap. Support research, development, technical assistance, entrepreneurial activity, and education in green chemistry science and technology.

A chemicals policy that makes steady progress toward meeting these goals would contribute to putting California on a developmental path that is socially, economically, and environmentally sustainable.

As described in this section, many policy mechanisms could be employed to achieve these three overarching goals; identifying those most appropriate for California will require resolution by a broad range of forward-looking stakeholders. We recommend that at this juncture the Legislature consider establishing a task force to explore various mechanisms and develop a legislative proposal based on the findings of this report. We recommend that the task force be charged with developing the proposal for the 2007 legislative session.

In reviewing the issues raised in this section, it should be kept in mind that the problems with chemicals policy in the U.S. have become apparent over many years and are deeply rooted. While the overarching objectives for correcting these problems are clear, the *details* of how best to do so are complex; they are not, however, insurmountable. In facing these complexities, it is reasonable for the Legislature to consider incremental measures that would lay the foundation for continued development toward a comprehensive chemicals policy. For example, it is reasonable to begin closing the Data, Safety, and Technology Gaps by focusing first on a subset of chemicals, such as those used in high volume in California. Identifying high-volume chemicals and their risks will require some form of chemical reporting in California that includes toxicity and basic exposure information, as noted below. There are numerous examples of steps such as this that would be both substantive and manageable.

Goal 1: Close the Data Gap

Ensure that chemical producers generate, distribute, and communicate information on chemical toxicity, ecotoxicity, uses, and other key data.

Closing the Data Gap will require some form of chemical reporting in California. A mechanism will be needed that enables the state to require chemical producers to generate and disclose standardized, robust information on chemical toxicity, ecotoxicity, basic measures of exposure, and other key data. It will be necessary to require this information as a condition of placing or keeping a chemical or chemical product on the California market. A mechanism will also be needed to enable the state to efficiently obtain additional, more detailed information as needed for evaluating and prioritizing chemical hazards in the state.

A chemical reporting system in California will provide a state agency with the information necessary for setting chemicals policy priorities in the state, and it will arm businesses and industry with the information they need to reduce or eliminate their use of hazardous chemicals. It will also enable businesses and industry to identify (or demand) safer, green chemistry technologies. Dissemination of chemical information in a simple communication format will allow consumers to make purchasing choices for chemical products. These corrections in the chemicals market are essential to driving green chemistry innovation and commercialization in California.

It is important to recognize that the chemical information needs of recipients differ. Government agencies need standardized, robust information on chemical toxicity and ecotoxicity as well as information on the ways chemicals are used in the state, such as their volume in commerce, purposes, potential routes of exposure, and so forth. Businesses and industry, on the other hand, need toxicity and ecotoxicity data as well as good technical information on alternatives to hazardous chemicals. Chemical producers need information on the myriad ways their products are used in commerce. Consumers, small-business owners, and workers need standardized, simple chemical information schemes that allow for rapid decision-making.

1.1 Who would produce chemical toxicity and ecotoxicity data?

The experience in both the U.S. and the E.U. makes it clear that the responsibility for generating and distributing chemical toxicity and ecotoxicity data has to rest with chemical producers rather than with public agencies. As detailed in Section 4, comprehensive, easy-to-use information is essential for decision-making by businesses and industries that use chemicals, government, workers, consumers, and the public. It is also essential for the proper function of the market. Chemical producers are best equipped to meet this need, and they should be responsible for transmitting the information in standardized formats to government and the businesses, industries, consumers, and workers that use their chemicals or chemical products. Additional mechanisms to improve the information flow from industrial chemical *users* to chemical *producers*—"back up the supply chain"—will also be needed to address a persistent communication gap between the producers and users of chemicals in California.

Chemical producers that export products to the E.U. are already preparing toxicity and other data to meet the requirements of REACH (Section 5). Representatives of chemical companies reported to the U.S. Government Accountability Office (GAO) in 2005 that the industry would share these data with the U.S. EPA if requested.[335]

With a chemical reporting requirement in California, it can be expected that consumer and trade groups will serve as information intermediaries in preparing and transmitting chemical information to small and medium-sized firms, consumers, and workers in forms that are useful to them. Organic farmers in California, for example, established the California Certified Organic Farmers (CCOF) label to allow consumers to make efficient choices about purchasing organically produced foods.[336] The label is based on an agreed-upon technical definition of "organic." Chemical reporting and communication in California should be designed to be efficient while also motivating change on the part of producers by clearly differentiating the safety of chemicals and chemical products on the market.

1.2 Who would produce information on the uses of chemicals in California?

Sales information, combined with toxicity data, is needed from chemical producers for a state agency to characterize, prioritize, and mitigate chemical hazards in the state. More detailed chemical "use" information is best produced by the businesses and industries that use chemicals. Many businesses do not maintain careful chemical inventories, and they are often unaware of the nature of chemical "throughput" in their operations. Chemical use reporting, as required in Massachusetts under the Toxic Use Reduction Act (TURA), improves accountability in chemical management and often leads to strategies by firms to reduce chemical throughput and costs (Section 6).

1.3 Who would pay for chemical reporting?

Chemical reporting should include a fee paid by the producer that increases as a function of volume in commerce. A mechanism should also be considered that would enable California to assess fees on the basis of various measures of toxicity, ecotoxicity, and exposure potential. The fee would fund California chemical regulatory efforts and other activities, such as market incentives, research, and education.

In 1998, the U.S. EPA estimated that it would cost the chemical industry about $427 million to provide a Standard Information Data Set (SIDS) I for the 2,800 chemicals produced or imported at more than one million pounds per year in the U.S., or about 0.2% of the total annual sales of $231 billion for the top 100 U.S. chemical companies.[50] The costs and amount of animal testing needed for generation of this chemical information could be lowered by the development of alternative chemical testing methods.

1.4 What chemicals would be reported?

As outlined above, 81,600 chemicals are currently listed in the inventory of the TSCA inventory, about 62,000 of which were placed on the inventory in 1979. This represents a large backlog of chemicals for which the Data Gap must be closed. It is therefore impractical to consider mechanisms in California that would close the Data Gap for all chemicals in commerce in a short period of time. Rather, a strategy is needed that allows for prioritizing the timing and nature of chemical reporting. For example, there are 8,282 chemicals in commercial circulation in the U.S. that are produced or imported at 10,000 pounds or more per year, and 2,943 HPV chemicals that are produced or imported at over one million pounds per year. The HPV chemicals constitute over 99% of chemicals in commercial circulation in the U.S., by volume. California could consider a reporting system that focuses initially on the HPV chemicals.

To support the need of industry for regulatory harmonization, California should consider reporting strategies similar to those of REACH. The October 29, 2003 draft of the REACH proposal requires registration over an 11-year period for about 30,000 chemicals produced or imported at over one ton per year per firm, and it sets out tiered data requirements in which more detailed toxicity information is required for higher-volume chemicals (Section 5).[337]

REACH also requires registration of chemicals that fall into a small number of hazard classes, regardless of their volume in commerce: persistent, bioaccumulative, and toxic substances (PBTs); carcinogens, mutagens, and reproductive toxicants (CMRs); very persistent and very bioaccumulative substances (vPvB); and endocrine disruptors. Establishing hazard classifications such as these would not possible, however, without standardized, robust toxicity information and basic California exposure data. Existing lists of hazardous chemicals, such as California's Proposition 65 list, are based on very limited information and are therefore unreliable.

Unless a chemical screen for a particular chemical property is used for essentially *all* chemicals in commerce, it is likely that a "volume of sales" criterion, as proposed under REACH, would be the most feasible way to define a class of chemicals for reporting in California.

1.5 What information would be required as part of a reporting system?

The Organization for Economic Cooperation and Development (OECD) has developed three chemical testing batteries, known as SIDS I, II, and III.[338] The U.S. EPA has recommended that the SIDS I battery represents a minimum screening-level dataset and that the SIDS II and III batteries would be necessary to "adequately assess the hazards of higher-exposure chemicals (e.g. chemicals in consumer products, chemicals to which children may be exposed, high-release TRI chemicals, chemicals with large numbers of exposed workers, etc.)."[50] Under the U.S. EPA's High Production Volume chemical program, U.S. chemical producers have voluntarily submitted screening-level data equivalent to the OECD SIDS I dataset for about 90% of HPV chemicals, and completion of this program is expected in 2006.[56] [JJ] Because HPV chemicals account for over 99% of chemicals in commercial circulation in the U.S., this dataset will provide a useful foundation for chemicals policy in California, assuming it can be linked to basic measures of exposure.

[JJ] Since the program's launch in 1997, about 700 additional chemicals have reached HPV status in the U.S. Chemical producers have voluntarily submitted information for about 100 of these, and the industry has announced an "Extended HPV Challenge" to address the remainder.

On the other hand, screening-level data are not sufficient for prioritizing chemical hazards, and the U.S. EPA presently has no efforts under way to obtain more extensive toxicity information on HPV chemicals or to gather screening-level data on the 5,000 chemicals produced or imported in the range of 10,000 to one million pounds per year.[58] To effectively support decision-making in chemicals policy, a reporting system in California will need to require the submission of a more extensive set of toxicity data than is currently being gathered under the HPV program, along with basic exposure data.

California could also consider adopting the battery of tests required under REACH, which requires more thorough data for higher-volume chemicals. Again, one advantage of this approach would be harmonization of requirements, which is important to companies that market products in both the E.U. and California.

Overall, a chemical reporting system in California should generate information sufficient to provide a reasonable evaluation of the toxicity and ecotoxicity of chemicals in, or proposed for, commercial circulation. Public disclosure and dissemination of this information will begin to direct the market toward favoring safer chemicals.

1.6 Who would have access to the information, and in what form?

The experience under TSCA suggests that producers will likely request that much of the information reported to the state be classified as confidential business information (CBI). Sixty-five percent of chemical information disclosures to the U.S. EPA under TSCA have been claimed as CBI (Section 3). CBI restrictions, of course, undermine the purpose of chemical reporting, which is to gather and disseminate information that is important for the users and regulators of chemicals. CBI restrictions also prevent public participation in government decision-making, which can lead to “capture” of the agency by the regulated industry.

On the other hand, producers have a legitimate interest in protecting their intellectual property. Small and medium-sized specialty chemical firms in particular face an ongoing threat from buyers who seek to vertically integrate their supply chains and terminate their dependence on small producers. A California chemical reporting system will have to balance the needs of chemical *producers* with those of chemical *users*, including businesses, industry, state agencies, workers, consumers, municipal governments and so forth.

1.7 How would the validity of toxicity data generated by producers be assured?

Data validation is an inherent challenge of a chemical reporting system that relies on submission of toxicity data by chemical producers who have a clear interest in preventing the release of information that could be damaging to their products. This conflict of interest, of course, is not unique to chemicals policy. In other arenas, the validity of data is assured through the use of third-party audits, legal sanctions, and other approaches. Independent laboratories such as Underwriters Laboratory (UL) routinely provide verifiable information on product safety in the U.S. Government laboratories funded by a reporting system could also be considered.

California can facilitate the generation of valid chemical information by assisting in the formation of consortia of producers that would pool resources for the purpose of developing toxicity data through an independent laboratory. Private laboratories that contract with the state to perform testing services would be subject to audit for adherence to internationally recognized standards of laboratory practice. California should support research into *in vitro* and other testing technologies that minimize or eliminate the use of animals in toxicity testing. The state should explore toxicity data-sharing arrangements with the European Chemicals Agency.

1.8 In what ways can California motivate timely and thorough reporting?

Chemical reporting would fail to achieve its purpose if the collection of data was continually challenged or delayed by producers or by businesses that use chemicals. California will therefore need to consider mechanisms to motivate timely and complete chemical reporting, such as by requiring reporting as a condition of marketing (or using) a chemical in California. For chemicals already on the market, fixed reporting deadlines will be needed. Incentives for early submission should be considered, along with escalating penalties for late submissions. For reporting data to stay current, automatic updating mechanisms will be needed, along with mechanisms that will enable California to efficiently gather additional information from producers and users of chemicals as needed.

1.9 How would chemicals in consumer and commercial products be reported?

Given the potential for "information overload" in chemical reporting, it is reasonable to require manufacturers of chemical consumer and commercial products to submit toxicity and other information on the *constituent* chemicals in their products but not on the chemical mixtures themselves. In addition, because some consumer products *unintentionally* release chemicals into indoor air that can pose a health threat, it is reasonable to expect that these products should be subject to reporting.

In general, information should be made available to the public in a platform that will allow trade associations and public-interest groups to access it and develop it into forms that are useful for consumers, workers, small-business owners, and so forth.

Goal 2: Close the Safety Gap

Strengthen government tools for identifying, prioritizing, and mitigating chemical hazards.

To close the Safety Gap, it will be necessary to significantly improve the tools available to government in its efforts to identify, prioritize, and mitigate chemical hazards. *Identifying* chemical hazards begins with chemical reporting, as described above, which should allow California to gather standardized chemical information and to request additional information as needed. *Prioritizing* chemicals requires the use of screening and evaluation tools. *Mitigating* chemical hazards requires the use of various policy tools to support, motivate, and require action on the part of businesses and industry.

This subsection discusses issues related to the burden of proof, the use of chemical screening and evaluation tools, and the importance of new approaches to decision-making in the interpretation of screening and evaluation data.

2.1 In what ways can the burden of proof be altered to improve efficiency in chemicals policy?

Altering the current burden of proof that is borne by government before it can take action on hazardous chemicals is the key element in closing the Safety Gap. A modern chemicals policy must make it easier for government to identify, prioritize, and mitigate chemical hazards. This represents a fundamental shift in the orientation of TSCA, in which producers that *lack* information on the safety of their products are free to market those products unless government is able to establish the existence of an unreasonable risk of harm, based on a very high burden of proof (Section 3). As the experience under TSCA has shown, this creates a structural, rational incentive for industry to resist generating and disclosing chemical safety information.

California should consider a range of options for altering the burden of proof. The proposed REACH initiative illustrates a useful model in this regard. Following implementation of REACH, the E.U. government will in most cases continue to carry the burden of proof in acting to restrict the use of a chemical; this burden, however, is significantly *lower* than that imposed on the U.S. EPA by TSCA. Under the REACH proposal, the E.U. government will be able to act if it concludes that there exists an "unacceptable risk to human health or the environment."[339] As previously described, TSCA places a much higher burden of proof on the EPA, which is required to produce "substantial evidence" that (1) the chemical presents or will present an "unreasonable" risk to health and the environment, (2) the benefits of regulation outweigh both the costs to industry of the regulation and the lost economic and social value of the product, (3) the action is the least burdensome way to eliminate only the unreasonable risk, and (4) the agency has considered the environmental, economic, and social impact of any action it proposes to take (Section 3).

The ability of government to act is further facilitated under the REACH *authorization* process, wherein the burden of proof is fully switched from government to industry for select classes of chemicals.[340] Under the authorization process, about 1,400 "chemicals of very high concern" will be *presumptively* barred from all uses in the E.U. unless the producer can meet specified authorization requirements on a use-by-use basis (Section 5). This creates a compelling incentive for the producer to either generate chemical toxicity and exposure information for these chemicals or remove them from commercial circulation.

The E.U. approach of *lowering* the burden of proof on government for most chemicals and *switching* it to industry for selected classes of chemicals might be a reasonable strategy for closing the Safety Gap in California. This would require that the Data Gap be closed in tandem so that hazardous chemicals used in the state could be systematically identified and prioritized. It would also require that classes of chemicals of particular concern be chosen and that criteria be specified for their identification. Aside from certain forms of toxicity, such as carcinogenicity, mutagenicity, and reproductive toxicity, basic exposure data and physical criteria such as persistence and bioaccumulation will be important for prioritizing chemicals used in California.

2.2 What is chemical screening?

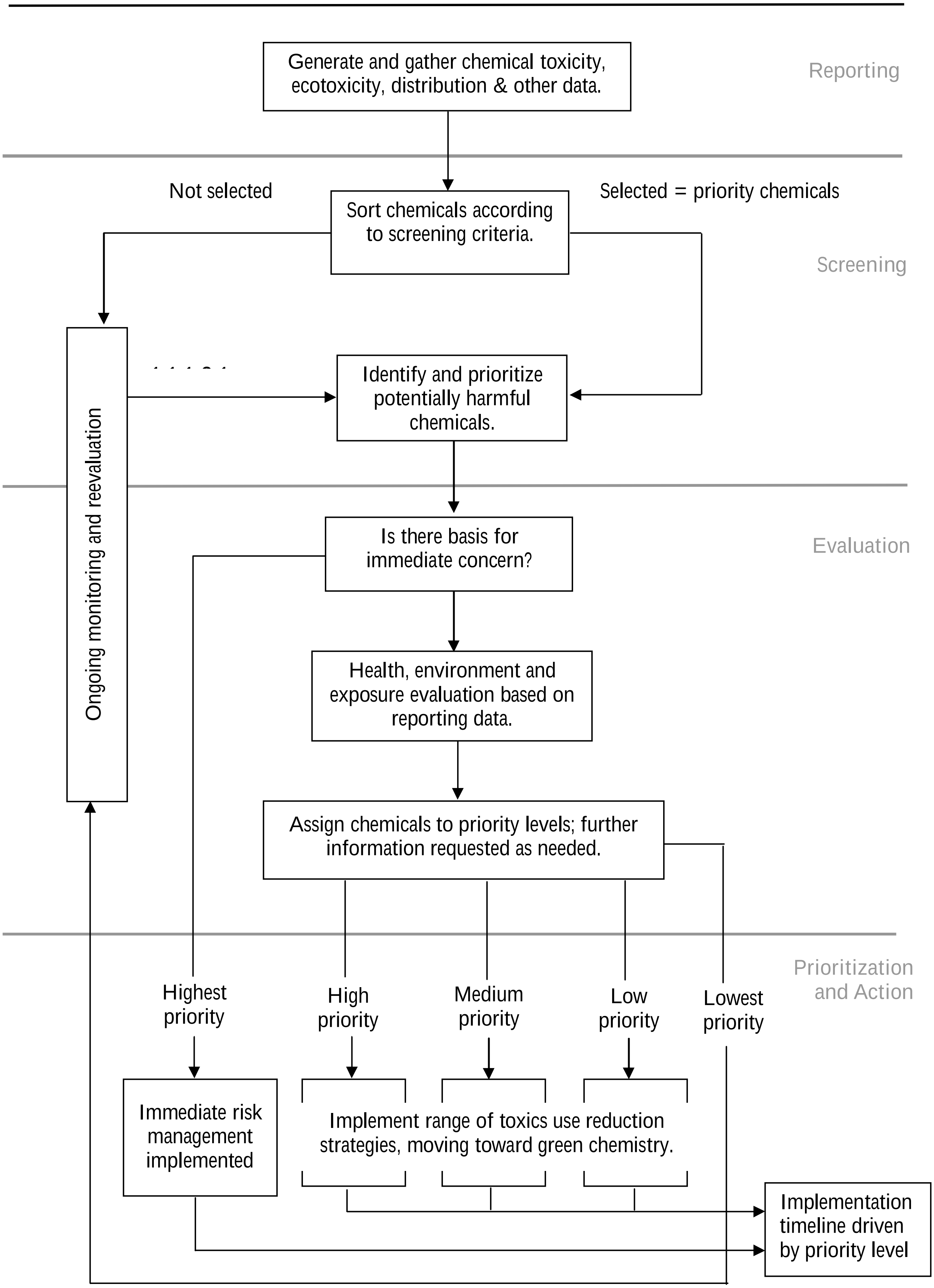
Chemical screening is the process of using inexpensive, relatively simple tools as a "first cut" to capture chemical attributes that do not necessarily require extensive toxicological testing but are important for public and environmental health. When combined with basic measures of exposure, screening tools are an important component of prioritizing chemicals. Chemicals used in closed industrial processes, for example, are generally of lower concern compared to those used in open processes and in consumer and commercial products. The U.S. EPA uses screening tools to evaluate chemicals submitted under the New Chemicals Program. California will need to identify screening tools such as these that are both efficient and scientifically robust.

2.3 How would chemical screening tools be used in California?

In the chemical reporting process, the data to be submitted by producers to close the Data Gap should be designed to permit the use of a set of screening tools by the producer. Established criteria could then be used by California to classify chemicals into priority groups, such as chemicals that warrant immediate action, chemicals that require more data, and so forth. Standardized, effectively communicated screening-level data can also be useful for consumers, workers, and businesses and industries that use chemicals.

Figure 18 presents a theoretical flow chart in which chemical reporting, screening, and evaluation are illustrated as part of a process of sorting chemicals into lowest-, low-, medium-, high-, and highest-priority groups. This model, adapted from the U.K. *Royal Commission on Environment Pollution*, represents one of many possible schemes and is presented here not as an endorsement but simply for purposes of discussion.[341]

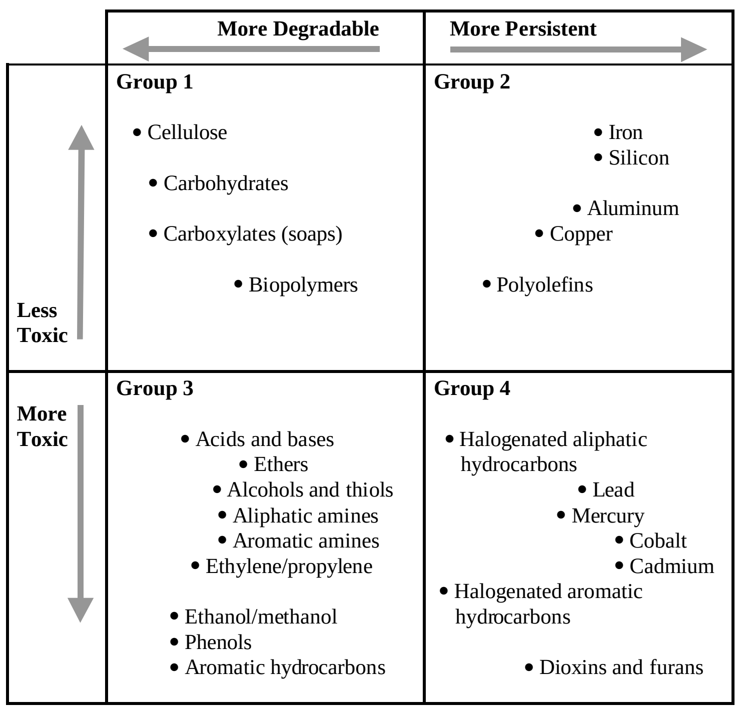
Figure 18. A flow chart showing chemical reporting, screening, evaluation, prioritization, and action.



2.4 What kinds of measures are included in chemical screening?

Chemical screening typically includes measures of environmental persistence, bioaccumulative potential, and basic measures of toxicity. Geiser has proposed a conceptual model for chemical screening that relies on the properties of environmental persistence and toxicity (Figure 19).[342] This model assumes that chemicals that are both persistent *and* toxic are especially problematic because they can give rise to toxic effects over a greater period of time and over greater distances compared to other chemicals. Many environmentally persistent chemicals also tend to be bioaccumulative. An agreed-upon technical definition of environmental persistence and toxicity is central to this and other screening models.

Figure 19. Geiser's model for classifying chemicals on the basis of toxicity and environmental persistence.



In Geiser's model, chemicals that appear in Group 4 would generally receive priority attention. Basic exposure data, however, is important to the application of this and similar models. For example, information on the way a chemical is *used* could affect its classification. A chemical in Group 4 that is used in small quantities in highly contained industrial processes would be of less concern than a chemical in Group 3 that is used in consumer products or with minimal controls in workplaces.

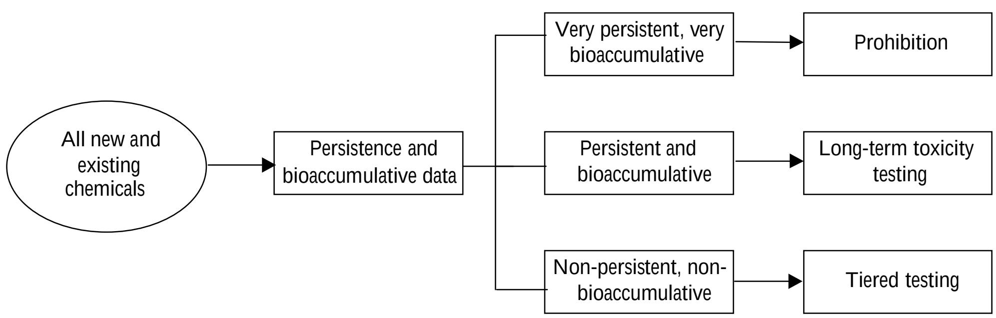
2.5 How is chemical screening used by businesses and industry?

As noted in Section 5, a number of California companies have developed chemical and material screening programs as part of their procurement policies, including Kaiser Permanente, Catholic Healthcare West, Intel, Hewlett-Packard, Bentley Prince Street, IBM, and Apple. These programs are based not on *clear evidence of cause-and-effect* but rather on a standard of evidence that could be characterized as *reasonable grounds for concern* (see below). The efforts of these leading businesses would be greatly facilitated by a California chemicals policy that closed the Data and Safety Gaps. This would also lower the threshold for a broader set of California businesses and industries to follow the example of leading firms in cleaning their supply chains.

2.6 How is chemical screening used in the European Union?

Concern with the properties of environmental persistence and bioaccumulation is reflected in chemicals policy developments in the E.U. The U.K. *Royal Commission on Environmental Pollution* has recommended that "where synthetic chemicals are found in elevated concentrations in biological fluids such as breast milk and tissues of humans, marine mammals or top predators, regulatory steps be taken to remove them from the market immediately."[343] Under the proposed REACH initiative, chemicals that are found to be "very persistent and very bioaccumulative" (vPvB) (regardless of toxicity) based on the use of screening tools will be presumptively removed from commerce (Section 5). A screening tool proposed by Swedish researchers relies on the properties of environmental persistence and bioaccumulative potential (Figure 20).[344]

Figure 20. A proposed model for prioritizing chemicals on the basis of environmental persistence and bioaccumulation.



The Quick Scan method of The Netherlands' *Strategy on Management of Substances* is a useful model that prioritizes chemicals on the basis of environmental persistence and basic measures of toxicity and exposure.[345] Other chemical screening tools in the E.U. include the Evaluation Matrix of the German Federal Environment Agency, the PRIO model of the Swedish Chemicals Inspectorate and the Column Model of the German Institute for Occupational Safety. The University of Massachusetts Lowell has prepared a brief discussion of these and other screening tools.[346]

2.7 What is chemical evaluation?

In evaluation, chemicals are subject to more-intensive scrutiny than during screening. Evaluation requires additional toxicity and ecotoxicity data, such as the OECD SIDS II and III batteries, together with basic measures of exposure. As noted above, toxicity data and basic exposure data—such as the volume in commerce and intended uses—are best acquired from chemical producers. More-detailed chemical accounting information for purposes of toxics use reduction planning has to be gathered from the businesses and industries that use chemicals.

In designing and interpreting chemical evaluation tools, California will need to develop an alternative to quantitative risk assessment (QRA). It has become apparent from the experience in both the U.S. and E.U. that QRA is a poor tool for most chemicals policy decision-making, particularly given the present scope of the Data Gap. A new approach to interpreting chemical screening and evaluation data is needed in California.

2.8 What are the alternatives to quantitative risk assessment in interpreting chemical screening and evaluation data?

Data gathered through chemical screening and evaluation are used to prioritize chemical hazards; this process, however, is driven fundamentally by the way in which screening and evaluation data are *interpreted*. The system by which chemical data are interpreted is thus critically important in chemicals policy. Quantitative risk assessment represents only one of a number of approaches to interpreting and using data.

Information on a chemical's toxicity and ecotoxicity can be illustrated using a continuum of theoretical standards of evidence, from *scientific suspicion of risk* to *clear evidence of cause-and-effect* (Figure 21).[347]

Figure 21. Various standards of evidence that could be used as the basis for decision-making in chemicals policy.

Each level could arguably be used as the basis for decision-making in chemicals policy. Government and industry could choose to act only on the basis of *clear evidence of cause-and-effect*, for example, arguing that in using this standard of evidence only genuine chemical hazards would be mitigated, which would allow resources to be used for other needs. On the other hand, this standard of evidence is expensive and time-consuming to achieve, and can produce highly uncertain results. Most importantly, it requires confirmation of harm to health or the environment before action can be taken. The evidentiary burden placed on the U.S. EPA under TSCA essentially requires this standard of evidence. As detailed in Section 3, this has prevented the agency from effectively assessing the hazards associated with the great majority of chemicals in commercial circulation or controlling those of greatest concern.

Acting strictly on the basis of *scientific suspicion of risk*, on the other hand, could preclude the use of chemicals that might have important social or industrial purposes, though it might also prevent the use of chemicals whose toxic effects might be partially evident now but which could become manifest later, at which point they could be irreversible and/or costly to ameliorate. The proposed $140 billion federal asbestos legislation represents a case in point.

California will need to develop a system for interpreting chemical data that avoids dependence on data-intensive quantitative risk assessment and moves the decision-making point closer to the center of the continuum illustrated in Figure 21.[348] In developing a decision-making system for interpreting and acting on chemical screening and toxicity data, there are a few points to consider:

First, in evaluating whether or not a chemical might be hazardous to biological or ecological systems, scientists consider a range of scientific evidence, such as illustrated in Figure 21. Like the concepts of "health" and "disease," scientific evidence related to the health and environmental effects of chemicals exists along a continuum; evidence is not simply "sound" or "unsound," as some industry representatives have urged.[349] The challenge is to develop decision-making tools that are both efficient (recognizing that "perfect information" is unobtainable) and scientifically robust (utilizing standardized evidence of chemical toxicity, ecotoxicity, basic measures of exposure, and so forth).

Second, because "perfect information" is unobtainable (especially with regard to the health or environmental effects of chemicals), policy decisions must inevitably be made under conditions of uncertainty. In a 1994 consensus resolution, the American Public Health Association argued that the lack of "perfect information" should not be used as a reason for delaying policy decision-making:[350]

- Proof of cause-and-effect relationships is often difficult to establish because of nonspecificity of health effects, long latency periods, subtle changes in function that are difficult to detect without resource-intensive studies, and complex interactions of variables that contribute to adverse health effects.

- Public-health decisions must often be made in the absence of scientific certainty, or in the absence of perfect information.

- Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

Given the reality of "imperfect information," scientists will often disagree about the nature of uncertainty and ambiguity in a body of evidence. We agree, however, with the American Public Health Association that it is imprudent to await the appearance of *clear evidence of cause-and-effect* before acting to protect public and environmental health.[144, 347, 351] This approach is particularly relevant in chemicals policy, given the enormous backlog of information on toxicity and ecotoxicity. As noted above, businesses in California that have enacted policies to clean their supply chains have done so not on the basis of *clear evidence of cause-and-effect* but on the basis of *reasonable grounds for concern.* This approach is appropriate for chemicals policy in California as well.

The experience under TSCA makes it clear that California will not make progress in identifying, prioritizing, and mitigating chemical hazards if the threshold of evidence for doing so is too high. To efficiently prioritize chemicals into lowest-, low-, medium-, high-, and highest-hazard classifications, California will need to develop a decision-making system that does not require waiting for the appearance of harm before steps can be taken to address potential risks. California can learn from the efforts of other governments around the world that face this same challenge in chemicals policy.

2.9 What policy mechanisms might California consider to close the Safety Gap?

California will need to provide a state agency with greater authority and improved decision-making models to identify, prioritize, and mitigate chemical hazards. The agency will then be faced with identifying the mechanisms that would most effectively meet the proposed policy goals. In general, U.S. and California environmental statutes have relied on a finite set of mechanisms to limit hazards directly (Table P) or indirectly (Table Q).

Table P. Policy mechanisms that directly limit hazards.

Policy mechanism	Description
Health-based standards	Describes required end results, leaving regulated entities free to choose compliance methods.
Design standards	Describes required emissions limits based on what a model technology might achieve; regulated entities use the model technology or demonstrate that another approach achieves equivalent results.
Technology specifications	Specifies the technology or technique the regulated entity must use to control emissions.
Product bans and limitations	Bans or restricts manufacture, distribution, use or disposal of products that present certain kinds of risks.
Tradeable emissions	Allows regulated entities to trade emission control units among themselves, provided the aggregate regulatory cap on emissions is met in a specified geographic area.
Regulatory challenges	Gives the regulatory entities responsibility for designing and implementing a program to achieve a target goal, with a government-imposed program or sanction if the goal is unmet by a deadline.
Integrated permitting	Incorporates multiple requirements into a single emissions permit, rather than having a permit for individual emission sources at a facility.

Table Q. Policy mechanisms that do not directly limit hazards.

Policy mechanism	Description
Pollution charges	Requires regulated entities to pay a fixed dollar amount for each unit of material used, emitted or disposed of; no ceiling on emissions.
Information reporting	Requires regulated entities to report emissions, product information or materials used to a public agency and the public.
Technical assistance	Provides regulated entities additional knowledge regarding consequences of their activities (e.g., costs of managing hazardous chemicals) and what techniques or tools could reduce those consequences.
Subsidies	Provides financial incentives to encourage innovation or use of cleaner technologies.
Liability	Requires regulated entities causing emissions that adversely affect others to compensate those harmed to the extent of the damage.
Voluntary initiatives	Encourages participation of regulated entities in programs to reduce emissions in ways that generally exceed regulatory requirements.

The 16-year experience of the Massachusetts Toxics Use Reduction Act suggests that a combination of mechanisms is more likely to be effective compared to single mechanisms implemented alone (Section 6). Closing the Data, Safety, and Technology Gaps in California will require *information reporting* on chemical toxicity and ecotoxicity, *health-based standards* in establishing a technical definition of green chemistry products and processes, *pollution charges* for the use of certain hazardous chemicals, *subsidies* to encourage investment in green chemistry innovation and use, *technical assistance* for small and medium-sized businesses, *product bans and limitations* to reduce the use of highest- and high-priority hazardous chemicals, programs to award *voluntary initiatives* by industry, and so forth.

2.10 What are some aspects of an "ideal" policy mechanism?

We propose that the most effective mechanisms would strive to:

- meet the proposed objective in a measurable way,
- place the least demands on government,
- leverage market forces,
- leverage existing statutes and programs,

- be cost-effective and fair,
- consider impacts across the chemical life cycle (including the workplace),
- ensure public access and participation,
- integrate environmental and occupational health justice factors,
- emphasize prevention (including green chemistry) over mitigation,
- encourage continual learning by the regulated entity,
- motivate technology innovation and diffusion, and
- be adaptable to change.

Goal 3: Close the Technology Gap

Support research, development, technical assistance, entrepreneurial activity, and education in green chemistry science and technology.

As described in Section 4, the broad adoption of green chemistry will require a technological transition by industry; this, however, introduces new costs and uncertainties that can be overcome only by market or regulatory drivers. The present lack of market and regulatory drivers represents a key barrier to the commercial success of green chemistry. Closing the Data and Safety Gaps is therefore essential to motivating investment by chemical producers in green chemistry research, development, and implementation. These measures represent the foundation for closing the Technology Gap.

To further close the Technology Gap, these measures should be augmented with incentives to encourage industry investment and entrepreneurial activity in green chemistry. These include market-based incentives and infrastructure-based incentives.

3.1 What kinds of market-based incentives would support green chemistry?

- Offer tax credits to chemical producers and manufacturers of chemical products to support a technology transition to green chemistry.
- Offer low-interest loans and grants to green chemistry entrepreneurs.
- Provide information and technical assistance to firms in toxics use reduction technologies, including green chemistry.
- Facilitate development of technical criteria for green chemistry processes and products.
- Facilitate a green chemistry certification and labeling program for chemicals and chemical products.
- Establish a program to redirect certain compliance fees to investments in green chemistry technologies.
- Establish a state government procurement program for existing green chemistry products, based on an agreed-upon set of criteria.
- Establish a state government procurement program to serve as "first buyer" of new green chemistry products.
- Provide information and technical assistance to firms in meeting the requirements of the proposed E.U. REACH initiative.

Infrastructure-based incentives are less immediately applicable to businesses in operation, but they establish the scientific and technical foundation for new technologies, such as green chemistry, just as government-funded research underpins the biotechnology, pharmaceutical, and electronics industries in California. Government funding will be needed to train the next generation of chemists, scientists, policymakers, and others concerned with a sustainable future in California.

3.2 What kinds of infrastructure-based incentives would support green chemistry?

- Fund research in the development and evaluation of chemical screening tools.
- Fund research into chemical evaluation tools that rely minimally or not at all on the use of animal testing.
- Fund research in basic green chemistry science.
- Fund research in green chemistry engineering, technology, law, and policy.
- Fund undergraduate and graduate education in green chemistry.
- Facilitate university-industry collaboration in green chemistry innovation initiatives.
- Establish collaborative relationships with institutions working to advance green chemistry in other U.S. states and around the world.

Administrative Arrangements

Implementing a comprehensive chemicals policy in California would be most efficient if a single agency is assigned primary responsibility and authority for the great majority of chemicals policy matters. The scope of the agency should eventually encompass chemical issues related to public and environmental health as well as those pertaining to the state's involvement in green chemistry technology innovation, investment, education, research, and planning. To maintain credibility with the public, industry, and the scientific community, agency decision-making and priority-setting should be guided by a multidisciplinary board. The board should serve in a genuine leadership role, not simply as a vehicle for providing input to the agency.

To be most effective, the agency's scope should eventually encompass chemicals throughout their *life cycle* (design, manufacture, transportation, use, disposal, recycling); as they appear in various *media* (the workplace, indoor air, outdoor air, drinking water, ground water, surface water, soil, hazardous waste); as they are put to differing *uses* (industrial processes, commercial products, consumer products); and as they are experienced by various *stakeholders* (consumers, workers, children, small-business owners, industry, lower-income, and minority communities, residents of developing countries).

The agency should develop the capacity to provide comprehensive, integrated, and easy-to-use information on the full scope of regulatory requirements in California related to chemicals; it should develop the capacity to provide information and technical support to businesses and industry in best practices, chemical accounting systems, toxics use reduction strategies, and green chemistry technologies, as they emerge. The agency should serve as the primary technical resource for chemicals policy matters affecting other state agencies, municipal governments, and the Legislature.

8. Conclusion

We have analyzed chemicals policy issues in California in the context of a key question facing the state:

> *How can California develop in ways that are environmentally, socially, and economically sustainable as its population grows from 36 to 55 million residents by 2050?*

A modern, comprehensive chemicals policy is a fundamental element in addressing this question. In an increasingly competitive global economy, and with global chemical production expected to double in the next 25 years, a new approach to chemicals policy is necessary for California to:

- reduce the burden of work-related disease attributable to chemical exposures;
- address concerns about chemical exposures that occur during fetal, infant, and child development;
- prevent the proliferation of hazardous waste and pollution of air, water, and land resources;
- meet the needs of business and industry for better information about chemical toxicity, ecotoxicity, and alternatives to hazardous chemicals;
- reduce or eliminate the use of the most hazardous chemicals;
- build productive capacity in ways that steadily improve public and environmental health and prevent continued growth in income inequality;
- proactively respond to sweeping chemicals policy changes occurring in the European Union;
- establish the scientific and technological basis for safer chemicals;
- motivate industry to invest in the design and use of safer chemicals;
- motivate the next generation of chemists to design and use safer chemicals; and
- position the state to become a global leader in green chemistry innovation.

Some of these issues have been previously broached in California in the form of individual legislative proposals; this report, however, illustrates that these issues are *all* relevant to a modern, comprehensive approach to chemicals policy. Developing a chemicals policy that addresses these issues is essential to a sustainable future in California.

We have proposed that problems associated with the present approach to chemical design, use, and management represent one of the major challenges of the 21^{st} century, and that a deep technological transition within the chemical industry will be needed to correct these problems. This transition, which has partially begun, will require the design of new chemicals and chemical processes that are inherently safer for biological and ecological systems. This will provide long-term solutions to the many chemical problems currently facing public and environmental health, business, industry, and government in California. Motivating the chemical industry to invest *proactively* in this transition represents a key, underlying rationale for a comprehensive chemicals policy in California. In light of developments in the European Union and among some large U.S. businesses, a chemicals policy that induces this transition in California could also position the state to become a global leader in green chemistry technology innovation.

Alternatively, in the absence of a comprehensive chemicals policy, a *reactive* transition could occur in the U.S. chemical industry in response to the many pressures described in this report. A reactive transition could have significant consequences for employment, public and environmental health, and productive activity in California, given the importance of chemicals in the California economy.

The analysis presented in the report is intended to support a proactive strategy in California by helping policymakers:

- understand the key weaknesses of federal statutes, particularly TSCA, that have given rise to the Data, Safety, and Technology Gaps;
- understand the problems the three Gaps have created in California for public and environmental health, business, industry, and government;
- recognize the need for a green chemistry technology transition in the chemical industry;
- understand the basis for resistance by chemical producers to policies that would induce this transition;
- recognize the significance of chemicals policy developments occurring in the European Union and among U.S. businesses and nongovernmental organizations;
- recognize the relevance of the Massachusetts Toxics Use Reduction Act to chemicals policy in California; and
- craft a chemicals policy that addresses health and environmental problems and motivates industry to invest in green chemistry technologies by closing the Data Gap, the Safety Gap, and the Technology Gap.

To close the Data Gap, we propose that a chemical reporting system will be needed in California. Closing the Safety Gap will require expanded regulatory authority and a new decision-making framework for a designated state agency. Closing the Technology Gap will require a range of market incentives and government support for green chemistry research, development, technical assistance, and education. A chemicals policy based on these goals is timely and necessary in California, given the state's expanding population, its health and environmental problems, and the pressures of an increasingly competitive global economy.

Because many policy mechanisms could be employed to reach these goals, the report recommends that as a first step the Legislature establish a chemicals policy task force to explore various mechanisms and develop a legislative proposal for a comprehensive policy based on the findings of this report. We recommend that the task force be charged with developing the proposal for the 2007 legislative session.

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Appendix A. Chemicals Policy Meetings Attended

As part of the process of preparing this report, the primary author attended 35 meetings and conferences during 2003–2006 pertaining expressly or in part to chemicals policy:

Title	Convener	Location	Date	Presentation by author
Integrating Policy, not Transferring Risk	Center for Occupational and Environmental Health, University of California	Berkeley, California	April 2003	Yes
Implications of the Precautionary Principle in Environmental and Occupational Health	Division of Occupational and Environmental Disease Control, California Department of Health Services	Oakland, California	May 2003	No
Covering California: An All Hazards Approach to Managing Emergencies	California Emergency Medical Services Authority	Oakland, California	September 2003	No
California Chemicals Policy Workshop	University of Massachusetts, Lowell, Center for Sustainable Production	Oakland, California	October 2003	No
Innovations in the European Union to Develop Integrated Chemical Policies: Lessons and Opportunities for California.	Office of the President, University of California; the University of Massachusetts; the European Environment Commission.	Berkeley, California	October 2003	No
Making it Real: Reforming Chemicals Policy in the U.S.	World Wildlife Fund	Washington, D.C.	February 2004	No
Moving Forward Together	California Integrated Waste Management Board, California EPA	Sacramento, California	March 2004	Yes
National Environmental Assistance Summit	U.S. EPA	Baltimore, Maryland	April 2004	Yes
U.S. – E.U. Transatlantic Environment Conference on Chemicals	Office of Pollution Prevention and Toxics, U.S. EPA	Charlottesville, Virginia	April 2004	No
Alternatives Assessment Strategies	Coming Clean, Kaiser Permanente	Oakland, California	May 2004	No

Promoting Primary Prevention in the California Workers' Compensation System	Northern California Center for Occupational and Environmental Health, University of California	Berkeley, California	October 2004	No
Public Health and the Environment	American Public Health Association	Washington, D.C.	November 2004	Yes
National Workshop on Chemical Reform	Coming Clean	Seattle, Washington	December 2004	No
Critical Building Blocks and Tools for Sustainability in the Chemical Industry: Identifying an Agenda for National Research	The Board of Chemical Sciences and Technology, National Academy of Sciences	Washington, D.C.	February 2005	No
REACH and U.S. Chemicals Policy	The Committee for the Environment, Public Health and Food Safety, the European Parliament	Sacramento, California	March 2005	No
Green Chemistry Retreat	Commonweal	Bolinas, California	April 2005	No
Framing a Future Chemicals Policy: A Working Forum for Stakeholders	University of Massachusetts, Lowell, Center for Sustainable Production	Boston, Massachusetts	April 2005	No
California Chemicals Policy Update (teleconf.)	The Phylmar Regulatory Roundtable	Berkeley, California	May 2005	Yes
National Environment, Health and Safety Conference	Kaiser Permanente	Walnut Creek, California	June 2005	Yes
Sensitizing Substances in the Cal/OSHA Permissible Exposure Limits	Division of Occupational Safety and Health, California Department of Industrial Relations	Oakland, California	June 2005	No
California Regulatory Update	ORC Worldwide, Inc.	Palm Springs, California	June 2005	Yes
California Regulatory Update	The American Chemistry Council	Sacramento, California	June 2005	Yes
Annual Conference	Western Regional Pollution Prevention Network	Tahoe City, California	September 2005	Yes

Annual Regulatory Update	The Pacific Industrial and Business Association	Vishay Siliconix, Santa Clara, California	October 2005	Yes
Green Chemistry in California	Women's Voices for the Earth	San Raphael, California	October 2005	No
Chemicals Policy in the European Union	Berkeley Roundtable on the International Economy	Berkeley, California	October 2005	No
Strategies for Chemicals Policy in California	Occupational Health Branch, California Department of Health Services	Richmond, California	October 2005	Yes
Occupational Medicine Grand Rounds	University of California, San Francisco	San Francisco, California	October 2005	Yes
Occupational and Environmental Health in the Developing World: Making a Difference	Center for Occupational and Environmental Health, University of California	Berkeley, California	October 2005	No
Green Chemistry and Engineering Education Roundtable	The Board of Chemical Sciences and Technology, National Academy of Sciences	Washington, D.C.	November 2005	No
California Issues Forum	Chemical Industry Council of California (CICC)	Lafayette, California	November 2005	Yes
Strategies for Chemicals Policy in California	Office of Environmental Health Hazard Assessment, (OEHHA) California EPA	Oakland, California	November 2005	Yes
Bridging the Gap: Science to Policy	California Industrial Hygiene Council & American Society of Safety Engineers	San Francisco, California	December 2005	Yes
Leading Change: Toward a Sustainable Future	California Manufacturers and Technology Association & Industrial Environmental Association	San Diego, California	December 2005	Yes
Environment Committee Meeting	Silicon Valley Leadership Group	Sony, San Jose, California	February 2006	Yes

Appendix B. Sales Data on Consumer and Commercial Chemical Products Sold in California

These data present daily sales in short tons and pounds per day of chemical consumer and commercial products in California.[153] These data are based on the most recently available (1997) sales information as reported by the California Air Resources Board on March 21, 2000. These data do not include chemicals sold for use in industrial processes.

ID #	Tons	Pounds	Category name	ID #	Tons	Pounds	Category name
1	73637.09	147,274,180	General purpose cleaners	51	8.39	16,780	Hair mousses
2	2966.33	5,932,660	Non-selective herbicides/defoliants	52	6.65	13,300	Flying insect insecticide
3	1358.65	2,717,300	Carpet and upholstery cleaners	53	5.25	10,500	Underarm deodorants
4	1325.01	2,650,020	Disinfectants	54	4.85	9,700	Wheel cleaners
5	530.33	1,060,660	Sanitizers	55	4.84	9,680	Metal polishes & cleaners
6	315.22	630,440	Lawn and garden insecticides	56	4.60	9,200	Automotive rubbing and polishing compounds
7	230.73	461,460	General purpose degreasers	57	4.34	8,680	Tire sealants and inflators
8	180.43	360,860	Floor wax strippers	58	4.19	8,380	Construction and panel adhesives
9	165.61	331,220	Selective herbicides/defoliants	59	4.06	8,120	Nail polish removers
10	108.84	217,680	Toilet bowl cleaners	60	3.72	7,440	Solvent parts cleaner
11	101.92	203,840	Glass cleaners	61	3.48	6,960	Aerosol cooking sprays
12	82.25	164,500	Crawling bug insecticides	62	3.39	6,780	Tire cleaners
13	64.46	128,920	Automotive waxes/polishes/sealants	63	3.20	6,400	Insect repellants
14	63.18	126,360	Fungicides and nematicides	64	3.12	6,240	Woodworking glues
15	56.72	113,440	Tub, tile & sink cleaners	65	2.86	5,720	Aerosol adhesive
16	53.91	107,820	Caulking compounds	66	2.58	5,160	Wood fillers
17	51.87	103,740	Hair spray	67	2.55	5,100	Bug and tar removers
18	51.44	102,880	Hand and body lotions	68	2.47	4,940	Wasp and hornet insecticde
19	51.21	102,420	Automotive windshield washer fluids	69	2.42	4,840	Insecticide foggers
20	50.17	100,340	Flexible floor wax/polish	70	2.40	4,800	Undercoatings
21	45.51	91,020	Liquid/pump spray air fresheners	71	2.23	4,460	Shoe care products
22	41.68	83,360	Laundry pre-wash	72	2.14	4,280	Sterilants (not including ethylene oxide)
23	38.88	77,760	Spot removers	73	1.77	3,540	Flea and tick insecticides
24	33.01	66,020	Cold process roof cements	74	1.76	3,520	Pipe cements and primers
25	29.73	59,460	Laundry starches, sizings etc	75	1.74	3,480	Fabric protectants
26	28.44	56,880	Paint thinners	76	1.74	3,480	Penetrant
27	27.37	54,740	Dusting aids	77	1.67	3,340	Non-resilient floor wax/polish
28	24.69	49,380	Carpet and upholstery cleaners	78	1.61	3,220	Automotive instant detailers
29	23.51	47,020	Hair styling gels	79	1.41	2,820	Automotive hard paste waxes
30	22.91	45,820	Underarm antiperspirants	80	1.30	2,600	Grafitti removers
31	21.38	42,760	Astringents/toners	81	1.29	2,580	Wood floor wax/polish
32	21.09	42,180	Multipurpose solvents	82	1.13	2,260	Nail polish
33	18.97	37,940	Rubber and vinyl protectants	83	1.02	2,040	Silicone based multi-purpose lubricant
34	18.23	36,460	Solid/gel air fresheners	84	0.91	1,820	Automotive adhesives
35	17.25	34,500	Paint removers and strippers	85	0.86	1,720	Electronic cleaner
36	17.02	34,040	Rubbing alcohol	86	0.75	1,500	Single phase aerosol air fresheners
37	15.30	30,600	Chacoal lighter materials	87	0.74	1,480	Carpet and tile adhesives
38	15.14	30,280	Dual phase aerosol air fresheners	88	0.73	1,460	Brush cleaners
39	14.59	29,180	Multi-purpose lubricant	89	0.66	1,320	Adhesive remover
40	14.43	28,860	Furniture waxes and polishes	90	0.60	1,200	Personal hygiene sprays
41	13.40	26,800	Specialty lubricant	91	0.46	920	Foot powders
42	12.86	25,720	Automotive brake cleaners	92	0.45	900	Hair shines
43	12.76	25,520	Oven cleaners	93	0.44	880	Contact adhesive
44	11.85	23,700	Engine degreasers	94	0.43	860	Personal fragrance products (>20% fragr)
45	11.64	23,280	Personal fragrance products (<20% f	95	0.37	740	Vinyl and leather cleaners
46	9.76	19,520	Carburetor, choke cleaners	96	0.17	340	Dual purpose air fresherners, disinfectants
47	9.73	19,460	Shaving creams	97	0.16	320	Base coats, undercoats
48	9.54	19,080	General purpose adhesive	98	0.11	220	Arts and crafts adhesives
49	8.99	17,980	Shaving gels	99	0.11	220	Battery cleaners
50	8.39	16,780	Carpet deodorizers				
			Total		**82,043 short tons**	**164,086,840 pounds**	