GREEN CHEMISTRY:

Cornerstone to a Sustainable California

The Centers for Occupational and Environmental Health
University of California

CONTENTS

OVERVIEW

The principles of chemicals policy outlined in this report highlight the need for a modern, comprehensive solution to pressing health, environmental and economic problems associated with California's management of chemicals and products. These policies will promote the science, technology, and commercial applications of green chemistry: the design, manufacture and use of chemicals, processes and products that are safer for human health and the environment. Building new productive capacity in green chemistry will support a vibrant economy, open new opportunities for investment and employment, and protect human health and the state's natural resources.

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FULL REPORT AND REFERENCES:

http://coeh.berkeley.edu/greenchemistry/briefing/ or www.coeh.ucla.edu/greenchemistry.htm

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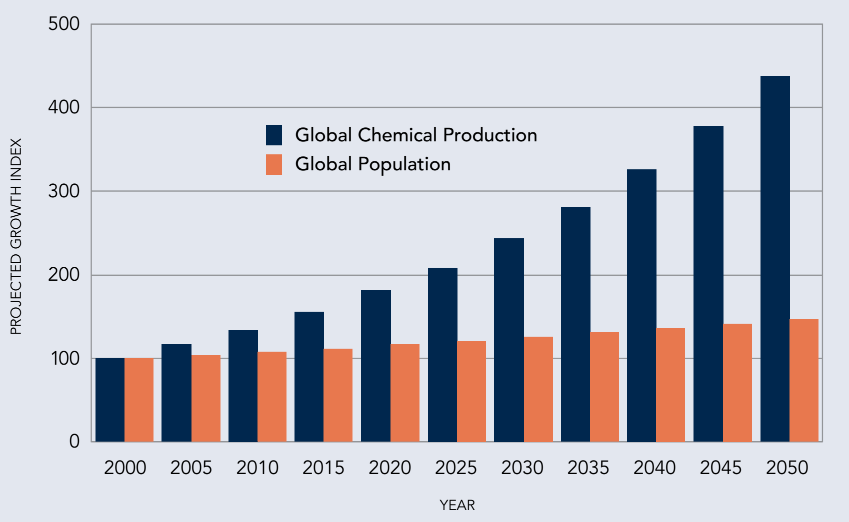
CALIFORNIA'S OPPORTUNITY

As a consequence of long-standing weaknesses in federal policy, the health and environmental effects of the great majority of some 80,000 industrial chemicals in commercial use in the U.S. are largely unknown.[1] This condition has produced a flawed market in which buyers, from individual consumers to the largest companies in California, lack the information they need to choose the least hazardous chemicals and products.

FIGURE 1. GROWTH IN CHEMICAL PRODUCTION



Growth in chemical production outpaces population growth. Global chemical production is expected to grow 3% per year, while global population will grow 0.77% per year. On this trajectory, chemical production will increase 330% by 2050, compared to a 47% increase in population, relative to year 2000. Source: Organization for Economic Cooperation and Development 2001; American Chemistry Council 2003; United Nations 2004.[5]

SUCCESSFUL TRACK RECORD

California policies supporting clean technology link economic development with improved conditions for human health and the environment:

- Emissions standards have improved the state's air quality and have stimulated innovation in lower-emission technologies nationwide.[2]
- After 30 years of improvements in energy efficiency, California now uses half as much electricity and emits nearly half the carbon dioxide per capita as the rest of the nation (Figure 2).[3]
- The state is now a global leader in climate change policy, with legislation that is expected to generate 89,000 new jobs in clean energy technologies by 2020.[4]

Buyers therefore choose chemicals and products primarily on the basis of their function, price, and performance, with much less attention given to their safety for human health and the environment.

Most of the ensuing costs of health and environmental damage caused by hazardous chemical exposures, pollutants and waste rest with the public.

California has demonstrated — by its forward-looking approach to air quality management, energy efficiency and climate change — that a vibrant economy need not come at the expense of human health and the environment (see sidebar). The state can apply this same strategy to the industrial chemical sector and the promising arena of green chemistry: the design, manufacture and use of chemicals, processes and products that are safer for human health and the environment.

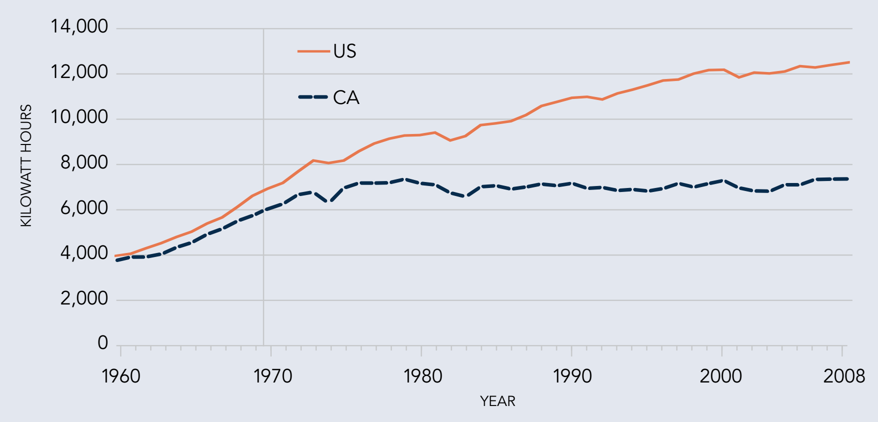
LONG-STANDING PROBLEMS

The scale and pace of chemical production is immense

Each day, a total of 42 billion pounds of chemical substances are produced or imported in the U.S. for commercial and industrial uses, 90% of which rely on fossil fuel feedstocks.[6] An additional 1,000 new chemicals are introduced into commerce each year.[7] Global chemical production is doubling every 25 years, rapidly outpacing population growth (Figure 1).

Many of these substances come in direct contact with people — in the workplace, in homes, and through air, water, food and waste streams. Eventually, most of them enter the earth's finite ecosystems.

FIGURE 2. PER CAPITA ELECTRICITY SALES (KWH/PERSON)



Energy-saving policies initiated in the 1970s altered the course of California's electricity consumption. The state now uses 50% of the electricity per capita compared to the nation as a whole, markedly reducing greenhouse gas emissions and saving a total of $56 billion for individuals and businesses through 2003. Changing the course of California's chemical industrial system will likewise require a multi-pronged, sustained approach; doing so could produce similar gains in economic growth, human health and environmental protection. Source: California Energy Commission, 2007.[9]

Policy gaps

Despite landmark environmental and occupational legislation in 1970, followed by passage of the federal Toxic Substances Control Act (TSCA) in 1976, chemicals policy has not been sufficiently protective of human health or the environment, nor has it promoted innovation in the chemicals market. There are three overarching chemicals policy problems that are rooted in the weaknesses of TSCA and other state and federal laws:[8]

INDEX OF ANNUAL CALIFORNIA HEALTH AND ENVIRONMENTAL INDICATORS	
Workplace health	
208,000	Number of new cases of chronic disease attributable to workplace chemical exposures[10]
4,400	Number of premature dealths from disease attributable to workplace chemical exposures[11]
$1,400 million	Direct and indirect costs of workplace diseases and deaths attributable to chemical exposures[12]
Community health	
159 million	Pounds of toxic chemicals emitted by California industries and reported to the U.S. EPA[13]
5%	Percent of total industrial chemical emissions accounted for under U.S. EPA reporting requirements[14]
$1,200 million	Direct and indirect costs of childhood diseases attributable to chemical exposures[15]
$1,100 million	Health and environmental costs resulting from commercial pesticide use[16]
1 million	Number of women of reproductive age with blood mercury levels exceeding what U.S. EPA considers safe[17]
Waste	
7,600 million	Pounds of plastic waste estimated to enter landfills[18]
3%	Percent of plastic waste recycled[19]
963 million	Pounds of electronics estimated to enter landfills[20]
147 million	Pounds of hazardous household waste estimated to enter landfills[21]
72%	Percent of the state's largest hazardous waste sites leaking toxic material into groundwater[22]

THE DATA GAP:
Manufacturers and businesses can sell a chemical or product without generating or disclosing adequate information about its potential health or environmental hazards.

THE SAFETY GAP:
Public agencies are unable to efficiently gather hazard information from producers; proactively regulate known hazards; or require producers to accept greater responsibility for the lifecycle impacts of their products.

THE TECHNOLOGY GAP:
There is insufficient public and private investment in green chemistry

The vast majority of industrial chemicals are new to human biology and ecosystems since WWII. They are now widely dispersed in the environment and in people: 287 chemicals and pollutants have been detected in umbilical cord blood.[23]

A fresh approach to chemicals policy in California is essential to building a modern, vibrant economy while safeguarding human health and the environment.

research, development, education, and technical assistance.

THE TIME IS RIGHT

In 2007, California launched a set of initiatives with the potential to make the state a national leader in transforming the management of chemicals and products (see box p. 3).

Facing a similar set of problems to those in California and the U.S., the 27-nation European Union (E.U.) is implementing sweeping new policies governing chemicals and products (see box). Because these policies apply equally to producers and importers, they are expected to spur global innovation in cleaner technologies, including green chemistry.[24]

Canada has also tackled the lack of chemical hazard information, collecting existing data for roughly 23,000 chemicals, nearly 20% of which have subsequently been targeted for further scrutiny on the basis of their potential risks.[25]

Likewise, some leading California businesses are attempting to identify and remove toxic and ecotoxic materials from their operations, motivated by concerns for worker safety, environmental protection, shareholder value, liability, cost and new E.U. regulations.[26]

These developments signal that a paradigm shift could occur in the design, manufacture and use of industrial chemicals, products and processes.

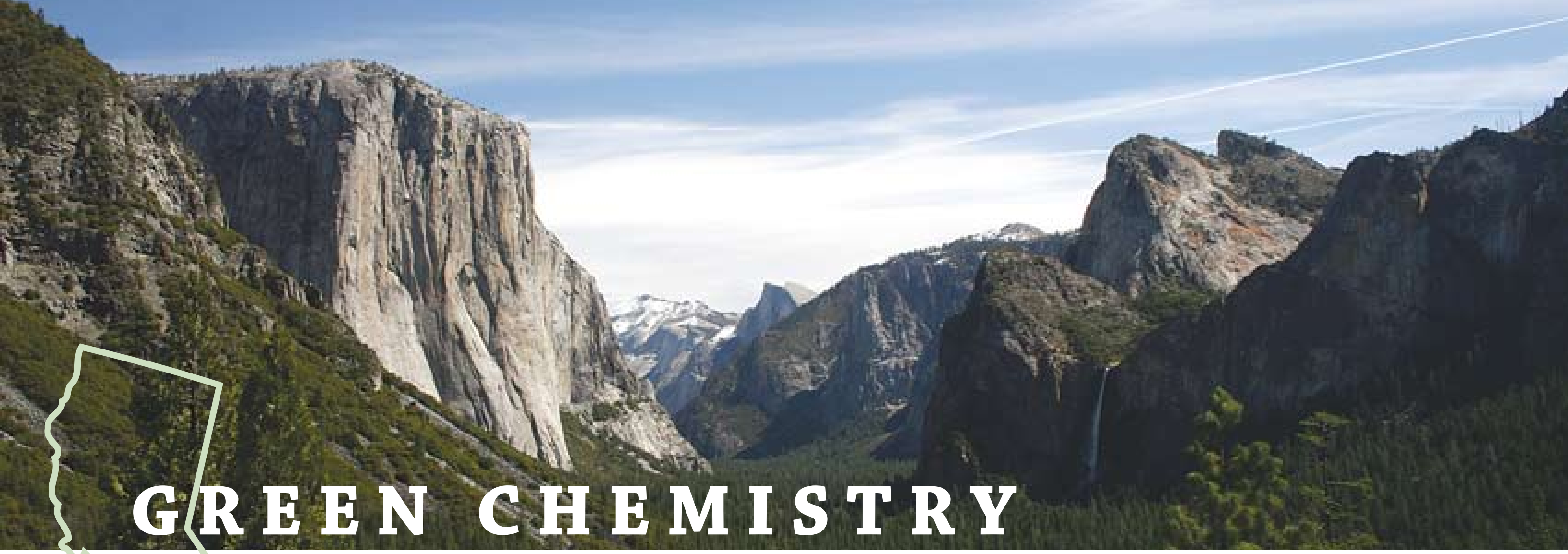
CALIFORNIA'S OPPORTUNITY

A comprehensive chemicals policy is a cornerstone to a sustainable California future. A chemicals policy that addresses the data gap, safety gap and technology gap will:

- Provide businesses and consumers with sufficient health and environmental information to choose the safest products for their needs
- Ensure that the manufacture and use of chemicals and products does not come at the expense of human health and the environment
- Motivate investment, entrepreneurship and employment in green chemistry
- Improve California businesses' health and environmental stewardship
- Apply the resources of the state's colleges and universities to green chemistry development
- Support California businesses in remaining competitive in the global market
- Prevent the sale in California of hazardous products that are prohibited outside the U.S.

CALIFORNIA LEADERSHIP ON CHEMICALS POLICY AND PRODUCT STEWARDSHIP, 2007

- Governor Schwarzenegger signed into law the nation's first state-based biomonitoring program to identify and track synthetic chemicals and pollutants in people.[27]
- Cal/EPA launched a far-reaching Green Chemistry Initiative.[28]
- The Integrated Waste Management Board drafted measures to substantially improve producer responsibility.[29]
- Dozens of local governments joined the California Product Stewardship Council to address rising costs of waste management.[30]
- California Legislators introduced forward-looking chemicals policy proposals.[31]
- A coalition of 30 public interest groups formed Californians for a Healthy and Green Economy (CHANGE) to advocate for chemicals policy reform.[32]
- California established the Ocean Protection Council to confront the problem of ocean plastic contamination.[33]



GREEN CHEMISTRY

California is positioned to become a national leader in new policies that promote the science, technology, and commercial applications of green chemistry: the design and use of chemicals, processes, and products that are safer for human health and the environment.[1] In essence, green chemistry seeks to "design out" the health and environmental hazards posed by chemicals and chemical processes. This approach differs markedly from current chemical management practices, which focus on reducing, rather than preventing chemical exposures and environmental contamination.

> "The principles of green chemistry guide firms in designing new products and processes in such a way that their impact on the environment is reduced… Green chemistry may unknowingly eliminate some critical environmental problems before we ever learn that such problems exist."
>
> *—RAND Science and Technology Policy Institute*[2]

These existing "end-of-pipe" approaches are often costly and minimally effective. Groundwater monitoring for industrial chemical contaminants, for example, costs insurers, businesses and the public about $30 million a year at California's largest hazardous waste sites.[3]

With global chemical production doubling every 25 years, a new approach is needed that motivates industry investment in the design of safer chemicals and products from the outset, before they enter commerce.[4]

THE PROMISE OF GREEN CHEMISTRY

Green chemistry is a fundamentally different approach that protects human and environmental health by replacing hazardous chemicals, processes, and products with safer alternatives. The principles of green

NANOTECHNOLOGY MEETS GREEN CHEMISTRY

The same novel physical, chemical and biological properties of engineered nanomaterials that make them potentially beneficial may also produce new hazards for human health and the environment.[5] The rapid development and commercialization of nanomaterials, however, is outpacing efforts to ensure their safety prior to widespread use.[6] Applying the principles of green chemistry to this sector would help ensure the safer implementation of nanotechnologies.

LIFECYCLE OF A CONSUMER PRODUCT

Green chemistry strategies target each stage of a product's lifecycle to continually improve its biological and ecological safety, reduce its energy consumption, and eliminate the production of hazardous and product waste.

chemistry can be applied to each of the four main phases of the chemical and product lifecycle: design, manufacture, use and end-of-life.[7]

Chemical design

- Formulate chemicals to be effective while reducing human and ecosystem toxicity
- Favor renewable materials over fossil fuel feedstocks where it provides a net ecological gain
- Design chemicals to break down into innocuous substances after use

Product manufacture

- Use energy-efficient processes at minimal temperature and pressure
- Reuse chemical intermediates and produce minimal or no waste
- Use biologically benign solvents

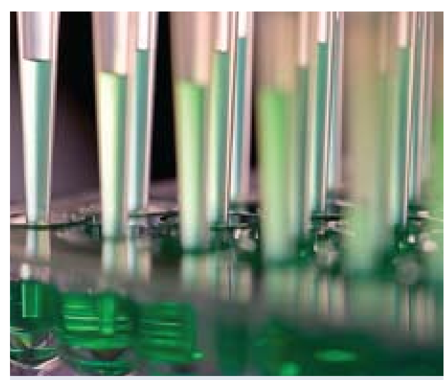
Product use

- Minimize or eliminate the use of toxic, bioaccumulative and/or persistent chemicals in products
- Maximize the proportion of re-used materials in new products
- Retain responsibility for products throughout their lifecycle, from design to re-use

End-of-life

- Prevent the generation of hazardous chemical and product waste
- Recycle chemicals and materials used in manufacturing processes and products
- Recover products at the end of their useful life

To realize the potential of a green chemistry industrial transformation, California will need new policies that re-orient the market such that it rewards producers for improving information transparency, product stewardship and innovation in cleaner technologies.



The premise of green chemistry is to design chemicals, materials and manufacturing processes that are inherently safer for humans and the environment, following principles of biological compatibility, renewability, biodegradability and closed-loop systems.

POLICY GAPS

To transform the management of chemicals and products, California will need to contend with three over-arching policy problems identified here as the data gap, the safety gap, and the technology gap. These policy gaps derive from structural weaknesses in federal and state laws, most notably the federal Toxic Substances Control Act (TSCA) of 1976. TSCA's limitations have been widely recognized by many analysts (see box p. 9) and have had far-reaching implications.[1]

Together, the three gaps have:

- Impeded proper operation of the market for chemicals and products
- Prevented adequate regulation of chemicals and products of greatest concern
- Discouraged private and public investment in green chemistry research and development

As a result, green chemistry has been unable to break out of niche markets, and costly health and environmental damage has continued largely unchecked.

> "TSCA … places the costly and time-consuming burden of obtaining data on EPA, rather than requiring chemical companies to develop and submit such data to EPA. Consequently, EPA has used its authorities to require testing for fewer than 200 of the 62,000 chemicals in commerce when EPA began reviewing chemicals under TSCA in 1979"
>
> *—John B. Stephenson, Government Accountability Office Testimony before U.S. Senate Committee on Environment and Public Works, August 2006*[2]

THE DATA GAP

Origins

TSCA does not require producers to investigate or disclose information about the hazardous properties of their chemicals and products. As a result, there is a significant lack of information on the health or environmental effects of most of the 80,000 industrial chemicals used in the U.S.[3] These include 62,000 chemicals that were already in commerce when TSCA was enacted and which were "grandfathered" into use without further review.[4] 92% of the highest production volume chemicals in commercial use today consist of these substances.[5] In addition,

EUROPEAN UNION INITIATIVES ON CHEMICALS AND PRODUCTS

- The Cosmetics Directive prohibits the use of 1,000 known or suspected carcinogens, mutagens, or reproductive toxicants in cosmetics (2004).[6]
- The Waste Electrical and Electronic Equipment (WEEE) directive requires producers to take back products at the end of their useful life (2005).[7]
- The Restriction of Hazardous Substances in Electrical and Electronic Equipment (RoHS) directive prohibits the use of lead, cadmium, mercury, and certain flame-retardants in all electronics sold in the E.U. (2006).[8]
- The Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) regulation requires that producers provide hazard and exposure information on over 10,000 chemicals and apply for authorization for the use of "substances of very high concern" (2007).[9]

The lack of information on the health and environmental impacts of most chemicals and products means that neither consumers nor businesses can choose the safest products for their needs.

the U.S. EPA has reported that 85% of new chemical notices submitted by companies lack data on health effects, and 67% lack health or environmental data of any kind.[10]

All other federal statutes combined regulate just over 1,000 chemicals and pollutants.[11] U.S. EPA has made limited progress in closing the data gap under the voluntary High Production Volume (HPV) Chemical Challenge, which encourages producers to submit "screening-level" information for about 3,000 chemicals produced or imported at more than one million pounds per year.[12] Screening-level information, however, is not sufficient to inform either business or consumer choices.[13]

Tracking data on chemical use in California is also lacking: there is no state-wide information on the volume or location of chemicals or products produced or imported, no catalogue of their commercial and consumer uses, and virtually no record of their ultimate disposal or environmental fate.[14]

Effects on businesses, consumers and public agencies

The data gap has produced a skewed chemicals market in which products compete on all attributes except safety.[15] As a result:

- Consumers are largely unable to choose products on the basis of their potential health and environmental impacts
- Businesses and manufacturers have limited information with which to identify and eliminate hazardous chemicals and products in their supply chains
- Public agencies have insufficient information to identify chemical hazards of highest priority for human health and the environment
- The deterrent function of the product liability and workers' compensation systems is undermined

Finally, without information on chemical hazards or uses, neither the market nor public agencies can stimulate or reward the development and commercialization of safer alternatives.

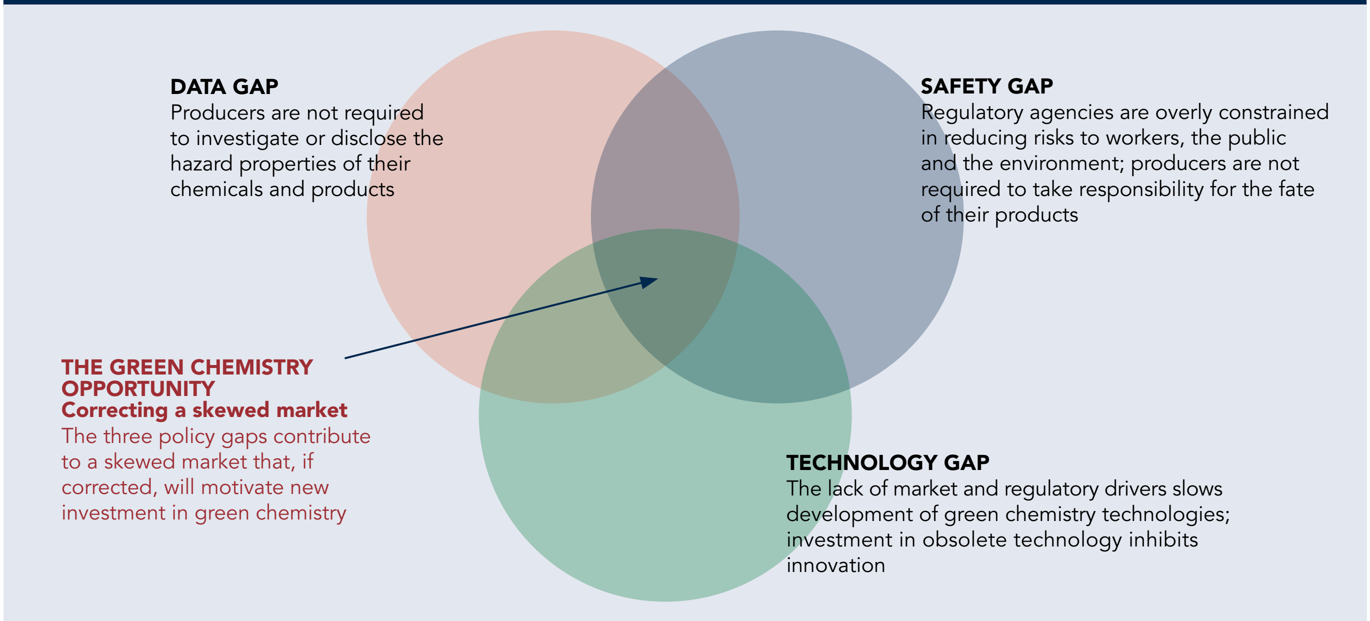
THE SAFETY GAP

Producers are not currently required to assume full responsibility for the health effects and environmental consequences that can occur over the lifecycle of their products. As a result, there is little impetus to minimize the potential hazards associated with the manufacture, use or disposal of chemicals and products.

Without sufficient data to inform

The data gap has produced a skewed chemicals market in which products compete on all attributes except their safety for human health and the environment

FIGURE 1. IMPLICATIONS OF THE THREE POLICY GAPS



Taken together, the three policy gaps produce fundamental obstacles to green chemistry innovation. Policy measures that correct the three gaps will lower these obstacles and open new opportunities for investment in green chemistry while also protecting human health and the environment.

the demand for safer products, or a system for product stewardship, public agencies are limited to regulating the use and disposal of existing chemicals and products, rather than taking preventive measures.

Even in this limited role, however, public agencies are often unable to act expediently, as a consequence of two key barriers: the burden of proof and the standard of evidence.

Public agencies carry the burden of proof

With the exception of pesticides and pharmaceuticals, laws governing chemicals in the U.S. and California generally require public agencies, not producers, to carry the burden of proof that a chemical or product causes unreasonable harm to human health or the environment before the agency can implement protective measures.[13]

Placing a high burden of proof on public agencies encourages producers not to investigate or disclose information about the health and environmental effects of their chemicals and products.

Even in cases where a hazardous chemical or product is clearly identified and a viable, safer alternative exists, agencies are often unable to require adoption of the alternative or efficiently control use of the hazardous substance.[14]

The standard of evidence exceeds agency resources

In satisfying its burden of proof, agencies must meet a standard of evidence that:[15]

- Requires health and exposure information that cannot be obtained from producers
- Often exceeds the limits of scientific knowledge
- Relies on estimates and assumptions that are easily contested
- Is limited to chemical-by-chemical assessments that poorly reflect actual exposures and can lead to substitution with another hazardous substance

This standard of evidence is expensive to achieve and is ineffective for chemicals policy decision-making, given the immense pace and scale of chemical production. In the absence of sufficient health and environmental information, potentially hazardous chemicals and products are allowed to enter or remain on the market.

THE TECHNOLOGY GAP

The difficult transition from concept to commercial application of green chemistry often requires that a company conduct extensive research and development, make potentially large capital investments, and assume the risks of being a leader in an emerging field.

The market and regulatory weaknesses caused by the data and safety gaps, together with organizational and institutional inertia within industry and a lack of public and private investment in green chemistry research and education, all make companies reluctant to take on these risks. This is producing a green chemistry technology gap that could have long-term implications for U.S. competitiveness in the global market for chemicals and products.

> "The nation's economy increasingly relies on a wide variety of chemical products and processes. Progress in slowing the use of potentially hazardous substances has not kept pace with other positive environmental trends over the past 30 years."
>
> —*RAND Science and Technology Policy Institute*[27]

IMPLICATIONS OF THE THREE POLICY GAPS

The data, safety and technology gaps (Figure 1) have produced a flawed market for chemicals and products, in which:

- The health effects of most chemicals are poorly understood
- Hazardous chemicals and products remain cost-competitive
- The costs of health and environmental damage are carried by the public
- There is minimal industry investment in green chemistry
- Government regulation does not adequately protect the public
- There is virtually no attention given to green chemistry in high school, college or university curricula

Not surprisingly, U.S. producers have not invested in green chemistry at a level commensurate with the scale and pace of chemical production: the industry's spending on research and development has decreased or remained flat since 2000, and over 90% of the highest volume chemicals used today were in use in 1979, when TSCA was implemented.[16]

Industry leaders are more likely to improve their investments in green chemistry if they can be confident that:

- The market favors these investments (the data gap is closed)
- The regulatory system favors these investments (the safety gap is closed)
- There are other incentives to reduce costs or risks (the technology gap is closed)

Data gap: Of the 81,600 chemicals in the TSCA inventory, 62,000 were not subjected to review for their potential hazards to human health or the environment. The U.S. EPA found that 85% of notices submitted by producers for new chemicals lacked health effects data.[26]

SHORTCOMINGS OF THE TOXIC SUBSTANCES CONTROL ACT (TSCA)

The shortcomings of TSCA have been described for more than 20 years. The following reports conclude that TSCA has not provided an effective vehicle for the public, industry or government to either assess chemical hazards or control those of greatest concern.

National Academy of Sciences[17]	1984
U.S. General Accounting Office[18]	1994
Congressional Office of Technology Assessment[19]	1995
Environmental Defense[20]	1997
U.S. Environmental Protection Agency[21]	1998
Former TSCA Administrator[22]	2002
National Pollution Prevention and Toxics Advisory Committee[23]	2003
U.S. Government Accountability Office[24]	2005
U.S. Government Accountability Office[25]	2007

ENVIRONMENT

California faces an array of environmental problems related to the manufacture, use and disposal of industrial chemicals and products. These problems are a natural consequence of market and regulatory weaknesses that discourage disclosure of chemical hazard information, producer responsibility and innovation in green chemistry.

Green chemistry offers solutions to these environmental problems by designing:

- Environmentally benign chemicals and materials
- Industrial processes that conserve energy and recycle raw materials, and
- Products whose components can be recaptured and reused at the end of the products' useful life

These and other green chemistry strategies prevent dispersion of hazardous substances into the environment and ultimately eliminate hazardous and product waste.

HAZARDOUS WASTE

The number of hazardous waste sites in the U.S. continues to rise: the U.S. EPA estimates that the country will require 217,000 new hazardous waste sites by 2033, a 180% increase over today's 77,000 existing sites.[1] Each year, more than $1 billion is spent on efforts to clean up hazardous waste Superfund sites. Cleanup costs for future sites are estimated at about $250 billion.[2]

The majority of California's largest hazardous waste sites are leaking: the state's Department of Toxic Substances Control (DTSC) estimates that 61 out of 85 sites are leaking into groundwater. Of the 51 sites inspected for groundwater intrusion, 94 percent were found to present, "a major threat to human health or the environment."[3]

ELECTRONIC WASTE

The U.S. EPA estimates that over 10 billion pounds of electronic products were discarded in U.S. landfills in 2000, or about 34 pounds per person.[4] Between 300 million and 1.6 billion pounds of electronic waste entered California landfills in 2003 (the latest year with available data).[5] Electronic waste contains many known toxic substances, including arsenic, nickel, cadmium, lead, mercury, phthalates, volatile

PLASTIC CONTAMINATION OF THE PACIFIC OCEAN

Contamination of the environment by plastic materials reflects a product management system gone awry. Plastic products are manufactured out of non-renewable materials, contain substances that are toxic to biological and ecological systems, and are designed and packaged for disposal rather than re-use. The resulting pollution presents unique environmental hazards; ocean plastics provide one example.

The North Pacific central gyre is a region of the Pacific Ocean between California and Hawaii in which ocean currents and wind patterns gather plastic and other debris into a central area. Plastic debris now covers an area of the gyre about twice the size of Texas. Researchers estimate that the mass of plastic particles is about six times greater than that of plankton, and that this ratio will grow ten-fold over the next ten years.[6] Nearly all of this material comes from urban areas. Plastic debris has been found in the stomachs of 43 to 86 percent of seabirds and marine animals studied.[7]

Due to their small size, plastic particles are not recoverable from the ocean; they are likely to remain in the marine ecosystem for hundreds of years. Ninety percent of the mass of floating debris in the world's oceans —and 99% of the material on the world's beaches —consists of plastic products and the pellets used to manufacture them.[8]

organic compounds and brominated flame retardants.[9]

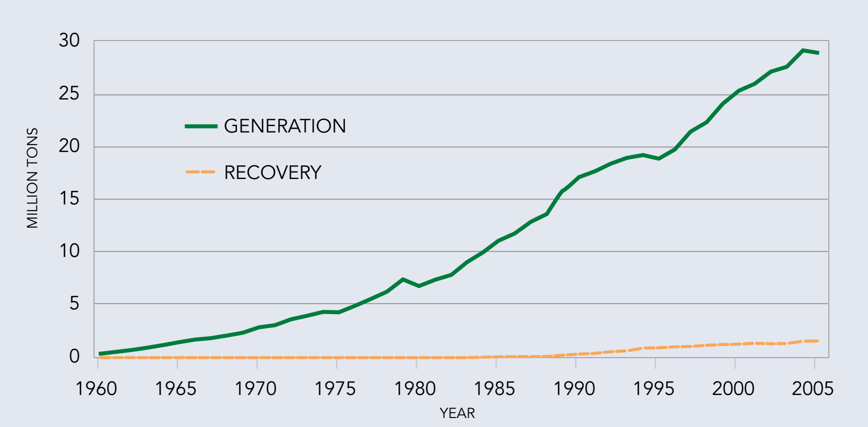
The California Integrated Waste Management Board estimates that in fiscal year 2007—08, the state's Covered Electronic Waste Payment System will capture and manage about 200 million pounds of computer monitors and televisions.[10] The final disposition of the majority of electronic waste is unknown, though some portion is shipped overseas for recycling.[11] Worker and environmental safety of electronic recycling abroad typically lags far behind that of California.[12] High levels of dioxins, furans, PCBs and flame retardants have been measured in the soil, air and water near electronic recycling sites in China, as well as in the breast milk of women living near these sites.[13]

Responding to similar problems with electronic waste, the European Union enacted legislation in 2005 that requires electronics producers to take greater responsibility for the full lifecycle of their products (see box p. 7). In 2006, the E.U. banned the use of lead, cadmium, mercury and other toxic substances in all electronics sold in the E.U.[14] These policies are expected to encourage producers to improve the health and environmental safety of their products at the point of design.

PLASTIC WASTE

California's municipal governments are grappling with a growing tide of plastic waste. An estimated six to nine billion pounds of plastic entered California's landfills in 2003, or about 150-250 pounds per person.[16] Only 3% of plastic waste is recycled (Figure 1).[17] Plastic comprises about 15% of materials in California landfills, by volume, and its relative percentage is increasing as it displaces glass, metal and wood in products and packaging.[18] There is growing contamination of the Pacific Ocean by plastic debris (see box).

FIGURE 1. PLASTIC WASTE GENERATION VS. PLASTIC RECYCLING



While the public perception is that plastics are recycled, in fact, plastic recovery has hovered around 3 percent, while plastic waste generation grows steadily. Source: U.S. EPA, 2005[15]

AIR AND WATER CONTAMINATION

According to the federal Toxics Release Inventory (TRI), large businesses in California emitted a total of 158 million pounds of toxic substances into air, water and waste streams in 2005, the latest year with available data.[19] These include chemicals that are known or suspected to cause cancer, birth defects and damage to the human nervous system.[20]

In 1989, however, the Congressional Office of Technology Assessment estimated that the TRI represents only about 5% (by weight) of total chemical releases by U.S. businesses.[21] According to this estimate, the total industrial chemical emission rate in California for 2005 is 3.2 billion pounds.[22] Additional mechanisms are needed to identify and prioritize emissions of greatest concern to human health and the environment.

In addition to industrial chemicals, 190 million pounds of pesticide active ingredients were released into the environment in California in 2006, along with millions of pounds of "inert" ingredients, some of which include known human and environmental toxicants.[23] Pesticides used on farms and roadways flow into lakes, rivers and bays, and leach into California's groundwater.[24]

California DTSC esimates that 61 of 85 of the state's largest hazardous waste sites are leaking into groundwater. Of 51 sites inspected for groundwater intrusion, 94% were found to present, "a major threat to human health or the environment."[25]

CHEMICALS IN PEOPLE

Human breast milk, umbilical cord blood, and adult tissues contain over one hundred chemicals and pollutants (see Table 1). Some of these substances are known to be toxic at low levels; some are increasing in concentration in sampled tissues.[1]

The presence of industrial chemicals and pollutants in people is not a necessary consequence of an advanced industrialized society.

Most synthetic chemicals identified in people are new to humans and the environment, having been introduced since World War II.[2] Their full implications for human health are unknown, particularly for developing fetuses, infants and children.

Over one hundred industrial chemicals have been measured in people

In 2005, the U.S. Centers for Disease Control and Prevention (CDC) looked for, and found, 148 chemicals in the blood and urine of a representative sample of the U.S. population.[3] The list of industrial chemicals identified in humans is likely to grow as investigators expand the set of tested chemicals.

Many chemicals persist in the environment and accumulate in humans and animals

Chemicals that resist breakdown can remain in the environment for decades, or even centuries.[4] Many of these environmentally persistent chemicals are very slowly metabolized, with the result that they increase in concentration (bioaccumulate) in the food chain. Although some of these chemicals, such as PCBs and DDT, have not been used for decades, they continue to be found in children born today.[5]

Bioaccumulative and persistent substances are often toxic

Many persistent and bioaccumulative chemicals are known to be toxic (PBTs) to humans and ecosystems. PBTs are of particular concern because both their presence in people and their associated health effects could be felt for generations.[6] Despite these concerns, PBTs are still in widespread use. Many organochlorines, for example, are

CASE: FLAME RETARDANTS

The polybrominated diphenyl ethers (PBDEs), a class of persistent and bioaccumulative chemical flame retardants, are added to many consumer products, including furniture, computers and televisions. PBDEs are found in humans and wildlife around the world; over the last 30 years, their levels have increased about 100-fold in human blood, breast milk, and tissues.[7] Women in California have some of the highest levels of PBDEs measured in breast milk, levels which are approaching those associated with adverse health effects in experimental animals.[8]

These effects include permanent learning and memory deficits in the offspring of exposed animals, changes to male and female reproductive structure and function, and low thyroid hormone levels, which impairs fetal brain development.[9]

Using a persistent, bioaccumulative substance in products designed to come into close contact with people is inherently problematic. If asked to do so, chemical producers will prioritize the development of more appropriate flame retardant technologies.

TABLE 1. SELECTED EXAMPLES OF TOXIC SUBSTANCES FOUND IN UMBILICAL CORD BLOOD, BREAST MILK AND ADULT TISSUES		
Contaminant	**Examples of known sources**	**How people are exposed**
Volatile Organic Compounds		
Naphthalene[10]	Vehicle exhaust, deodorizers, paints, glues	Outdoor and indoor air, drinking water, workplaces
Perchloroethylene	Dry cleaning solvent, degreasing products	Treated clothing, proximity to dry cleaners, workplaces
Benzene	Gasoline, glues, detergents, vehicle exhaust	Outdoor air, workplaces
Agricultural Products		
Organophosphates	Pesticides, flea & tick pet products	Food, proximity to agriculture, field work, indoor air
Atrazine	Herbicide	Food, water, proximity to agriculture, field work
Persistent Organic Pollutants		
Polybrominated diphenyl ethers (PBDEs)[11]	Flame retardants in furniture and electronics	Food, indoor air and dust
Dioxins & Furans	Byproduct of waste incineration, paper mills, manufacturing	Food, outdoor air, drinking water
PFOA/PFOS[12]	Non-stick and stain-resistant coatings	Consumer products, food, water, workplaces
Plastics Components		
Phthalates	Cosmetics, detergents, household cleaners, vinyl materials, lacquers	Skin contact, indoor air, food, soft plastics
Bisphenol A[13]	Hard plastic containers, canned food linings	Food, water
Heavy Metals		
Cadmium	Batteries, fertilizer production, waste incineration, plastics, metal coatings	Food, air, water, workplaces
Lead	Paint, electronics, batteries, fossil fuels	Toys, food, soil, drinking water, workplaces

Over one hundred synthetic chemicals and pollutants have been detected in umbilical cord blood, human breast milk and the blood, urine and tissues of adults. Many of these substances are known or probable human carcinogens, reproductive or neurological "toxicants", or all three. Sources: LaKind et al. 2004, CDC 2005, EWG 2005, unless otherwise noted.[14]

used in solvents, pesticides and a variety of common household materials. A 1994 consensus statement by the American Public Health Association concluded 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… are recognized as significant workplace hazards."*[15]

Despite uncertainties, early action is warranted.

While it is known that many of the chemicals and substances appearing in peoples' bodies are toxic, and that the levels of some of these substances are increasing, it is still unclear exactly how people are exposed and what the long-term consequences for human health may be.[16]

Because of their potential to persist for generations, however, bioaccumulative and persistent substances should be phased out of commercial use, beginning with those that are known to be toxic. Preventive action of this type is warranted, despite the uncertainties.

A case in point is the elimination of lead from gasoline, a landmark victory in preventing neurological damage to children. This measure produced a dramatic decline in blood lead levels for the entire population, and children have been the most obvious beneficiaries.[17] By addressing the fundamental principles of chemical and product design, new green chemistry policies could result in similar benefits, while avoiding the problems associated with chemical-by-chemical bans.

Breast milk contains many industrial chemicals, including methylene chloride, toluene, trichloroethylene and xylene.[18] *While on balance breast milk protects infant health, the potential effects of even minute amounts of chemical contaminants in breast milk are of serious concern.*[19]

CHILDREN AND WORKERS

Chemical exposures can have profound implications for human health. People are exposed to industrial chemicals and pollutants in workplaces and homes, and via air, water, food, and contaminated waste streams.

Although chemical exposures are relevant to the general population, two groups — children and workers — are particularly vulnerable. Even low levels of synthetic chemicals can disrupt the rapidly developing physiology of infants and children.[1] Many workers, depending on their occupation, are exposed to more highly toxic substances and in greater concentrations compared to the general public.[3]

The vast majority of chemicals to which children are commonly exposed have never been examined for their long-term effects on the developing brain.[2]

Immigrants, minorities, and lower-income groups in California are more likely to experience the highest levels of exposure, both as residents and as workers. California adopted an Intra-Agency Environmental Justice Strategy in 2004 in recognition of the inequitable distribution of toxic exposures.[4]

CHILDREN'S HEALTH

Despite unanswered questions about the relationship between chemical exposures and human health, early childhood development is clearly characterized by windows of vulnerability to these exposures.

There is some urgency, then, for California to identify, prioritize and reduce the commercial use of chemicals to which children are most likely exposed and to which diseases or disorders are most closely linked.

Evolving knowledge, unanticipated harm

The historical record illustrates that overconfidence in the safety of industrial substances can lead to years of preventable health damage. Specific blood levels of mercury, for example, were first correlated with health effects in children over 30 years ago, but research since then has revealed that effects in fact occur at levels 1,000 times lower than those originally thought to be safe.[5]

Likewise, in 1997 the EPA established standards for airborne particulate matter (PM) based primarily on hospital admissions and mortality data.[6] It is now recognized that PM can also contribute to cardiovascular disease, lung cancer, pre-term birth, low birthweight, and asthma exacerbations.[7]

Compared to our understanding of the hazards of mercury and PM, knowledge about the long-term health effects of most industrial chemicals is in its infancy. It is therefore rational to take preventive action based on early indicators of harm, recognizing that current science may underestimate the full extent of health effects attributable to industrial chemicals and pollutants.[8]

Health effects

Rising incidence of some cancers,

Coming generations will carry the greatest burden of industrial chemical contamination. California has the opportunity to turn the tide on this significant public health problem.

asthma, and developmental disorders may be due in part to chemical exposures, particularly in young children (Figure 1).[9] A variety of male reproductive abnormalities may also be linked to *in utero* exposures to certain pesticides or endocrine disrupting chemicals.[10]

Similarly, recent studies in California's farming communities have reported higher rates of learning difficulties in the children of women who were more highly exposed to certain pesticides during pregnancy.[11]

Many chemicals once considered safe are now recognized as hazardous to the developing fetus and child. In assessing the state of knowledge, a 2007 consensus statement of the *International Conference on Fetal Programming and Developmental Toxicity* concluded that, "prevention efforts against toxic exposures to environmental chemicals should focus on protecting the embryo, fetus and small child as highly vulnerable populations." [12]

Increased vulnerability

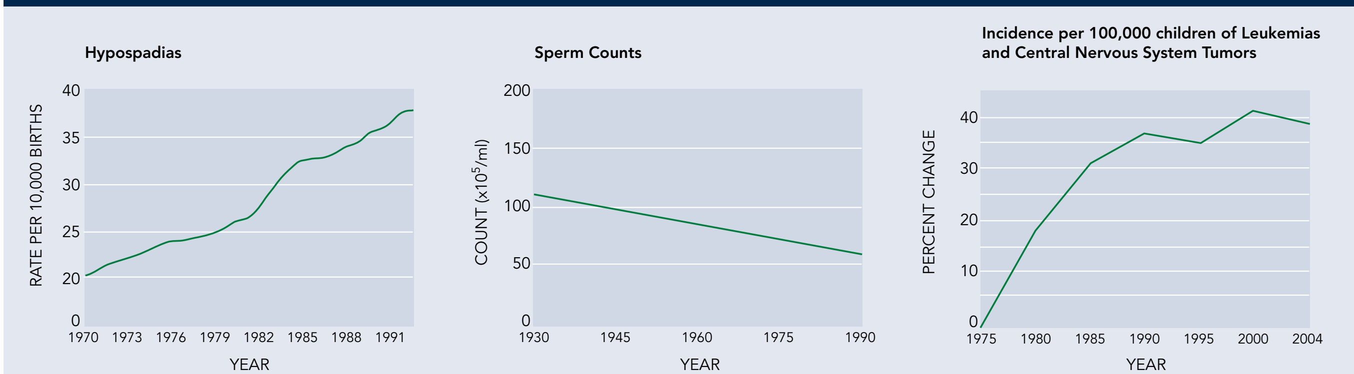
Exposures to industrial chemicals are potentially more harmful during fetal and child development than during adulthood because of three primary factors:

- **Disproportionate exposure:** Biomonitoring studies often find higher levels of chemical contaminants in children than in adults.[13] This may be due to differences in metabolism, children's close contact with soil and dust, or because, pound-for-pound, infants and toddlers eat, drink and breathe more than adults.[14]
- **Increased susceptibility:** Specific windows of vulnerability occur throughout fetal, infant and child development, during which synthetic chemicals can disrupt precise physiological events (see box). These include the cascade of hormone signals that guide reproductive development and the connections that

ENDOCRINE DISRUPTORS: ALTERING THE BODY'S SIGNALS

A growing body of evidence indicates that certain synthetic chemicals commonly found in consumer products can disrupt the endocrine system, a complex network of hormones that affect the development of all organs in the human body. Even small alterations in hormone levels by endocrine disrupting chemicals (EDCs) can affect development of the body's neurological, reproductive and metabolic systems.[18] These alternations can produce permanent changes, affecting the body's responses to food, chemicals and hormones even later in life.[19] Early research suggests that this "reprogramming" may contribute to obesity, pre-diabetic insulin resistance and breast and prostate cancers.[20] Strikingly, evidence from animal studies suggests that the effects of EDCs are heritable; that is, passed on through as many as four generations after an animal is briefly exposed during fetal development.[21]

FIGURE 1. TRENDS IN REPRODUCTIVE HEALTH AND CHILDHOOD CANCERS, UNITED STATES



The incidence of certain pediatric and reproductive health disorders is on the rise, including hypospadias, reduced sperm count (variable by region), and the childhood cancers that are most commonly linked to chemical exposures. Source: Sharpe and Irvine, 2004, Surveillance Epidemiology and End Results (SEER) Program 2004.[17]

occur among billions of neurons in the developing brain and nervous system.[15] The blood-brain barrier remains relatively permeable well into the first year of life and allows passage of synthetic chemicals from the bloodstream directly to the infant's developing brain and nervous system.[16]

- **Lifelong impacts:** Health effects that occur from early exposures have a longer period of time to develop compared to those occurring later. Exposure to even low doses of industrial chemicals during critical periods of fetal and early child development may produce health effects that continue through adulthood.[22]

Better information on chemical toxicity, workplace exposures and occupational disease is needed to reduce workplace hazards and create incentives to develop inherently safer technologies, informed by the principles of green chemistry.

OCCUPATIONAL HEALTH

Because many industrial processes involve close contact with hazardous substances, workers are disproportionately affected by chemically induced diseases.[23]

In 2004, an estimated 200,000 Californians were diagnosed with a preventable chronic disease attributable to chemical exposures in the workplace; another 4,400 died prematurely as a result. These diseases produced an estimated $1.4 billion in direct and indirect costs.[24] California's agricultural workers and farming communities are also disproportionately affected by both acute and chronic effects of pesticide exposures.[25]

An unnecessary burden of disease

Occupational diseases resulting from chemical exposures are eminently preventable. As it stands, however, California is unable to realize the benefits of prevention because of gaps in knowledge about the toxic effects of chemicals, the scope of workplace exposures, and the extent of the diseases they contribute to.

Toxicity: The current document for communicating chemical hazard information to workers, the Material Safety Data Sheet (MSDS) requires little to no information on the health effects of chemicals and is widely recognized as inade-

HEXANE: A NEUROTOXIC CHEMICAL IN WIDESPREAD USE

Between 1995 and 2003, California auto repair workers were exposed to hexane, a well-known neurotoxic chemical found in automotive brake cleaners and many other commercial products. In 2000, several workers developed a neurological disorder that caused decreased function of their arms and legs.[27] Each year, millions of cans of hexane-based products were sold in California as an alternative to chlorinated solvents, which were also hazardous but were more heavily regulated in the state.[28]

The use of hexane, which continues today, highlights problems that are universal to current chemical and product management:

- Uncontrolled use: Hexane was introduced without restrictions into the California market and used in higher volume and with fewer worker protections than anticipated by manufacturers.[29]
- Disproportionate impact: The most highly exposed workers were those in entry-level jobs, held mainly by Latino and Asian immigrants.
- Lack of authority: Agencies lacked the authority to obtain sales data from manufacturers. As a result, they could neither assess the scope of the health threat nor identify specific workers at risk. Agencies also lacked the authority to phase-out the use of these products.
- Regrettable substitution: The phase-out of chlorinated solvents, though appropriate, occurred without an effective strategy for managing substitutes, resulting in the introduction of a new hazard, in the form of hexane.
- Barriers to safer alternatives: Safer, water-based cleaners were available but appeared more expensive than hexane-based products, whose true costs were externalized to the public. These costs included worker diseases, air pollution, and the disposal of 6 million aerosol cans of hazardous product waste each year into public landfills.[30]

A comprehensive chemicals policy would simultaneously address this full set of problems by pairing the regulation of known hazards directly with the evaluation and adoption of safer alternatives.

WORKERS ARE INADEQUATELY PROTECTED FROM CHEMICAL HAZARDS

The standard regulatory mechanism for protecting workers from chemical exposures is the Permissible Exposure Limit (PEL), which establishes an exposure level considered safe for most workers, based on a 40-hour workweek. While California has established 688 PELs (compared to 453 federal PELs) this represents only a small fraction of the hazardous chemicals and mixtures to which workers are potentially exposed.[31]

In December 2007, California's Office of Environmental Health Hazard Assessment (OEHHA) identified workplace chemicals listed under the state's Proposition 65 as known to cause cancer or reproductive/developmental toxicity.[32] Of this set of chemicals, OEHHA found that:

- PELs have not been established for 44 workplace carcinogens
- Of the workplace carcinogens with established PELs, 62 are not regulated specifically as occupational carcinogens
- Risk of cancer for six workplace chemicals is estimated to be greater than one in ten for workers exposed at levels equivalent to the PEL
- 60% of workplace chemicals suspected of causing cancer or reproductive harm are High Production Volume chemicals (produced or imported at more than one million pounds per year in the U.S.)

quate.[26] The health effects of chemical mixtures, which account for the great majority of workplace exposures, are almost entirely unknown.

Exposure: There is no requirement for consistently tracking the type or extent of workplace chemical exposures, and regulations to control those exposures are inadequate. There are Permissible Exposure Limits (PELs), for just 7% of the nearly 3,000 high production volume (HPV) chemicals in the U.S. (those produced or imported at more than one million pounds per year).[33] Uncontrolled exposures are more likely to occur for chemicals lacking PELs (see box). Most exposure information collected by the California Division of Occupational Safety and Health (DOSH) is not used to inform prevention.

Disease: The long lag time between exposure and diagnosis makes it difficult to distinguish occupational from non-occupational diseases.[34] There are minimal resources dedicated to occupational disease surveillance or regulatory control.

Green chemistry protects worker health

Better information on toxicity, workplace exposure and occupational disease will provide agencies and employers with additional incentives to develop inherently safer technologies, informed by principles of green chemistry. Generating this information is a core element of chemicals policy and requires closing the data gap.

Given the safety gap, ensuring the health of California's workforce will also require an effective legal framework that improves agency capacity to respond to workplace hazards. Green chemistry will provide the technical basis for producers to develop safer alternatives to the chemical hazards of greatest concern for the health of California workers.

In 2004, more than 4,000 Californians died prematurely from chronic diseases attributable to workplace chemical exposures.[35]

> "Green chemistry offers many promises, including substantial reductions in the environmental footprint of many chemical processes, improvements in the health and safety of those exposed to chemicals, and enhanced security at facilities with hazardous materials."
>
> — *RAND Science and Technology Policy Institute*[36]

ECONOMIC CONSEQUENCES

As it currently operates, the U.S. market for chemicals and products externalizes to the public many of the costs of health and environmental damage associated with industrial chemicals, their products and wastes. These include direct and indirect costs of chemically related diseases among workers, as well as a portion of childhood diseases linked to environmental contaminants.

State and local governments incur the costs of managing hazardous and product wastes, cleaning up

FIGURE 1. DISEASE CASES AND COSTS ATTRIBUTABLE TO CHEMICAL EXPOSURES IN THE WORKPLACE, CALIFORNIA 2004

	Cases			Costs ($millions)	
	Disease	Hospitalizations	Deaths	Direct medical	Indirect
Cancer	113,999	8,700	3,845	$617.2	$620.5
COPD	42,606	1,145	361	$42.6	$42.8
Asthma	45,856	460	11	$25.4	$7.5
Pneumo-conioses	1,710	171	132	$15.3	$21.0
Chronic renal failure	2,854	128	21	$4.9	$5.7
Parkinson's disease	699	27	37	$1.1	$1.3
Total	**207,724**	**10,631**	**4,407**	**$706.5**	**$698.8**
				TOTAL	**$1,405.3**

In 2004, preventable diseases resulting from workplace chemical exposures cost California insurers, employers, workers, and their families a total of $1.4 billion in both direct medical costs and indirect costs, including lost wages and benefits and lost years of productive life. Source: Leigh, et al., in preparation.[2]

FIGURE 2. CHILDHOOD DISEASE CASES AND COSTS ATTRIBUTABLE TO ENVIRONMENTAL EXPOSURES, CALIFORNIA 2004

	Cases			Costs ($millions)	
	Disease	Hospitalizations	Deaths	Direct medical	Indirect
Asthma	237,363	3,952	8	$144.8	$91.7
Cancer	690	156	15	$8.3	$28.3
Mental retardation	565	0	0	$136.9	$601.4
Cerebral palsy	137	0	0	$28.1	$141.0
Total	**238,755**	**4,108**	**23**	**$318.1**	**$862.3**
				TOTAL	**$1,180.4**

In 2004, an estimated 240,000 cases of preventable childhood disease in California were attributable to chemical substances in food, water, air, soil, the home and community. These cases resulted in approximately $1.2 billion in both direct medical costs and indirect costs related to premature death, lost school days, state services and other factors. Source: Leigh, et al., in preparation.[3]

In 2004, direct medical costs of chemical and pollution-related diseases among children and workers totaled over one billion dollars in California.[1] New policies can dramatically reduce these costs, as well as the broader social and economic impacts of the years of future productive life lost.

Plastic debris on beaches and in the ocean threatens California's $46 billion ocean-dependent tourism-oriented economy.[4]

Green chemistry technologies can contribute to a sustainable economy, relieving the economic pressures on state and local governments, improving the profitability of businesses using safer materials, providing job opportunities, and protecting human health and the environment.

contaminated sites, and contending with the long-term implications of air pollution, water pollution and ecosystem degradation.

Some of these costs are reported here; others have not yet been quantified. Because of knowledge gaps in chemical toxicities, exposure pathways and associated diseases, these figures likely underestimate the true rates (Figures 1 and 2).

THE COST OF HAZARDOUS WASTE

The state of California, local governments, taxpayers and businesses all pay to manage hazardous wastes generated by the manufacture and use of chemicals and products.

In fiscal year 2006-07, California's Department of Toxic Substances Control spent $131 million to monitor and clean-up hazardous waste sites, manage hazardous waste, and prevent pollution. These costs represent a 42% increase over FY 1996-97.[5]

Each year, legacy landfills — historically contaminated areas that include some designated Superfund sites — cost California companies, their insurers and taxpayers $30 million in groundwater monitoring expenses alone.[6] This economic burden is projected to continue in perpetuity and ultimately transfer to the state.

Using hazardous chemicals is expensive for businesses; the lifecycle costs of managing chemicals, including transport, handling, disposal and worker protection can range from one to ten times the purchase cost.[7] It is necessary to account for these costs when evaluating the economic benefits of green chemistry alternatives.

THE COST OF PRODUCT WASTE

Municipal governments are grappling with the costs of managing a growing stream of product waste. In 2003, the latest year for which data are available, local governments incurred the costs of handling 6 to 9 billion pounds of plastic waste, or about 160 to 260 pounds per California resident.[8] Only 3% of plastic waste is recycled into secondary uses.[9]

Local governments also dealt with 300 million to 1.6 billion pounds of electronic waste entering landfills in 2003, on top of nearly 150 million pounds of household hazardous waste.[10]

Green chemistry policies can relieve the growing economic pressures created by hazardous and product waste and can reduce the burden of disease, improve the profitability of businesses, and provide the job opportunities necessary for a sustainable economy.

HEALTH AND ECOSYSTEM COSTS OF PESTICIDE USE

A full accounting of the economic impact of pesticide use and regulation must consider indirect effects such as food safety, health consequences for workers and agricultural communities, pesticide resistance and environmental damage, such as groundwater contamination and loss of wildlife, beneficial organisms and pollinators. This analysis has not been undertaken in California; however, an estimate based on a model developed for the U.S. as a whole places the health and environmental costs associated with commercial pesticide use between $870 million and $1,300 million each year.[11]

SOLUTIONS

Although some leading businesses have adopted sustainable practices, the vast potential of green chemistry remains untapped. A comprehensive chemicals policy should include information-based strategies, direct regulation, extended producer responsibility, technical assistance, market-based incentives and public support for research and education. These strategies can position California to become a national and global leader in green chemistry innovation.

> "Over the next 5 to 10 years, green chemical innovation could be a significant source of competitive advantage for companies manufacturing chemicals used in consumer products."
>
> *—European Social Investment Forum[1], 2005*

CLOSE THE DATA GAP:

Generate sufficient information for businesses, consumers and public agencies to choose viable alternatives

Disclosure of hazard information will enable California's businesses, consumers and policymakers to choose the alternatives that provide maximum protection of human health and the environment. This information should improve the prospects for businesses seeking to market green chemistry alternatives.

In addition to hazard information, public agencies need chemical tracking data to characterize human exposure potential. Hazard and tracking data together will help agencies identify and prioritize substances of greatest concern (see box).

Generating the data

- Chemical producers and product manufacturers should be required to provide hazard and tracking data as a condition of use or sale in California. Chemical and product distributors should also be required to contribute tracking data.
- An external independent panel should define and periodically update a set of hazard traits to provide a scientific basis for decision- making.
- California should identify the best available toxicity testing methods and support research and development of new methods.
- Toxicity testing methods and reporting of results should produce consistent data, permitting comparison of chemical hazards.
- Producers should reimburse taxpayers for the costs of California's chemical management program

Ensuring data quality

- California should provide oversight to ensure the completeness, quality and credibility of hazard and tracking data submitted by producers.
- California should adopt the highest standards for independence of experts advising the state, modeled on International Agency for Research on Cancer standards.[2]
- Hazard data must not be considered confidential business information.

Collecting and disseminating the data

- California should establish a standardized format for submission of hazard and tracking data and make that information publicly accessible online.
- To improve understanding of the links between exposures and disease, hazard and tracking data should be integrated with key California programs, including the biomonitoring program, the Environmental Health Tracking program, the Environmental Protection Indicators for California project, occupational disease surveillance programs, and the state's disease registries.[3]

CLOSE THE SAFETY GAP:

Address known hazards

To close the safety gap, California agencies need new tools to efficiently identify, prioritize, and mitigate chemical hazards. This requires a new legal framework for agencies to act on reasonable grounds for concern, even where complete hazard or tracking data is not yet available.

Prioritizing substances

- The state should create a tiered catalog of chemicals that categorizes substances according to their relative hazards. Priority should be placed on chemicals of greatest concern to the most vulnerable populations, including pregnant women, young children and workers.
- Lists developed by Canada and the European Union can provide a starting point; however, California's catalog should be tailored to reflect chemical uses specific to the state.[5]
- The cataloging system should be responsive to the introduction of new substances, changes in chemical production or sales volume, the emergence of new health effects data, and advances in hazard characterization.

DATA NEEDS[4]

Hazard:
Characterize the potential that a chemical is:

- Bioaccumulative or persistent in the environment
- Genotoxic, carcinogenic or teratogenic
- Toxic to adult or developing reproductive, neurological, endocrine or immune systems
- A respiratory sensitizer
- Acutely or chronically toxic to the heart, liver, kidney, bone marrow, eye or skin
- Toxic to aquatic organisms

Tracking:
Establish a roadmap of chemicals produced or sold in California based on a life cycle approach including:

- Sales volume and distribution
- Industrial and consumer uses
- Environmental releases
- Disposal practices

California has the resources to retool the chemical production system into one that continually develops cleaner technologies and protects its greatest assets: healthy people, vital ecosystems and a thriving economy.

California should invest in education and technical training to prepare a workforce capable of designing and producing the sustainable materials, manufacturing processes and products that are anticipated to play a key role in emerging global markets.

California can provide technical assistance to small businesses, helping them make the transition from concept to commercial application of cleaner technologies that incorporate the principles of green chemistry.

BUILDING CALIFORNIA'S GREEN ECONOMY

California's energy efficiency policies have attracted over 100 clean energy technology companies to the state.[6] Investments in the state's clean energy industry are anticipated to seed 52,000 to 114,000 new jobs statewide by 2010.[7]

By supporting economic development in the clean energy sector, California stands to gain in several ways:

- Creating new opportunities for investment in 21st-century technologies
- Providing new employment opportunities, including in California's low-income urban areas
- Reducing energy costs for residents and businesses
- Reducing the state's environmental footprint

A new chemicals policy that supports green chemistry could produce similar benefits, opening new business and employment opportunities in safer chemicals and products while also improving human health and environmental protection.

- The chemical cataloguing process should not delay expedient action when a chemical's hazard potential is known or a viable safer alternative is available.

Mitigating known hazards, adopting safer alternatives

- The introduction and continued use of chemicals of particular concern should be subject to agency review and approval. Where no safer viable alternative exists, the distribution and use of such chemicals should be subject to appropriate controls. If a viable safer alternative exists, its adoption should be mandated and the chemical of concern should be phased out.
- California should require companies to periodically evaluate the availability of inherently safer chemicals and processes and report on their evaluations.
- The producer should assume the burden of establishing that a chemical is not of particular concern, or that no viable alternative is available.

Improving producer responsibility

Producers should take responsibility for the full lifecycle costs of their chemicals and products, including production, use, releases, and disposal or re-use.

- The California Integrated Waste Management Board's "Framework for Extended Producer Responsibility" should be implemented.[8]

CLOSE THE TECHNOLOGY GAP:

Support green chemistry research, education and implementation

Correcting the data and safety gaps will realign the market to support investment in green chemistry products and technologies. In addition, California can close the technology gap by supporting green chemistry research, education and implementation.

Public Support for Research

Publicly funded basic science research has underpinned California's biotechnology, pharmaceutical, and electronics industries. There is no equivalent support for green chemistry. Publicly funded research should:

- Identify the chemical information needed by businesses, agencies and consumers to make informed decisions, and how this information could be most effectively communicated.
- Develop tools for accurately and expediently evaluating the health and environmental effects of chemicals, products and mixtures, including the use of high-throughput testing and predictive toxicology methods.[9]
- Develop assessment tools for identifying safer alternatives.
- Develop methods for evaluating exposures to chemical mixtures and the cumulative effects of chronic, simultaneous exposure to multiple environmental contaminants.

Education and training

Education in green chemistry and sustainability can ensure a skilled workforce. It should be integrated across academic disciplines and included in the curriculum from elementary through graduate-level education.

California's colleges and universities should develop professional and vocational training programs in sustainability, including green chemistry.

Technical Assistance and Incentives

California's public agencies and universities should collaborate to assist companies as they:

- Transition from concept to commercial applications of sustainable practices
- Identify the risks and expenses associated with new green chemistry technologies
- Move green chemistry technologies from the laboratory to full-scale production
- Transition green chemistry technologies from niche markets to broad-scale commercial success.

California can support adoption of green chemistry technologies by:

- Conducting demonstration projects of best business practices
- Developing assessment tools for identifying suitable alternatives to chemicals of concern
- Developing design standards and technical specifications
- Assessing regulatory obstacles to innovation of safer chemicals and processes.

Identify safer alternatives

- California should develop technical criteria to define the attributes that qualify a chemical or process as a safer alternative.
- These criteria should prevent shifting of hazards from one population or environmental medium to another.
- California should consider establishing a list of viable safer alternatives as a basis for phasing out hazardous products and processes.

Market-based incentives

Targeted market-based incentives can also accelerate the adoption of green chemistry. These include:

- A state procurement system for preferred chemicals and products
- Green chemistry certification and labeling standards
- Low-interest loans for investment in green chemistry technologies
- Tax credits for meeting hazard reduction targets and for improvements in health and environmental performance that exceed standard industry practice

California's ability to link economic opportunity with human health and environmental protection will be a cornerstone for a sustainable future.

- Recognition awards for leading industries.

CALIFORNIA IS POISED TO MEET THE CHALLENGE

A modern, comprehensive chemicals policy will address California's pressing health, environmental and economic problems associated with the management of chemicals and products. Such a policy will promote the science, technology, and commercial applications of green chemistry: the design, production and use of chemicals, processes and products that are safer for humans and the environment.

Building new productive capacity in green chemistry will support a vibrant economy, open new opportunities for investment and employment, and protect human health and the state's natural resources. Given California's unparalleled innovative potential and its scientific, technical and financial resources, the state is well-positioned to become a national leader in green chemistry innovation.

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