French Industry and Sustainable Chemistry:

The Benefits of Clean Development

Frank Ackerman & Rachel Massey
Global Development and Environment Institute
Tufts University
Medford, MA 02155

Acknowledgements

The authors would like to thank Yannick Vicaire and Aurele Clemencin for their help throughout this project, Myriam Beaulne for excellent research assistance and translation of documents, Nadia Haiama and Michael Warhurst for help in framing and initiating the study, and Alex Freiszmuth for translation of the final report. This report was made possible by a grant from Greenpeace France. The contents of the report are, of course, the sole responsibility of the authors.

About the authors

Frank Ackerman is the director of the Research and Policy Program at the Global Development and Environment Institute at Tufts University. He is the co-author of *Priceless: On Knowing the Price of Everything and the Value of Nothing* (The New Press, 2004), and *The Flawed Foundations of General Equilibrium: Critical Essays on Economic Theory* (Routledge, 2004). He and Rachel Massey co-authored *The True Costs of REACH* (2004), a study for the Nordic Council of Ministers.

Rachel Massey is a researcher at the Global Development and Environment Institute. In addition to co-authoring *The True Costs of REACH*, she is the author of *Surviving REACH: A Guide for Companies That Use Chemicals* (Chemical Secretariat International, 2005), and *Building a Healthy Economy: Chemicals Risk Management as a Driver of Development* (Swedish Chemical Inspectorate, 2005).

Corresponding author: Frank Ackerman, Frank.Ackerman@tufts.edu

Tufts University, 44 Teele Avenue, Medford, MA 02155 USA
TEL: 617 627-3530 • FAX: 617 627-2409 • E-MAIL: GDAE@tufts.edu
WEB SITE: http://ase.tufts.edu/gdae

Suggested citation: Ackerman, Frank, and Rachel Massey, *French Industry and Sustainable Chemistry*, Medford, Mass.: Global Development and Environment Institute, Tufts University, October 2005.

Cover photo: Pierre Gleizes
Design: Minona Heaviland

Table of Contents

Executive Summary

I. The chemical industry in context: economics and health

The French economy is one of the five largest in the world, with a gross domestic product (GDP) of €26,500 per person. French workers are remarkably productive, with output per hour of labor higher than in the US, Japan, and almost all EU nations. Thus it is not surprising that French citizens enjoy a high standard of living and extensive social benefits.

Over the long run, French economic performance has been similar to that of other leading industrial economies: rapid growth in the decades following World War II, giving way to restructuring and then slower growth from the 1980s onward. Restructuring quickly led to success in foreign trade; French exports have exceeded imports every year since 1992.

The costs of environmental protection are quite often overestimated in advance, and do not threaten the French economy. Recent European experience in international trade shows that environmental protection does not harm industry or undermine competitiveness. In recent years, the world's leading exporter has been Germany. If European wages and regulations made a country uncompetitive, as pessimistic observers sometimes suggest, then neither Germany nor France would be thriving in world markets. Yet in fact, both countries are very successful exporters.

The chemical industry had worldwide sales of €1.8 trillion ($2.2 trillion), more than 5% of world GDP, in 2004. Despite growing production in some developing countries, the majority of global chemicals production occurs in the EU, US, and Japan; these countries, especially the EU, routinely have trade surpluses in chemicals with the rest of the world. France produced 5.3% of the world's chemicals in both 1980 and 2004, confirming that the country is holding its own in a changing, competitive global market.

Pharmaceuticals are now the fastest-growing branch of the chemical industry in France and in many other countries. In 2004, pharmaceuticals accounted for 41% of the turnover of the French chemical industry; other specialty chemicals such as perfumes and cosmetics, paints, soaps and cleaning products, and agricultural chemicals accounted for 31%; and basic chemicals and plastics made up the remaining 28%.

With rapidly rising productivity, the chemical industry has been able to produce a growing output with a shrinking labor force. Total employment in the French chemical industry decreased from 266,000 in 1990 to 237,000 in 2004, losing an average of about 2000 jobs, or 0.8% of industry employment, each year. The decrease in chemical industry employment has proceeded even more rapidly in the US, Japan, and the EU as a whole. Job loss in French manufacturing as a whole has averaged 1.4% annually since 1990; the decline in the chemical industry has been slower than average.

Some of the apparent decline in chemicals employment may reflect the growing use of subcontractors; UIC cites the increased spinoff of jobs to subcontractors as a reason why the drop in employment is not as significant as it seem. Academic research confirms that there was a rapid rise in subcontracting throughout the French economy in the 1980s, with more than half of all SMEs working as subcontractors to larger firms by 1990.

UIC reports that there are 2600 enterprises in the French chemical industry. Companies with less than 100 workers account for 85% of enterprises, but only 18% of employment. At the other extreme, companies with more than 500 employees account for 3% of enterprises and 52% of employment. The numerous companies with less than 500 employees include many affiliates of foreign chemical companies, as well as French businesses. With the rapid pace of mergers and acquisitions within the chemical industry, ownership and even names of companies are constantly shifting. The top three nonpharmaceutical chemical companies, Arkema (formerly Atofina), Air Liquide, and Rhodia, are among the 50 largest in the world. Sanofi-Aventis, the dominant pharmaceutical company, is number one in Europe and number three in the world.

Health hazards. The French chemical industry is clearly succeeding in producing, exporting, and expanding in a competitive global market. Unfortunately, this success in the marketplace has been accompanied by continuing hazards to the health of workers and consumers. The 2001 explosion at Atofina's AZF fertilizer factory in Toulouse, which killed 30 people and damaged more than 11,000 buildings, was the worst accident in recent years -- but not the only one. From 1992 through 2004, accidents in the chemical industry accounted for a total of 73 deaths, including 10 in 2003 and 14 in 2004. Chemical products are involved in 17% of all occupational accidents in France, including many outside the chemical industry.

Less visible than accidents and explosions, but much more deadly in the long run, are the occupational and environmental illnesses caused by exposure to dangerous chemicals. Recent research in France has found that childhood leukemia is related to home and garden insecticide use, and that deaths of farmers from bladder cancer are linked to exposure to pesticides in vineyards.

The best studied hazards are cancers attributable to occupational hazards. A study of the surprisingly high rate of cancer in the Paris suburb of Seine Saint-Denis found that more than 70% of local cancer patients (for whom information was available) had been exposed to at least one known carcinogen at work; half had been exposed to three or more carcinogens.

A study from the Institut de Veille Sanitaire estimates that occupational exposure to recognized carcinogens caused between 3,767 and 7,656 new cases of five types of cancer among men in 1999. Since there are other types of occupational cancer and other likely carcinogens, and since women also get occupational cancers, the total number of occupational cancers is much higher, perhaps as high as 20,000 per year.

Asbestos is currently the leading source of occupational cancers. Tragically, it was used for decades after its toxicity was well established. The courts have now established a strict standard of liability for companies that exposed their workers to asbestos in the past. Under this standard, companies become responsible for ensuring the safety of their workers, and can be penalized severely if they gamble and lose on the safety of untested chemicals. Thus employers as well as workers will benefit from a precautionary approach to chemical safety, as called for under REACH.

II. Cleaner Alternatives: Framework and Case Studies

It is often more effective to reorganize production so that pollution is not created in the first place, rather than cleaning it up after the fact. Cleaner production has frequently been found to save money for companies, for example by reducing the need for raw materials purchases (because chemicals are being recovered and reused, or are simply being used in smaller quantities). Many case studies from France and around the world document the successes and the opportunities for pollution prevention via cleaner production techniques.

A new analytical approach, "green chemistry," attempts to systematize this process, to design chemical products and processes from the outset to minimize the production and use of hazardous substances. The goals are two-fold: to create better, safer chemical products, and to choose the safest, most efficient ways to synthesize those chemicals. Green chemistry works from the premise that chemical products can be designed so that they are completely effective, and yet pose little or no hazard to human health or the environment. Some broad guidelines include preventing waste, using renewable feedstocks, using safer solvents and reaction conditions, increasing energy efficiency, and designing chemicals to break down into innocuous substances after use. The green chemistry approach, although relatively new, has already yielded a range of economically important innovations.

Under the Aarhus Convention, governments are committed to facilitating public access to environmental information. Successful achievement of cleaner production requires participation of the people who are often most directly affected by environmental hazards: workers and local communities. Workers have first-hand knowledge of the practicality of alternative production options and are often in the best position to make sound judgments about whether a given product or process will be workable in practice. Similarly, the communities that live near industrial facilities are often the strongest and most persistent advocates for change.

Four case studies highlight dangerous chemicals produced in France, for which safer alternatives are available:

PVC (polyvinyl chloride) is one of the most widely used, and most hazardous, plastics. It creates health risks at every stage of its life cycle. PVC is the only common plastic that contains chlorine, a poisonous gas which can react with organic molecules to give rise to dioxin and other carcinogens. Vinyl chloride monomer (VCM), the "building block" used to make PVC, is a known carcinogen. Many PVC products contain additives, such as phthalates, which introduce health hazards of their own. When PVC products are burned, either intentionally in incinerators or accidentally in fires, they release hydrochloric acid fumes and can create toxic chemical byproducts.

As of 2003, France had the capacity to produce 1.3 million tons of VCM and 1.4 million tons of PVC annually, just over 4% of worldwide capacity. Atofina (now Arkema) was the leading producer of both VCM and PVC, followed by Solvin. Often VCM and PVC are produced at the same or nearby sites, in order to minimize transportation costs and risks. Arkema, however, produces most of its VCM near Marseilles, and most of its PVC near Lyon. VCM is shipped by barge to Lyon, and then through a 45 km pipeline connecting two Arkema plants. Barges carrying 2500 tons of VCM, a toxic, explosive chemical, travel up the Rhône three or four times a week, putting neighboring communities at risk. The pipeline is likewise a potential hazard to communities along its path.

The largest uses of PVC in Western Europe are for siding, windows, and profiles, pipes and fittings, film and sheet products, wire and cable, and flooring. In each of these applications, practical, affordable, and safer alternatives are available. Often the same companies produce the alternatives. For example, Arkema advertises its Lotryl resins as ideal for the growing markets for products that are "halogen-free" (which means, among other things, PVC-free). For siding and windows, attractive alternatives to PVC include wood siding and windows, fiber cement siding (a relatively new, durable, non-toxic product), and fiberglass and aluminum windows.

In pipes, traditional pipe materials such as copper, iron, and concrete remain important alternatives, along with newer plastic pipe options. Polyethylene pipe offers important physical advantages over PVC, including greater strength under pressure and under low temperatures, and lower rates of leaks and breakage. Polyethylene water pipes have been installed by a number of communities in France, as well as in North America.

Health concerns have mounted over the past several years regarding phthalates, chemicals that are added to PVC as plasticizers (to make flexible plastic products). The EU has banned the use of the most common phthalates in childcare articles and toys. As with PVC itself, there are many safer alternatives to phthalates.

Glycol ethers are a family of related chemicals that are used as solvents in paints, inks, and cleaning fluids, and in other applications such as hydraulic and brake fluids, coatings, adhesives, and other roles in manufacturing. A number of glycol ethers have been identified as toxic to reproduction, particularly those in the more toxic "E-series"; the others, in the "P-series," are not thought to be equally hazardous.

Glycol ethers were formerly used extensively in the semiconductor industry, including at IBM plants in both France and the US. In the course of a lawsuit by IBM workers in the US, it was discovered that workers at the French plant had much higher than expected rates of testicular cancer and leukemia. IBM and other semiconductor companies have now voluntarily stopped using glycol ethers.

Europe is the world's largest producer and consumer of P-series glycol ethers; the P-series market has grown rapidly, both from expansion of the market for glycol ethers in general, and from substitution for E-series in response to toxicity concerns. In 2003, Western Europe had an annual production capacity of 859,000 tons of glycol ethers. In France, BP Chemicals, based in Lavéra, had the capacity to produce 135,000 tons annually.

EU regulations have begun to restrict the use of the most toxic glycol ethers, and their production has declined. As of early 2005, the nine glycol ethers classified as category 2 reproductive toxins (those that have been proved to be toxic to animals, and probably are to humans as well) were reportedly no longer produced in France. However, workers continue to be exposed to considerably higher levels of glycol ethers than those considered acceptable for consumers. The CGT is calling for a complete ban on reproductive toxins in industrial settings.

Safer alternatives include switching from the E-series to the probably safer (although less thoroughly researched) P-series glycol ethers, and the development of less toxic solvents and cleaners that can replace glycol ethers entirely. As with PVC, some of the same major companies sell both glycol ethers and the safer alternatives.

Phosgene, a poisonous gas used as a chemical warfare agent in World War I, is one of the most acutely toxic substances used in commerce today. Currently phosgene is used as a chemical intermediate to produce isocyanates (which are used to produce polyurethane resins, pesticides, and other products), polycarbonate plastic, and a number of chlorinated organic chemicals. It is used in a range of industries, including production of pharmaceuticals, agrochemicals, and others.

Acute inhalation of phosgene can cause choking, coughing, painful breathing, serious lung problems, and even death. Severe eye and skin problems are also caused by phosgene; even low levels of exposure can lead to chronic lung inflammation. Isocyanates, some of the major products made with phosgene, cause health hazards of their own. The Bhopal tragedy in India involved methyl isocyanate. Even under less disastrous circumstances, workers exposed to isocyanates may develop severe respiratory and skin problems.

Europe has the capacity to make about 2 million tons of phosgene per year; France is one of at least seven countries with significant phosgene production. As of 2003, Isochem produced phosgene at its Le Pont de Claix facility, while Orgamol made phosgene at Saint-Vulbas. Isochem formerly operated another phosgene plant at Toulouse, adjacent to Atofina's Grande Paroisse fertilizer plant which exploded in 2001; it was closed by the government after the explosion.

The toxicity of phosgene has stimulated interest in safer alternatives. Leading chemical companies around the world have begun to develop processes and products that eliminate the use of phosgene. There are also options for reducing the toxicity of isocyanates, which are a major concern in their own right. The extensive experimentation with alternatives shows that is feasible to replace phosgene; the surprise is that France, and Europe, still tolerate the production of vast quantities of such a poisonous substance.

Pesticides, used widely in French agriculture pose hazards to industrial workers who make them, to agricultural workers who apply them, and to everyone who consumes pesticide residues in food. Pesticide exposures among children are a particular concern, because even small exposures during critical windows of developmental vulnerability can produce life-long consequences. A disastrous fire at a pesticide manufacture and storage facility in 2005 highlighted the dangers associated with pesticide production as well as the lack of public access to key information about toxic chemicals production.

As of 2002, France had the largest market for agrochemicals in all of Europe, with sales of nearly €1.9 billion (excluding fertilizers). Germany and Italy are the next largest users. Among the pesticides produced in France, more than a dozen are characterized by particular health concerns and/or have been severely restricted or banned in some countries.

The European Union Agricultural Pesticides Directive is slowly leading to review of the safety of pesticides on the market. However, many countries have moved faster and farther to regulate a broader range of substances. Sweden, and the Canadian province of Québec, have regulations effectively banning hazardous products for which safer alternatives have been identified. All of the Scandinavian countries have pesticide taxes, aimed at creating incentives to reduce the use of pesticides.

Safer alternatives are available for most toxic pesticides. Alternatives include both substitution of safer products in place of more dangerous pesticides, and changes in agricultural practices. Sustainable agriculture practices include rotating crops to maintain soil health, monitoring for pests rather than using routine pesticide applications, and using biological controls. Integrated pest management (IPM), using a variety of techniques combined with limited, targeted use of pesticides when necessary, has been applied in many contexts, including examples in France.

III. REACH and beyond: risk, regulation, and chemical safety

Individual workers and consumers, acting on their own, cannot protect themselves against the chemical hazards created by modern industry. Protective regulation is essential; it is quite literally a matter of life and death. REACH, the proposed new EU chemicals policy, is designed to fill the gaps in existing regulations, taking a precautionary approach toward uncertainty, and requiring registration and testing of all chemicals used in industry. Yet ever since REACH was proposed in 2001, there has been intense debate about the merits of its precautionary style of regulation. We address three aspects of the debate, involving the costs of regulation, the impacts on SMEs, and the arguments for new risk-based priorities.

The costs of REACH are estimated to be either very large, in a handful of industry-sponsored studies, or very small, in studies by government agencies and NGOs. The direct costs of registration and testing of some 30,000 chemicals are not the primary focus of debate; most parties agree that these costs will come to a few billion euros, spread over the entire European economy over a period of 11 years. The direct costs are an extremely small percentage of industry revenues, or of European GDP.

Rather, the debate concerns the indirect economic impacts, the ripple effects of testing and other requirements under REACH. In the government and NGO studies, the indirect costs of REACH are no more than 1-6 times as large as the direct costs. Costs of this magnitude are easily outweighed by the health-care savings from even a small reduction in occupational illness, or by the savings on reduced cleanup costs for hazardous chemical waste in the future.

In contrast, two major industry studies found huge indirect economic impacts of REACH, some 400-650 times as large as the direct costs. The more impressive and detailed of the industry studies was done by the consulting firm Arthur D. Little, for a German industry group. Yet in fact, the Arthur D. Little study is based on exaggerations and misrepresentations throughout, as explained and documented in our 2004 report to the Nordic Council of Ministers, *The True Costs of REACH*.

A similar but much less detailed study was done by Mercer Management Consulting for UIC. It has apparently never been published except as a PowerPoint slide show. The reader can only wonder about the many anomalies seen on Mercer's slides: How could the pharmaceutical industry face a cost increase of 8.8% as a result of REACH? (The total cost of REACH registration and testing, in all industries and all countries, is much less than 8.8% of the European revenues of a single pharmaceutical company, Sanofi-Aventis.) Why should 25% of the costs of substitution of chrome pigments in the iron and steel industry consist of litigation?

A newer Mercer study claims to describe the unacceptable cost impacts on the downstream industries that use chemicals. Again, extreme statistical claims are presented without documentation. If industry is able to innovate, as it has done in the past, it may be able to overcome new regulatory hurdles at a tiny fraction of the frightening costs projected by Mercer.

Impacts on SMEs have frequently been raised as an argument against strict health and environmental regulations. Lacking the financial and technical resources of larger firms, and using chemicals in smaller volumes, SMEs are said to face a proportionately greater burden from REACH.

While impacts on SMEs should not be ignored, there are two reasons why their importance is frequently overstated. First, as discussed earlier, many SMEs are subcontractors to larger firms. The fortunes of subcontractors depend on the larger businesses that they work for, not just on their own, more limited resources. The ability of a subcontractor to respond to new technical requirements, and to absorb and pass on regulatory costs, has more to do with the size of the dominant firm than with the subcontractor.

Second, some enterprises with less than 250 employees are affiliates of larger foreign corporations. These do not meet the full, formal definition of SMEs, which requires not only employment of less than 250, but also the absence of links to larger firms. However, informal discussion of SMEs is often based only on employment; this approach counts MGM, Warner Music-France, BASF Agro, SmithKline Beecham Sante et Hygiene, and other subsidiaries of major foreign firms as SMEs in France. "Small and medium subsidiaries," of course, do not have the problems, needs, or limitations as genuine SMEs.

Despite these qualifications, there are independent SMEs that are neither subcontractors nor subsidiaries of foreign firms. Some of them may even need assistance in coping with regulations such as REACH. However, there are fewer of them than is commonly believed -- which implies that the cost of helping them will be moderate as well.

At the same time, REACH is also a benefit to SMEs among downstream users, the industries that use chemicals: it provides assurance that the chemicals they use are safe, eliminating potential hazards and liabilities that they might otherwise face. Workers, consumers, and downstream users need protection from the very real chemical hazards that are most often produced by very large companies.

Risk-based prioritization is now said to be needed to improve the "workability" and affordability of REACH. This proposal, from industry groups and conservative politicians, sounds at first like a sensible, objective way to improve regulation. But on closer examination, it turns out to be neither necessary nor feasible; it would be a distraction from the agenda of protecting the health of workers and consumers.

The argument for setting new risk-based priorities begins with the notion that it is essential to reduce the costs of registration and testing under REACH. But as we have seen, the costs are in fact quite modest; only a few unpersuasive, industry-sponsored studies have found huge costs. On the more reasonable cost estimates produced by all other studies, there is no great urgency about additional cost reduction; rather there is a danger that complicated new formulas and bureaucratic procedures could confuse and disrupt the generally well designed REACH process.

Moreover, the enormous amount of information required for risk assessments is not available, and cannot be collected at reasonable cost. Risk assessments examine not only the inherent hazard of chemicals, but also the likely exposure of people to those chemicals. This requires extremely complex, expensive additional studies. In practice, the advocates of new risk-based priorities propose to use simple approximations of risk, based on much less -- not more -- information than REACH would collect. These approximations do not accurately reflect the state of knowledge about chemical hazards and risk. Ad hoc estimation of risk, based on limited information, is not a scientific advance over REACH, no matter how grand a theoretical preamble is attached to the idea.

Finally, risk assessments are based on numerous assumptions about exposures, human behavior, chemical effects, and other factors; different analysts will make different assumptions and obtain different results. In contrast, volume- and hazard-based prioritization of testing and registration is a far more transparent and straightforward option. Risk assessment asks the wrong question. Once a substance has been identified as potentially harmful, the more important question is, how hard is it to replace it with safer alternatives? It is the substitution of safer alternatives, not lengthy risk assessments, which should be encouraged in order to protect the health of workers and consumers who are exposed to chemical hazards.

I. The Chemical Industry in Context: Economics and Health

I. A. Economic Background

France has one of the five largest economies in the world; within Europe it is second only to Germany. The gross domestic product (GDP) of 1,648 billion euros, as of 2004, amounts to €26,500 per person.[1] Over the ten years from 1994 to 2004, GDP per capita, corrected for inflation, grew by 1.8% per year. French workers are remarkably productive, with output per hour of labor higher than in the US, Japan, and all EU nations except Belgium and Luxembourg.[2] Thus it is not surprising that French citizens enjoy a high standard of living and extensive social benefits.

Over the long run, French economic performance has been similar to that of other leading industrial economies: rapid growth in the decades following World War II, giving way to restructuring and then slower growth from the 1980s onward. Numerous statistics confirm that France has done as well as other industrial nations by many economic measures. For example, since the mid 1980s French investment in manufacturing, as a percentage of GDP, has been about as high as in any large industrial country except Japan.[3]

Restructuring in the 1980s quickly led to success in foreign trade; French exports have exceeded imports every year since 1992.[4] A comparative study of the French economy comments on foreign trade, "Overall, the behavior of France in this area was not and is not very different from that of other European countries."[5] Despite high wages, social benefits, and environmental regulations, France has enjoyed a long-term trade surplus in manufacturing as a whole -- including surpluses both in the chemical industry itself, and in major chemical using sectors such as the automobile industry.

Within this context of long-run success, there are of course serious problems facing the French economy. Unemployment remains stubbornly high, threatening to exclude youth, immigrants, and minorities from the mainstream of society. The aging of the population leads to rising costs for pensions and medical care, resulting in growing demands on government budgets. These problems are not unique to France, but are shared to varying degrees by many high-income countries.[6] Solutions to these problems are beyond the scope of this report.

However, the problems of the French economy are not caused by any lack of competitiveness in the leading sectors of industry, which remain successful in a highly competitive global economy. In particular, health and environmental regulation has not crippled industry -- and it is not about to do so, even with the adoption of measures such as REACH. Rather, health and environmental regulation is protecting workers and consumers from the manifold harms caused by dangerous chemicals. The production of hazardous chemicals is not essential to prosperity; the safer alternatives described in Section 2 of this report will not bankrupt or impoverish French industry.

Fears about economic impacts of regulation are common but groundless; research shows that the costs of environmental protection are quite often overestimated in advance. One American study found that compliance costs for environmental regulation were overestimated in advance in 11 out of 12 cases. Another study found that advance cost estimates for environmental compliance turned out to be more than 25% too high in 14 out of 28 cases, while they were more than 25% too low in only 3 of the 28 cases.[7] An international review of the costs of controlling chlorinated substances, for Environment Canada, confirmed that overestimation of regulatory costs is more common than underestimation.[8] The same pattern shows up in advance predictions of the costs of major European regulations.[9]

There are several reasons for this repeatedly lighter-than-expected burden. Costs of safer alternatives often come down, as industry gains experience with them and produces them on a larger scale; these cost reductions are not usually anticipated in advance. Regulations sometimes spur innovation, leading to the development and adoption of better, lower-cost technologies. And inflated predictions of costs may at times be a bargaining tactic for industry in arguing against environmental protection.

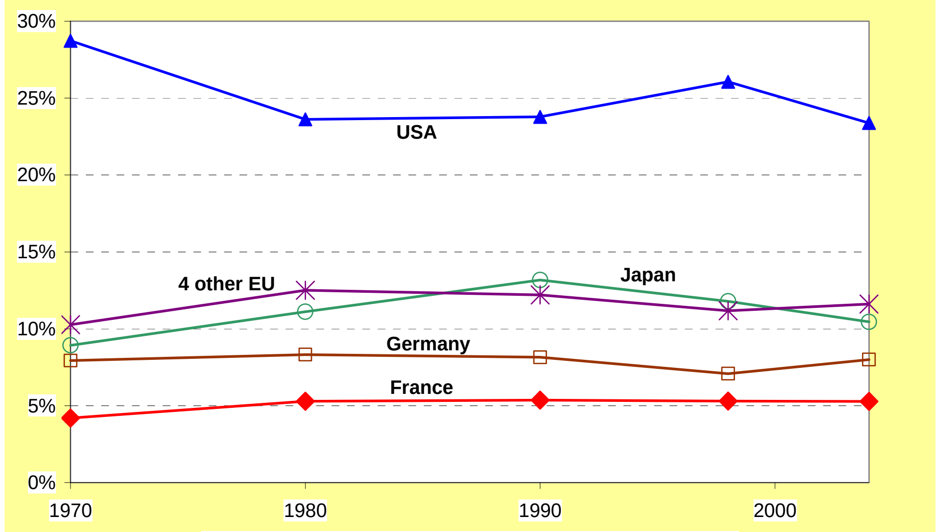
REACH, the ambitious new EU chemicals policy, calling for manufacturers and importers to register and test chemicals on a large scale, will impose costs on the EU as a whole of €2 billion - €4 billion.[10] Spread throughout the European economy over an 11 year period, these costs will raise the average price of chemicals by no more than .0006, or 1/16 of 1%. Predictions of enormous harm that might result from REACH, circulated by some business groups, are based on pyramids of mistakes and misrepresentations -- as we explain in Section 3 below. The more realistic predictions from government and academic sources, of prices increasing by only small fractions of 1%, make it clear that REACH will not harm the competitive position of European industry.

Recent experience in international trade also shows that environmental protection does not harm industry or undermine competitiveness.[11] In recent years, the world's leading exporter has been Germany.[12] With an economy roughly one fourth the size of the US, Germany exports more than the US -- or Japan, China, or any other nation. Germany is well-known for its strict environmental regulations, and has wages, labor standards, and per capita GDP broadly comparable to France. If European wages and regulations made a country uncompetitive, as pessimistic observers sometimes suggest, then neither Germany nor France would be thriving in world markets. Yet in fact, both countries are very successful exporters. Germany's greater success shows that France has not reached any absolute upper limit on exports: despite its high wages and environmental standards, Germany exports almost 40% more per person than France does.[13]

I. B. Portrait of the Chemicals Industry

The chemical industry had worldwide sales of €1.8 trillion ($2.2 trillion), more than 5% of world GDP, in 2004.[14] Growth has been rapid in recent years, and projections through 2020 suggest that sales of chemicals will continue to grow slightly faster than world GDP.[15] As a technologically advanced sector requiring large-scale investments, the chemical industry has long been dominated by industrial countries. Despite growing production in some developing countries, the majority of global chemicals production occurs in the EU, US, and Japan; these countries, especially the EU, routinely have trade surpluses in chemicals with the rest of the world.[16]

Figure 1. Shares of world chemical industry output, 1970-2004



note: 4 other EU = sum of Belgium, Italy, Netherlands, and UK

Indeed, the leading industrial countries have had remarkably stable shares of the world market for decades, as shown in Figure 1. France produced 5.3% of the world's chemicals in both 1980 and 2004. The US, Japan, and the six European nations included in Figure 1 together produced 61% of all chemicals in 1980, and 59% in 2004. The principal changes since 1980 have occurred in the remainder of the market: the sharp decline in the market share of Russia and Eastern Europe was almost exactly matched by the rise of China, Korea, Taiwan, and other new producers.[17]

The market for basic chemicals is mature and slow to change. Of the 50 highest volume chemicals in 1977, 46 were still on the top 50 list in 1993, often in the same order.[18] Chemical substances reaching a volume of more than one million tonnes accounted for an estimated 1.3% of all substances in use in the EU in the late 1990s, but more than 75% of the volume of chemicals. Those exceeding 10,000 tonnes accounted for 11% of substances, but 99% of chemicals by volume.[19] (More complex, specialty products frequently have higher prices than basic chemicals; therefore basic chemicals account for a much smaller fraction of sales revenue than of physical volume.)

As basic chemicals have become standardized bulk commodities, and production has started to shift to developing countries, the European industry has moved into more specialized and complex chemical products. Pharmaceuticals are now the fastest-growing branch of the chemical industry in France and in many other countries. In 2004, pharmaceuticals accounted for 41% of the sales revenue (turnover) of the French chemical industry; other specialty chemicals such as perfumes and cosmetics, paints, soaps and cleaning products, and agricultural chemicals accounted for 31%; and basic chemicals and plastics made up the remaining 28%.[20]

The chemical industry is technologically dynamic; while sales have increased, productivity per worker has increased even faster. This means that the industry has been able to produce a growing output with a shrinking labor force. Although pharmaceuticals, the fastest-growing sector, has had modest growth in employment, it has not been enough to make up for the contraction of the labor force in other parts of the industry. Total employment in the French chemical industry decreased from 266,000 in 1990 to 237,000 in 2004 -- losing, on average, about 2000 jobs, or 0.8% of industry employment, each year.[21] This problem is not confined to France; in fact, the decrease in chemical industry employment has proceeded even more rapidly in the US, Japan, and the EU as a whole. The loss of jobs has also been more rapid in French manufacturing as a whole, which has suffered an average annual decline of 1.4% in employment since 1990.[22]

While employment in the chemical industry has been gradually declining, it has also been shifting toward higher skilled occupations, as shown in Table 1. Therefore, there has been a rapid decline in the jobs for workers without technical training. Some of the decline in chemicals employment may reflect increased use of subcontractors by major companies. Commenting on the decrease in employment, the web site of Union des Industries Chimique (UIC), the industry trade organization, says, "this drop is not as significant as it seems. One must take into account the increase of externalisation and subcontracting, which resulted in staff moving to what economists call spinoff jobs. There are many such jobs in professions such as cleaning, transport, computer science and telecommunications."

Table 1. Chemical industry employment by level of qualifications

	1985	***2002***
Unskilled workers	64%	43%
Supervisors and technicians	25%	36%
Engineers and executives	11%	21%
Total, all employees	100%	100%
	This	

Source: UIC web site

This trend has occurred not just in chemicals, but throughout the economy. The restructuring and privatization of French industry in the 1980s led major companies to concentrate more narrowly on their core businesses, while subcontracting more work to smaller firms. For France as a whole, the percentage of small and medium sized enterprises (SMEs) that were subcontractors to larger businesses increased from 37% in 1980 to 59% in 1990.[23] Although similar figures are not available for the chemical industry, it is likely that the SMEs in the industry include many subcontractors.

According to UIC, there are some 2600 firms in the chemical industry. Most of the companies are small, but most of the employment is in the bigger firms.As Table 2 shows, companies with less than 100 workers account for 85% of enterprises, but only 18% of employment in the industry. At the other extreme, the 3% of companies that have 500 or more workers account for 52% of all employment. Commenting on the abundance of companies with less than 500 employees, the UIC web site says, "such businesses include a significant amount of French chemical groups affiliates as well as foreign ones - American, German, English, Dutch, Scandinavian, Italian."

Table 2. Chemical industry enterprises by size

Employees per enterprise	Number of enterprises	Percent of enterprises	Percent of employees
< 20	1463	56.3	4.0
20 – 99	740	28.4	14.3
100 – 499	315	12.3	29.7
500 - 1999	68	2.6	26.2
> 2000	14	0.4	25.8

Source: UIC web site

Ownership of chemical companies is constantly shifting, as the industry engages in a continual process of mergers, acquisitions, and spinoffs. From 1986 to 1995 there were 188 chemical industry mergers and acquisitions in which both companies were French, as well as 185 transactions in which a French chemical company acquired a subsidiary in another EU country, and 151 cases in which other EU chemical companies acquired French subsidiaries. In addition, there were numerous acquisitions of chemical companies in the EU by outside, primarily North American and Japanese, firms.[24]

Table 3 lists some of the largest chemical companies as of 2003. The top three chemical companies, Air Liquide, Rhodia, and Atofina, were among the 50 largest chemical companies (excluding pharmaceuticals) in the world in 2004, according to an industry trade magazine.[25] EMC, still a major chemical company as of 2003, was a state-owned mining and chemical enterprise which is selling its remaining assets and ceasing operation as of 2005. Other basic and specialty chemical companies shown in Table 3 include several subsidiaries of leading American, German, and Belgian firms. The list of pharmaceutical companies is dominated by Aventis and its joint ventures with other firms, and again includes affiliates of leading international companies.

Table 3. Top Chemical Companies, 2003

(with 2003 sales in millions of euros)

Basic and Specialty Chemicals		Pharmaceuticals	
Air Liquide	8393	Aventis	17815
Rhodia	5453	Sanofi-Aventis	8048
Atofina	5397	OCP	6778
EMC	2433	Alliance Sante	4964
Bayer Cropscience	2095	Aventis Pharma	3381
BASF en France	1776	Glaxosmithkline	2942
Exxonmobil Chemical	1665	CERP-Rouen	2897
Procter & Gamble-France	1630	Sanofi Winthrop Industrie	2877
Groupe Roullier	1009	Servier	2200
Henkel-France	851	Aventis Pasteur	2114
Colgate-Palmolive	830	Bristol-Myers Squibb	1440
Groupe SNPE	784	Pierre Fabre	1426
3M-France	751	Lilly-France	1422
Carbone Lorraine	629	Astrazeneca-France	1301
DuPont-France	611	CERP-Rhin-Rhone-Mediterranee	1295
Dow-France	608	Pfizer	1244
Agfa-Gevaert	521	CERP-Lorraine	1234

Source: L'Expansion (www.lexpansion.com). Sales figures for French companies may include worldwide revenues.

The following brief descriptions of some of the leading companies are based on the companies' own web sites.

Air Liquide, founded in 1902, describes itself as "the world leader in industrial and medical gases and related services."[26] Its core industrial business is to supply oxygen, hydrogen, nitrogen, and other basic chemicals to industries such as steel, oil refining, electronics, and other chemical companies. In medicine, it provides oxygen therapy, aerosol treatments, and related services both to hospitals and to large numbers of home health-care patients. It now has 130 subsidiaries in 70 countries worldwide, and has diversified into related activities including the provision of gases for welding, engineering and construction, the European space program, and professional and recreational diving. Worldwide employment rose to 35,900 in 2004, 30% in France and 32% in other European countries.

Rhodia is a manufacturer with eight business groups providing a diverse range of highly specialized chemical products: paints and coatings, surfactants and lubricants, silicones and other automotive and optical chemicals, acetate for cigarette filters, polyamides and other high-strength engineering plastics, and a number of specialized organic and pharmaceutical intermediates. It also collects and reprocesses used sulfuric acid. The company has 20,600 employees at 95 locations around the world; 12,400 of the employees are in Europe, including 7600 in France. Rhodia was spun off in 1998 from the chemical company Rhône-Poulenc, which then merged with the German company Hoechst to form Aventis. A contentious debate erupted in 2005 about whether Rhodia was saddled with an unfair share of the parent company's pension costs and environmental liabilities in the 1998 spinoff, contributing to Rhodia's substantial recent losses.

Atofina, formerly the chemicals division of the oil company Total, became an independent company and changed its name to **Arkema** as of October 2004. It was originally formed by the earlier merger of the chemical operations of the oil companies ELF, Total, and Fina. Arkema has three divisions, producing PVC and vinyl products, industrial chemicals such as acrylics and fluorochemicals, and high-performance polymers and other specialty chemicals. Arkema has 90 production facilities around the world, 60 of which are in Europe and 35 in France; four of its six research facilities are also located in France. It has 18,600 employees, 61% in France, 16% elsewhere in Europe, and 24% in the rest of the world.

Other major companies are active in a range of markets. **Bayer Cropscience** and **Roullier** produce agricultural chemicals. **SNPE**, formerly a military company, still specializes in explosives, and also includes **Isochem**, a specialty chemicals producer.

Among pharmaceutical firms, there are many mergers and joint ventures, so that descriptions of the leading companies quickly become out of date. However, **Aventis** is clearly number one. Since 2004 it has been merged into the **Sanofi-Aventis** group, now the largest pharmaceutical company in Europe and the third-largest in the world. While it operates worldwide, with a strong presence in the United States, most of the group's manufacturing and research facilities are in Europe. Of the nearly 100,000 employees worldwide, one third are sales representatives. More than half of the total workforce, 54,600 employees, are in Europe, of whom 27,700 are in France.

I. C. The Burden of Toxic Chemicals: Hazards to Workers and Consumers

The French chemical industry is clearly succeeding in producing, exporting, and expanding in a competitive global market. Unfortunately, this success in the marketplace has been accompanied by continuing hazards to the health of workers and consumers. Chemicals made and used in industry are literally killing people, even though safer alternatives are available. Although health standards have improved over time, and the number of dangerous jobs is declining, much more needs to be done to protect the health and safety of people who make and use chemicals in France.

The deadly risks of chemical production were suddenly front-page news in 2001. On September 21 of that year, a huge explosion tore through the AZF (Azote de France) fertilizer factory in Toulouse, leaving 30 people dead (22 of them workers or subcontractors at the plant) and nearly 2500 injured. At least 300 tons of ammonium nitrate, a highly explosive fertilizer, was being stored on the site at the time of the explosion. The blast created a crater 50 m in diameter and 10 m deep. In addition, more than 11,000 houses and apartment buildings were damaged, with glass being broken at a distance of 7 km from the site. The site belongs to Grande Paroisse, an Atofina subsidiary that was France's largest fertilizer manufacturer. Total, Atofina's parent company, ended up paying compensation to 90,000 people, for a total of €1.9 billion.[27]

The Toulouse explosion was the worst, but not the only, serious accident in the chemical industry in recent years. The Bureau d'Analyse des Risques et Pollutions Industrielles (BARPI) has analyzed all of the industrial accidents recorded in France from 1992 through 2004.[28] Throughout that period there were one to three fatal accidents in the chemical industry each year, accounting for a total of 73 deaths. Although 2001 was the industry's worst year, there were also 10 deaths in the industry in 2003, including four in the explosion at the Billy-Berclau explosives factory, and 14 deaths in 2004.

Examining all occupational accidents, fatal and nonfatal, from 1992 through 2004, BARPI found that 8% occurred in the chemical industry. Chemical products were involved in 17% of all accidents, including many outside the chemical industry. BARPI included a special focus on "the sometimes underestimated dangers" of chlorine production and use, highlighting the 199 "accidents or incidents" that occurred at facilities using large quantities of chlorine.

Accidents involving release of hazardous chemicals unfortunately continue to occur. On August 7, 2005, the Total refinery at La Mede released 10 tons of hydrocarbons into the air, resulting in a fine black rain at Sausset-les-Pins, 7 km from the refinery, and material damage to 700 houses. Total blamed the event on human error, and sanctioned four employees; local government officials and union representatives maintained that Total had failed to comply with relevant environmental regulations.[29]

Less visible than accidents and explosions, but much more deadly in the long run, are the occupational and environmental illnesses caused by exposure to dangerous chemicals. A study of childhood leukemia in Lille, Lyon, Nancy, and Paris found a significant positive relationship between the disease and home and garden insecticide use.[30] A study of French farmers found that deaths from bladder cancer were linked to exposure to pesticides in vineyards.[31]

The most widely studied problems caused by chemicals are cancers attributable to workplace hazards. A long-term research project has been started to investigate the unusually high rate of cancer in Seine Saint-Denis, a working-class suburb of Paris. In the project's first year, researchers interviewed 175 cancer patients newly admitted to the hospitals in the department in 2002-03. They obtained employment histories for 107 men and 20 women, and found that 74% of the men and 70% of the women had been exposed to at least one known carcinogen at work; half had been exposed to three or more carcinogens. Construction was by far the most common industry for the men, followed by public administration and metal fabrication; most held blue-collar jobs. The women most often had worked in retail trade, health care, and education, usually as service employees (such as secretaries or cleaning workers).

Among those whose work histories were known, exposure to asbestos was twice as common as any other carcinogen; it was followed by polycyclic aromatic hydrocarbons, crystalline silica, benzene, welding fumes, chlorinated solvents, lead, and other, less common substances. Under the official system for compensation for occupational disease, the researchers believed that 26 of the patients would qualify, and 21 of them actually received compensation. All 21 were men; 20 of them had been exposed to asbestos, usually in combination with several other carcinogens.[32]

Another study, by Ellen Imbernon of the Institut de Veille Sanitaire, estimates the incidence of several types of occupational cancer within the male population of France as a whole.[33] Using both French and international studies of the fraction of certain cancers that are attributable to occupational causes, the study develops estimates of the number of occupational cancers among men in France in 1999. The study includes only those cancers attributable to workplace exposure to recognized carcinogens (classified in group 1 by the International Agency for Research on Cancer). Sufficient data were available only for lung cancer, mesothelioma, bladder cancer, sinonasal cancers, and leukemia. The results are shown in Table 4: the likely range is from almost 4000 to almost 8000 cancers per year. The higher and lower estimates reflect the differing estimates found in the scientific literature for the proportion of each cancer caused by occupational hazards.

Table 4. Estimated incidence of cancers attributable to occupational factors within the male population of France, 1999

		Estimates of Incidence in 1999		Cases Compensated
Cancer	Occupational agents	Lower	Higher	In 1999
Mesothelioma	Asbestos	537	599	310
lung cancer	Asbestos	1871	3742	438
lung cancer	8 chemicals, ionizing radiation	562	1685	20
bladder cancer	aromatic amines, PAH, coal tar	625	1115	7
sinonasal cancers	wood dust, nickel, chromium	60	102	67
Leukemia	benzene, ionizing radiation	112	413	27
Subtotal	Asbestos	2408	4341	748
Subtotal	all others	1359	3315	121
TOTAL		**3767**	**7656**	**869**

Source: Ellen Imbernon, "Estimate of the number of cases of certain types of cancer that are attributable to occupational factors in France," Institut de Veille Sanitaire, 2005

Cancers attributable to asbestos account for more than half of the total identified in the study -- and a much larger fraction of the cases of these cancers that received government compensation for occupational illness. However, even in this study there are significant numbers of cancers attributable to other workplace hazards, including hundreds of lung cancers due to other chemical agents and/or radiation. The figures in the table are sure to be underestimates of the total number of work-related cancers, for several reasons: there are many cancers of occupational origin that are recognized by Social Security, but were not included in the study; there are other workplace hazards that are proven to cause cancer, but are not recognized by Social Security; and the estimates in Table 4 refer only to men, not women. Considering all these factors, CGT has estimated that the number of avoidable cancers of occupational origin is greater than 20,000 per year.[34]

The tragic experience with asbestos, which was used for decades after its toxicity was well established, is now the major source of occupational cancers, and will be for some time to come. It is also becoming a major financial burden for the industries that used it. In 2002, the social affairs chamber of the Cour de cassation (France's highest civil and criminal court) established a strict standard of liability, declaring that companies had committed an "inexcusable error" in exposing their workers to asbestos, and that they could not have been unaware of the danger. Asbestos has been known to be toxic since the beginning of the 20th century; it was classified as carcinogenic by the social security system in 1946, prior to the period of very heavy use in the early postwar decades. Under the standard established by the court, which could apply to other hazardous products as well as asbestos, companies become responsible for ensuring the safety of their workers, and can be penalized severely if they gamble and lose on the safety of untested chemicals.[35] Thus employers as well as workers will benefit from a precautionary approach to chemical safety, as called for under REACH and other French and EU regulations.

II. Case Studies of Cleaner Alternatives

While the French chemical industry remains in a relatively strong economic position, hazardous chemicals are producing accidents and illnesses at an unacceptable rate. These dangers are unnecessary; better alternatives are available. Real opportunities exist for research, development, and production of chemicals that do not pose significant hazards for human health and the environment. The companies that succeed in developing and commercializing these chemicals will be the most successful competitors in an international market that is increasingly responsive to such concerns.

In this section, we begin by presenting the ideas of clean production (or pollution prevention) and green chemistry, which offer powerful models for modernizing and improving the chemicals industry. Closely related is the importance of public and worker participation and access to chemical information, as mandated by the Aarhus Convention.

We then explore four case studies of chemical products currently produced in France, which can be replaced by safer alternatives:

- PVC plastic and vinyl chloride; we include a brief look at phthalates, which are frequently used as plasticizers (softeners) in PVC products.
- Glycol ethers, a workplace hazard which has been partially regulated.
- Phosgene, a highly toxic intermediate used in a range of industries.
- Selected pesticides that are produced and used in France.

In each case, adoption of the alternatives will allow the French chemicals industry to stay ahead of the curve and maintain its competitiveness in a market with increasingly high environmental standards. And there is no reason to think that these are the only four examples of that encouraging trend.

II. A. Alternative frameworks: cleaner production and green chemistry

It has become common, in discussions of environmental protection, to emphasize the virtues of cleaner production, or pollution prevention. Traditional "end of pipe" pollution controls have played, and continue to play, an important role in protecting society from the worst environmental hazards. But in many cases, it is more effective to reorganize production so that pollution is not created in the first place, rather than cleaning it up after the fact. Cleaner production has frequently been found to save money for companies, for example by reducing the need for raw materials purchases (because chemicals are being recovered and reused, or are simply being used in smaller quantities).

A wealth of case studies have been generated on successful industry efforts to implement cleaner production options; United Nations agencies, among others, have collected such studies. Cleaner production case studies are available for chemicals production itself, as well as for important chemical-using industries such as electrical machinery, textiles, printing, paper production, leather tanning, metals finishing, and more.[36] A number of cleaner production efforts at chemical manufacturing facilities within France were showcased in case studies from the 1990s, as collected by the United Nations

Environment Program (UNEP). Several of UNEP's French case studies involve successes in recycling and purification of waste water, and recovery of metals and organic chemicals that were formerly released in wastewater from chemical plants.[37] Other case studies are available from other industries and countries around the world.

Many cleaner production efforts have focused on reducing use of toxic organic solvents. Efforts to reduce or eliminate use of trichloroethylene (TCE), for example, have led to important innovations. TCE is frequently used to clean metal parts. Many industries have found that they can replace TCE satisfactorily for this purpose with detergent-and-water solutions, or with water-based enzyme solutions. Some companies have even found that they can eliminate the need for any cleaning of metal parts by keeping the metal parts clean and free of grease throughout the production process (see box on Exact Springs).

Exact Springs: A Case Study in Creative Solutions[38]

The Exact Springs company in Sweden manufactures metal springs for use in door locks, staplers, and electric switches. For many years, the company used a large number of chemicals, including greasing oils and solvents. In 1996, the management decided to reduce the company's environmental impact. The company hired an environmental consultant, who developed more than sixty proposals for production changes.

One goal was to find a way to clean the springs without TCE, a toxic chlorinated solvent that the company used to clean metal parts. After exploring a variety of alternative chemicals, the company took a step back and asked a broader question: Why do the springs need to be washed at all?

It turned out that most washing was unnecessary. Sometimes the springs were not really dirty; in other cases, the springs had become dirty or greasy unnecessarily, and could be kept clean through simple changes in the production process.

Within a year after coming to this realization, the company achieved a 90% reduction in its use of TCE. Today, the company does not wash any of its products, as all are kept clean throughout the production process. Through this and other creative solutions, Exact Springs reduced its environmental impact and improved working conditions for its employees. In addition, the company achieved financial benefits, saving more than US $13,000.

While there are many important and heartening stories about cleaner production in particular companies and industries, there was, until recently, little systematic theory about how to expand its benefits. "Green chemistry" is an attempt to develop such a theory; it is an approach in which chemical products and processes are designed from the outset to minimize the production and use of hazardous substances.[39] Green chemistry builds health and environmental considerations into decision-making both about what chemicals we produce, and about how we produce them. The goals are two-fold: to create better, safer chemical products, and to choose the safest, most efficient ways to synthesize those chemicals.

At the most general level, green chemistry calls upon scientists and industry to design safer chemicals and products. Green chemistry works from the premise that chemical products can be designed so that they are completely effective, and yet pose little or no hazard to human health or the environment. Some broad guidelines include preventing waste, using renewable feedstocks, using safer solvents and reaction conditions, and increasing energy efficiency.

Another guiding principle is that chemicals should be designed to break down into innocuous substances after use. Chemicals that are persistent in the environment, or that bioaccumulate in the bodies of animals and humans, generally share certain easily identified structural properties. Thus, it should be possible to predict in advance which types of chemicals are likely to be persistent and bioaccumulative, and to design chemicals that will not have these properties. In contrast, the current system of selling chemicals and dispersing them in the environment before testing for persistence or bioaccumulative properties is wasteful and inefficient.

Green chemistry also offers very specific guidance to chemists working to design new chemicals and/or develop alternative mechanisms for synthesizing chemicals that are already on the market. For example, it encourages the use of techniques that minimize waste in chemical synthesis. Chemists are encouraged to "maximize atom economy," designing syntheses that maximize the number of atoms from the starting materials that actually end up in the final product. Other important themes in green chemistry include minimizing waste by using catalytic reactions (catalysts are used in small amounts and can be used repeatedly, in contrast to stoichiometric reagents, which are used in large amounts and work only once); and carrying out reactions in safer solvents.

Green chemistry in practice: Alternatives to VOCs [40]

The green chemistry approach, although relatively new, has already yielded a range of economically important innovations. One important example is the search for alternatives to volatile organic compounds.

Organic solvents, some of them toxic, are used in a wide range of industries, including the production of pharmaceuticals, paints, inks, and aerosols. In some applications solvents can be recovered after use, but in the case of paints, inks, and aerosols, all the solvent is lost to the atmosphere, creating air pollution problems. Volatile organic compounds (VOCs) are frequently used as solvents because they evaporate easily. VOCs used as solvents in paints, for example, simply evaporate as the paint dries. Exposure to VOCs can cause a range of serious health problems.

Nearly half of VOC emissions come from production and application of surface coatings, including car finishes. Paints and other surface coatings used by consumers, as well as pesticides, are also important sources of VOC emissions. There are many solutions to the VOC problem; two of the most important involve water-based systems, and solvent free systems.

Many reactions that have been traditionally carried out using organic solvents can be redesigned to be carried out with water as the solvent. Unlike organic solvents, water is naturally occurring, inexpensive, and non-toxic, and has a high specific heat capacity, helping to control chemical reactions that release heat. For production of flavors and fragrances, carrying out reactions in a water solvent can eliminate the significant costs associated with removing VOCs after production. A particularly promising application for water-based solvents is in water-based coatings, such as paints.

Many production processes can be redesigned so that the need for a solvent is eliminated. Sometimes this is accomplished by using one of the reactants as a solvent itself. Many high-volume chemicals, including benzene, phenol, and polypropylene, are now produced in solvent-free processes or use reactants as solvents. Research is now underway on options for solvent-free production of more complicated fine chemicals.

Public and Worker Participation: Key Ingredients for Success

Successful achievement of cleaner production requires participation of the people who are often most directly affected by environmental hazards: workers and local communities. Workers are the “canaries in the coal mine” for the threats to human health posed by toxic chemicals: in many cases, disease and disability associated with a toxic exposure has appeared first in workers, and has only later become evident in the general population. Workers also have first-hand knowledge of the practicality of alternative production options and are often in the best position to make sound judgments about whether a given product or process will be workable in practice. Similarly, the communities that live near industrial facilities are often the strongest – and the most practical – advocates for change. When local communities depend on nearby industrial facilities for employment, there is all the more reason for them to be active participants in decision-making about the interplay between production decisions and over-all safety.

Under the Aarhus Convention on Access to Information, Public Participation in Decision-making, and Access to Justice in Environmental Matters, governments are committed to facilitating public access to environmental information, among other responsibilities.[41] French institutions involved in implementing this commitment include the Register of Pollutant Releases, which provides data on some 3,500 industrial plants.[42] Key information remains unavailable for some facilities, however. For example, as we discuss in the pesticides case study below, a recent fire involving stored pesticides exposed firefighters as well as local residents to a toxic mix of chemicals. The responsible facility still has not provided a full accounting of the chemicals to which people were exposed as a result of the fire.

Experience in the United States has shown that requiring firms to provide publicly accessible data on toxic emissions creates a powerful incentive for firms to reduce or eliminate toxic chemical use. The Toxics Release Inventory (TRI) has provided the data necessary for community and worker groups to become involved in pressing for adoption of safer alternatives in a range of industrial settings.[43] In the state of Massachusetts, the Toxics Use Reduction Act (TURA) provides an illustration of the substantial successes that can be achieved when government authorities work together with industry and workers to devise plans for reducing use of toxic substances.[44]

II. B. Case Study: PVC and Vinyl Chloride

Polyvinyl chloride, also known as PVC or vinyl, is one of the most widely used, and most hazardous, plastics. It creates health risks at every stage of its life cycle, from production through use to disposal. Although manufacturers have found it to be a versatile, low-cost material with numerous uses, there are less toxic alternatives available for everything made from PVC. Some alternatives cost no more than PVC products, or even slightly less; others cost slightly more. Like PVC, all of the alternatives create jobs for industrial workers -- but the alternatives create safer jobs, free of the health hazards of PVC production.

The hazards associated with PVC start at the beginning of its production process. It is the only common plastic that contains chlorine; in fact, it is more than half chlorine by weight. Production of chlorine often involves the use of large quantities of mercury, a toxic heavy metal. Chlorine in its pure form is a poisonous gas; when it reacts with organic chemicals, it can give rise to dioxin and other carcinogens. Chlorine is an essential ingredient of vinyl chloride monomer (VCM), the chemical "building block" that is used to make PVC -- and VCM is a known carcinogen. In the 1970s, PVC workers in the US and Italy were found to have high rates of cancer, probably due to their exposure to VCM. While emissions are now much lower than in the 1970s, new evidence has shown that VCM is harmful at surprisingly low levels.

In order to make PVC versatile, a wide range of other chemicals are added to it, some of which introduce health hazards of their own. Flexible PVC products such as medical equipment and children’s toys can leach toxic additives during their useful life. If they catch fire, vinyl building materials and other PVC products release hydrochloric acid fumes, and can create toxic chemical byproducts including dioxin. For this reason, Germany's Environmental Protection Agency (UBA) has called for a ban on the use of PVC in products that are susceptible to fire.[45] The same hazards arise when PVC waste products are incinerated. For all these reasons, many efforts are under way to replace PVC with other materials.

VCM and PVC Production

Both VCM and PVC are produced in many European countries; within Europe, France is second only to Germany in output. The country's massive output of VCM and PVC comes from just a handful of very large facilities. As of 2003, France had an annual capacity for VCM production of 1.3 million tons, or 4.1% of the world total of 31.5 million tons.[46] Atofina together with Vinylfos, a joint venture majority-owned by Atofina, accounted for about three quarters of French production; Atofina was the eighth largest VCM producer in the world. The remainder of French production came from Solvin, a joint venture majority-owned by Solvay, a Belgian chemical company (see Table 5).

In PVC production, France had an annual capacity (again as of 2003) of 1.4 million tons, or 4.4% of the world total of 31.9 million tons.[47] As shown in Table 6, Atofina and Vinylberre, a joint venture majority-owned by Atofina, accounted for most of France's PVC capacity, followed by Solvin and Societe Artesienne de Vinyle, a unit of the Belgian company Tessenderlo.

It is no accident that the numbers are so similar for VCM and PVC capacity, both for France and for the world. VCM has virtually no other uses besides the production of PVC; and production of PVC is impossible without VCM. Typically the two stages of production are fully integrated, frequently occurring at the same or nearby sites in order to minimize transportation costs and risks.

In the case of Atofina, however, the company's VCM and PVC production are located relatively far from each other. Most VCM production occurs near Marseille, at the Lavera and Fos plants. But most of the PVC production occurs near Lyon, at the St-Fons and Balan plants. Atofina ships VCM by barge to Lyon, and then through a 45 km pipeline connecting St-Fons and Balan.[48] In terms of public safety, the company argues that this is an improvement over the former arrangement, which involved trains full of VCM running through the heart of Lyon.

Still, the transport via barge and pipeline is far from being a safe solution. Barges carrying 2500 tons of VCM, a toxic, explosive chemical, travel up the river as often as three or four times a week. The VCM traffic on the Rhône puts communities such as Avignon, Valence, and Vienne at risk. The continual flow, with several barges always en route, means that Atofina is in effect storing a substantial inventory of VCM on the Rhône rather than at its factories. The main storage tank at St-Fons, one of the most dangerous facilities associated with the chemical industry in the Lyon area, holds "only" 4200 tons of VCM, less than two barges' worth. The 45 km pipeline between St-Fons and Balan holds 800 m^3, or 720 tons, of VCM; this, too, amounts to a form of permanent storage of dangerous chemicals, since the pipeline is never empty.

Table 5: VCM Production in France

Company	Location	Annual capacity 2003 (thousands of tonnes)
Atofina	Martigues/Lavéra	470
	Saint Auban	125
Solvin*	Tavaux	320
Vinylfos**	Fos sur Mer	375
Total		**1290**

* formed as a merger between Solvay (75%) and BASF (25%) in 1999

** owned 79% by Atofina and 21% by Solvin

Source: Chemical Economics Handbook, 2003.

The risks are even greater for the workers in the major VCM production facilities, Atofina Fos and Atofina Lavéra, and for the large numbers of people who live within a few kilometers of these plants. In both Europe and the US, high levels of persistent, bioaccumulative toxic byproducts have been found near VCM plants.[49]

Vinyl chloride (VCM) air emissions were recorded in ten locations in 2003, as shown in Table 7. The largest emissions come from Atofina facilities, particularly from two of its VCM plants. While no air emissions were recorded for the Solvin plant in Tavaux, a resolution was passed by the local government, restricting use of the water in the area for drinking due to contamination.[50]

Alternatives to PVC

More than half of the PVC consumed in Western Europe is used in building and construction. The largest uses are for siding, windows, and profiles (28% of the total, as of 2002), pipes and fittings (26%), film and sheet products (21%), wire and cable (7%), and flooring (5%). In each of these applications, practical, affordable, and safer alternatives to this toxic plastic are available. Often the same companies and workers could produce the alternatives; in some instances, the conversion away from PVC is as simple as increasing production of another plastic that is already produced by the same company. Arkema (Atofina) is not only the leading French producer of PVC; it is also a major producer of polyethylene, polypropylene, and many other plastics. In fact, Arkema advertises its Lotryl resins as ideal for the growing markets for "halogen-free"alternatives (chlorine is a member of the halogen family of chemical elements, so halogen-free means chlorine-free, and therefore PVC-free).[51]

Here we briefly discuss alternatives to the leading uses of PVC in construction, based on American and European sources, followed by a review of the problems created by phthalates, which are common additives in flexible PVC products.

Table 6: PVC Production in France

Company	Location	Annual capacity 2003 (thousands of tonnes)
Atofina	Balan	300
	Brignoud	40
	Saint Auban	125
	Saint Fons	205
Société Artésienne de Vinyle	Mazingarbe	260
Solvin*	Tavaux	295
Vinylberre**	Berre l'Etang	220
Total		**1445**

* Owned 75% by Solvay and 25% by BASF.

** Owned 65% by Atofina and 35% by Solvin. Acquired from Shell in 2000.

Source: Chemical Economics Handbook, 2003.

Siding and windows. Vinyl has become a popular material for low-cost buildings, thanks to its ease of installation and promise of "maintenance-free"exteriors. However, extensive experience with vinyl siding in North America suggests that it is not always entirely maintenance-free; under some circumstances vinyl can warp, develop mildew, and/or need repainting.

Alternative siding materials include wood, the classic and still the preferred material for high-end construction; and fiber cement, a relatively new product made primarily from cement, sand, and cellulose fibers. Fiber cement requires less maintenance (less frequent painting) than wood, although more than vinyl; and unlike vinyl, fiber cement does not warp or burn. The US magazine *Consumer Reports* surveyed both the initial cost and the expected lifetime of different siding materials; its data show that on an annualized cost basis, wood is cheaper than vinyl siding for high quality construction, while fiber cement is cheaper than vinyl for low-cost buildings.[52]

For windows, vinyl again promises maintenance-free exteriors, but its thermal properties are inferior to several alternatives. Windows can also be made from fiberglass, from aluminum, or from wood -- either all wood, or with a minimal cladding of vinyl. Among these alternatives, vinyl windows have the greatest coefficient of thermal expansion, so they experience the greatest expansion and shrinkage with temperature changes, creating a risk of breaking the seal (at which point the window has to be replaced).[53]

Pipes. Alternatives to PVC use in pipes include traditional pipe materials such as copper, iron, concrete, and vitrified clay, which remain important for large diameter pipes, and other plastic pipe materials. Plastic alternatives include acrylonitrile butadiene styrene (ABS), which is sometimes used for drain pipes, and polyethylene (PE), the most important plastic pipe material after PVC. PE offers important physical advantages over PVC, including greater strength under pressure and under low temperatures, and lower rates of leaks and breakage. Production of polyethylene is not pollution free, but is far less toxic than production of PVC. PE's share of the North American pipe market, although much smaller than PVC, has grown rapidly in recent years.[54] In France, a number of communities and water systems have installed PE pipe.[55]

Table 7: Vinyl Chloride Air Emissions

Company	Location	Air Emissions, 2003 (kg/year)
Atofina	Château-Arnoux/Saint-Auban	383,000
Atofina	Martigues/Lavéra	110,000
Renault	Douai	64,500
Vinylfos	Fos-sur-Mer	25,100
Atofina	Balan	24,900
Atofina	Saint-Fons	15,100
Artesienne De Vinyle	Bully-les-Mines	10,600
Atofina	Jarrie	7,200
Vinylberre	Berre-l'Étang	7,060

Source: Pollution emissions registry

(http://www.pollutionsindustrielles.ecologie.gouv.fr/IREP/index.php)

Wire and cable. According to a presentation on the Arkema web site, advertising the virtues of polyolefins (a chemical family including polyethylene and other non-chlorinated polymers) as PVC-free cable materials,

"PVC is still the main resin used in the cable industry. However, three main drawbacks have forced the development of alternative halogen free materials:

- Fire behavior of PVC... [in fires, PVC forms black smoke, and releases harmful chlorine derivatives]
- Environmental considerations...
- Limited temperature resistance... [PVC performs poorly above 110°C]

"... Polyolefins are good candidates for the substitution of PVC in cables." The presentation goes on to explain that halogen free, fire resistant polyolefin cable materials, available from Arkema, provide the benefits of good combustion properties, excellent dielectric properties, good physical properties, recyclability, and good performance/price balance.[56]

Flooring. Vinyl flooring is advertised as a uniquely affordable, durable, and easily maintained product. However, while vinyl generally minimizes initial costs of purchase and installation, it is not usually the longest lasting choice, nor is it always the cheapest or easiest to maintain. In high-traffic public spaces, higher maintenance costs can actually make it one of the most expensive flooring options on a life-cycle basis.[57] In addition, health concerns associated with use of vinyl flooring include possible adverse effect on respiratory health and during ordinary use, as well as toxic emissions in case of fire.[58] As Arkema says on its web site, "Materials for flooring application that are halogen free, flame retardant, low smoke and non-toxic are increasingly in demand, this is forcing the development of PVC compound alternatives."[59]

Alternatives to PVC flooring include the following. *Cork* flooring is of course renewable, and can be very long-lasting; some cork floors that were installed in the early 20th century are still in use. *Linoleum,* a traditional floor covering, is made from renewable materials including linseed oil, pine or other resin, ground cork dust, wood flour, mineral fillers, and pigments. *Stratica,*a relatively new, non-vinyl polymer floor covering, is manufactured by Amtico in both European and US plants, using a polymer that was originally developed by DuPont. Stratica provides a high-gloss, low-maintenance surface, and is made from a low-VOC, nonallergenic material.[60]

Phthalates

PVC is not naturally a flexible material. Therefore additives, called plasticizers, must be mixed into PVC in order to create flexible plastic products. Recently, health concerns have been mounting about one of the most popular types of plasticizers, the family of chemicals called phthalates. Of the approximately 1 million tonnes of phthalates that are produced annually in the EU, more than 90% are used as plasticizers in flexible PVC products.[61] Phthalates are also used in some cosmetic products, including perfumes. The best-known phthalate, diethylhexyl phthalate (DEHP), accounts for about half of all phthalate production, but there are many others in use as well.

Some specific phthalates, including DEHP and di-isononyl phthalate (DINP), have been identified as potential problems by several researchers. Harmful health effects seen in animal tests include: liver and kidney lesions: reproductive abnormalities, including testicular atrophy, altered development of reproductive tissues and subtle effects on sperm production, cell line transformations; and cancers, including those of the liver, kidney, and mononuclear cell leukemia. Recent research in humans has found a (negative) link between sperm quality and use of personal care products that contain phthalates.[62] A recent study showed a relationship between a mother's exposure to phthalates during pregnancy and changes in the ways that baby boys' genitals develop.[63] Although some phthalates appear to be biodegradable in the environment, this does not seem to be the case for long-chain phthalates such as DEHP.[64]

The European Union has banned the use of six phthalates, including DEHP, in childcare articles and toys.[65] Two phthalates, DEHP and dibutyl phthalate (DBP), are regulated under the EU cosmetics directive that came into force in 2004.[66] The use of DEHP in PVC medical supplies is currently being evaluated for possible regulatory action.

As with PVC itself, there are many safer alternatives to phthalates. Plasticizers that can be used in place of phthalates include adipates, benzoates, phosphate, alkyl sulphonates, trimellitates, and citrates.

II. C. Case Study: Glycol Ethers

Glycol ethers are a group of some thirty related chemicals that all have the useful property of being soluble in both water and oils.[67] They have been used since the 1930s, but their range of use expanded significantly in the 1960s and 1970s. More than half of glycol ether use is as a solvent in products such as paints (including car paints), inks (especially those used for screen printing), and cleaning fluids. Glycol ethers are also used in hydraulic and brake fluids, anti-icing agents, coatings for cans and wood products, anticorrosion coatings, adhesives, some cosmetics, manufacture of specialty chemicals including pharmaceuticals, and manufacture of electronic equipment and leather goods.[68]

Glycol ethers can pose a range of health hazards. In particular, a number of glycol ethers have been identified as toxic to reproduction. While some action has been taken to protect consumers from those glycol ethers that have been identified clearly as reproductive toxins, workers have not enjoyed the same level of protection. Furthermore, regulation has been far from precautionary: substantial evidence of harm accumulated before any action was taken, and both consumers and workers continue to be exposed to the less-studied members of the glycol ether family, for which health effects are largely unknown.

Glycol ethers are categorized in two broad groups: the E series, which are derivatives of ethylene glycol, and the P series, which are derivatives of propylene glycol.[69] Particular health concerns have been raised about the E-series glycol ethers, leading firms to make the transition from E-series to P-series for many -- but not all -- applications.

Health Effects

The available scientific data suggest that the E-series glycol ethers pose greater health hazards than P-series glycol ethers, particularly with regard to reproductive toxicity. To date, the EU has categorized seven E-series glycol ethers as category 2 reproductive toxins, meaning that there is evidence of reproductive toxicity in animals and toxicity is probable in humans. One other has been categorized as category 3, meaning that toxicity in humans is possible based on suggestive animal or other data. One P-series glycol ether and its acetate have also been classified as category 2 reproductive toxins, due to impurities.[70]

Until recently, use of glycol ethers in the semiconductor industry has been a major area of concern. From the 1970s until the mid-1990s, glycol ethers were widely used in semiconductor manufacturing, including at two IBM plants, one in the US (at Fishkill, NY) and one in Corbeil Essonnes. A 1996 lawsuit by former IBM employees in the US brought to light possible health effects of exposure to glycol ethers, including testicular cancers, leukemia, and malformations and neurological problems in children born to women exposed during pregnancy.

At the request of the plaintiff's lawyers, the French group Trace investigated the Corbeil Essones site.[71] At the Corbeil Essones plant, during the 20 year period 1974-1994, the investigation found 18 times more testicular cancer cases and 8 times more leukemia cases than the national average (11 cases compared to 0.6 expected for testicular cancer, and 5 cases compared to 0.6 expected for leukemia). Ten cases of birth defects or impaired neurological development were also observed.[72] IBM and other semiconductor companies have now voluntarily stopped using glycol ethers.[73]

Production and Consumption

Western Europe is the world's largest producer and consumer of P-series glycol ethers, accounting for 59% of all consumption (based on data for North America, Brazil, Japan, and Western Europe) in 2002. The US is the largest producer and consumer of E-series glycol ethers, accounting for 45% of the same market, while Western Europe accounted for 34%.[74]

The P-series market has grown significantly in the past decade. This growth has resulted both from expansion of the market for glycol ethers in general, and from an increasing tendency to replace E-series with P-series options in response to toxicity concerns. The growth of the glycol ethers market in general has resulted in large part from the increasing use of water-based coatings that use glycol ethers as coalescing agents (ingredients that evaporate more slowly than water and help bring molecules together in a continuous film after the water has evaporated).[75]

Glycol ethers are produced in a number of Western European countries, as shown in Table 8. Total capacity was 859,000 tons as of 2003. Germany was the largest producer, followed by the Netherlands. In France, glycol ethers are produced by BP Chemicals, based in Lavéra, with a capacity of 135,000 tons, or about 16% of total production in Western Europe. As of 2003, BP Chemicals produced both E-series and P-series glycol ethers. In general, glycol ether production capacity is flexible because the equipment used to make glycol ethers can also be used to make other chemicals (polyethylene and polypropylene glycols, polyether polyols, and ethanolamines).[76]

Table 8: Glycol Ether Production in Western Europe

Country and Producer	Annual capacity 2003 (thousands of tonnes)	Type of production, 2003	
		E-series	P-series
Belgium			
INEOS NV	80	X	X
France			
BP Chemicals	135	X	X
Germany			
BASF	125	X	X
Clariant	24	X	
Dow Deutschland	155		X
Sasol Olefins & Surfactants	70	X	
Italy			
Dow Italia	15	X	
Netherlands			
Lyondell Chemical Nederland	95		X
Shell Nederland Chemie	160	X	X
Total	**859**		

Source: Chemical Economics Handbook, July 2004

Regulation of Glycol Ethers: Insufficient Protection for Workers

Over the past decade, a number of glycol ethers have been classified with regard to reproductive toxicity, and regulations have been adopted accordingly to limit glycol ether exposure. Five EU directives[77] govern labeling of the nine glycol ethers that are classified as reproductive toxins; these directives are the basis for national regulations protecting consumers. The EU directives ban the sale of preparations containing 0.5 % or more of substances classified as category 1 or 2 reproductive toxins, carcinogens, or mutagens.

Four glycol ethers had been identified as category 2 reproductive toxins as of 1994, and products containing more than 0.5% of these substances were removed from the market. Five other glycol ethers received the same classification in 2004 and are now similarly regulated. In addition, France has banned four of the E-series glycol ethers that are category 2 reproductive toxins from use in cosmetics and drugs (which are not covered by the above regulations).[78]

A 2002 report by the Conseil Supérieur d'Hygiène Publique de France (CSHPF) concluded that current regulatory limits for glycol ethers classified as toxic to reproduction were still not sufficient to ensure adequate protection from dangerous exposures in the home environment.[79]

EU directives also require labeling of reproductive toxins when they are present at a minimum concentration of 0.5% (for categories 1 and 2) or 5% (for category 3) in products.[80]

Production of the four most toxic glycol ethers decreased in France from 4,000 tonnes in 1997 to 135 tonnes in 2003.[81] According to an industry source, as of early 2005, the nine glycol ethers classified as category 2 reproductive toxins were no longer produced in France.[82]

While some glycol ethers are banned from consumer products, they continue to be used in industry, where workers are exposed to considerably higher levels than those considered acceptable for consumers. While exposure limits have been recommended by the Ministry of Labor for six glycol ethers, these limits are not legally binding. [83]

A workers' protection rule[84] adopted in February 2001 put in place new controls on worker exposures to carcinogens, mutagens and reproductive toxins (CMRs). This regulation has been generally interpreted as requiring the substitution of CMRs Categories 1 and 2.

These steps provide only partial protection for workers. The Confédération Générale du Travail (CGT, the French labor federation) is calling for substitution of all carcinogens, mutagens, and reproductive toxins in industrial settings.[85] The categories assigned to carcinogens and reproductive toxins do not denote level of risk; they simply refer to the level of proof. Category 1 reproductive toxins are those for which ample scientific evidence of harm is available; categories 2 and 3 are not necessarily characterized by lower risk, but simply by lower levels of evidence. As stated by CGT:

> Category 3 CMR substances are carcinogens or reproductive toxins whose carcinogenic or reproductive toxic potential has been demonstrated in biological models. Waiting to prove their effect in humans is to conduct a large-scale experiment on humans in the industrial environment.[86]

CGT points out, further, that category 3 reproductive toxins are now clearly labeled as posing hazards to the reproductive system and to the developing fetus, including moved indications of "possible risk of changes in fertility" and "possible risk of adverse effects during pregnancy."[87] Thus, failure to protect workers from category 3 reproductive toxins is inexcusable.

Alternatives to Glycol Ethers

As evidence has accumulated on the reproductive and developmental toxicity of some E-series glycol ethers, firms have moved to replace these with other glycol ethers.

Increasingly, firms have switched from E-series to P-series compounds. Often this makes sense from an economic as well as an environmental perspective. For example, the P-series glycol ethers have been demonstrated to be cost-effective replacements for some E-series glycol ethers in coatings, cleaning products, and inks. Some cleaning products containing P-series glycol ethers are actually less expensive than equivalent products containing an E-series glycol ether, and some blends of P-series glycol ethers with alcohols outperform the E-series options as coupling agents in waterborne coating applications.[88]

P-series glycol ethers pose some health concerns of their own, but in general they are considered far safer than their E-series relatives. Thus, this switch to safer options within the broad category of glycol ethers represents a significant step in the right direction. The process, however, has been neither as swift nor as systematic as it should have been; over the years, workers have suffered massive exposures to untested chemicals. There is an urgent need to fill in the remaining blanks in the toxicological data on both E- and P-series glycol ethers. Precautionary measures must be taken to protect workers and consumers so long as safety testing has not been completed.

While substantial progress has been made in switching from E-series to the less toxic P-series glycol ethers, there are also interesting efforts under way to replace glycol ethers completely in some applications. For example, in the semiconductor industry, glycol ethers have traditionally been used to dissolve dyes and resins for the manufacture and removal of inks. Substitute solvents with similar characteristics but without the toxic effects of glycol ethers have been developed. For example, the DieMark Ink Remover 800 by Xandex is advertised as a glycol-ether-free product that can clean a variety of inks.[89]

The SUBSPRINT campaign (an acronym for Substitution of Organic Solvents in the Printing Industry) has demonstrated the practicality of using products based on vegetable oil in place of toxic organic solvents in printing.[90] Cleaning of offset printing machines is a significant contributor to volatile organic chemical (VOC) emissions in Europe. Alternatives based on vegetable oils were developed in Denmark in the late 1980s, and are now used in about 30% of Danish printing shops and some 5 to 10% of German printing shops.[91]

Many manufacturers of glycol ether-containing products also offer similar or equivalent products that are glycol ether-free.[92] For example, the multinational chemical company Lyondell produces both glycol ethers and their alternatives;[93] ADF Systems offers "solvent-free" cleaners[94] for multiple applications; and Church & Dwight offer sodium bicarbonate-based cleaners.[95] Thus, there is ample room for the producers of glycol ethers to carve out new market niches for themselves in provision of glycol ether alternatives.

II. D. Case Study: Phosgene

Phosgene (carbonyl chloride), a compound that does not occur in nature, was discovered in 1812 by John Davy, who created it by shining light on a mixture of chlorine and carbon monoxide.[96] An extremely poisonous and reactive gas, phosgene was used as a chemical warfare agent in World War I, and is widely recognized as one of the most acutely toxic substances used in commerce today.[97]

Currently phosgene is used as a chemical intermediate to produce isocyanates (which are used to produce polyurethane resins, pesticides, and other products), polycarbonates (a type of plastic), and a number of chlorinated organic chemicals. It is used in a range of industries, including production of pharmaceuticals, agrochemicals, and others.

Health Effects

Phosgene is a poisonous gas at ambient temperature (21°C). With cooling and pressure, it can be converted into a liquid so that it can be shipped and stored. When liquid phosgene is released, it turns into a gas heavier than air that stays close to the ground and spreads rapidly. As a gas, phosgene may seem colorless or appear as a white to pale yellow cloud. At low concentrations, phosgene has "a pleasant odor of newly mown hay or green corn" while at high concentrations, its smell may be strong and unpleasant.[98] Phosgene poses an insidious threat because it has toxic effects at concentrations lower than those producing an unpleasant smell. Thus, odor does not serve as an effective warning of the presence of hazardous levels of phosgene.[99]

Acute inhalation of phosgene can cause symptoms including choking, chest constriction, coughing, painful breathing, and bloody sputum (spitting up blood), and can result in pulmonary edema (fluid in the lungs), pulmonary emphysema, and even death. Exposure to phosgene can also cause severe eye irritation and skin burns.[100] Even at low doses, long-term exposure to phosgene can lead to chronic lung inflammation.[101]

Isocyanates, some of the major products made with phosgene, cause health hazards of their own. The Bhopal tragedy in India involved methyl isocyanate. Even under less disastrous circumstances, workers exposed to isocyanates may have symptoms such as eye irritation, congestion, dry or sore throat, cough, shortness of breath, wheezing, or chest tightness. Direct skin contact can also cause inflammation. Isocyanates have been reported as asthma sensitizers, causing more severe asthma attacks in people exposed to them repeatedly. Death from severe asthma in some sensitized subjects has been reported.[102]

Phosgene Production

The main companies making phosgene today are the producers of isocyanates and polycarbonates. In Western Europe, large companies producing isocyanates include BASF, Bayer, Dow and Huntsman, while large producers of polycarbonates include Bayer, Dow and General Electric Plastics. A number of smaller companies also make phosgene for use in production of specialty chemicals. Europe has the capacity to make about two million tonnes of phosgene per year, almost half of it in Germany, with the rest divided among Belgium, the Netherlands, Italy, France, Spain, and Portugal[103].

In France, as of 2003, Isochem produced phosgene at its Le Pont de Claix facility, while Orgamol made phosgene at Saint-Vulbas. SNPE, the parent company of Isochem, acquired the Le Pont de Claix plant from Rhodia in 2001. Among other markets, Isochem supplies phosgene to Bayer CropScience, which uses it to produce herbicides. Isochem formerly operated another phosgene plant at Toulouse, adjacent to Atofina's Grande Paroisse fertilizer plant which exploded in September 2001. After the explosion the government ordered the shutdown of the Toulouse phosgene plant, paying Isochem compensation for the loss of the facility. Isochem also has phosgene production facilities in China, Hungary, and the US.[104]

A large proportion of phosgene use is for the production of isocyanates, a family of highly reactive, low molecular weight chemicals. Isocyanates are widely used in the manufacture of flexible and rigid foams, fibers, coatings such as paints and varnishes, and elastomers. Their varied applications include the automobile industry, autobody repair, and building insulation materials. A wide range of retail, commercial, and industrial spray-on polyurethane products contain isocyanates and are used to protect cement, wood, fiberglass, steel and aluminum, etc.[105]

Alternatives to Phosgene

A promising area of research and development in green chemistry is in developing safer alternatives to processes that use very acutely toxic chemicals, such as phosgene. Since two of the main uses of phosgene are to make isocyanates and polycarbonates, researchers have put substantial effort into finding ways to make these two products by other means. A number of alternative chemical syntheses are available to make isocyanates.[106]

Some of these alternatives are already entering commercial application. Because of phosgene's extreme toxicity, corrosiveness, the costs and difficulties in ensuring its safe use and its somewhat inefficient performance, several major companies have actively sought to develop and adopt alternatives:[107]

- Monsanto has used a process to generate isocyanates and urethanes through the direct reaction of carbon dioxide with amines.
- Dupont has developed a catalytic process to produce isocyanates.
- Asahi Chemical (Japan) has reported using a molten state reaction to produce polycarbonates, eliminating both phosgene and methylene chloride, a known carcinogen. The polycarbonate produced through this process is reputedly of higher quality than its phosgene-produced counterpart.
- EniChem Synthesis (Italy) has developed a less toxic intermediate, dimethyl carbonate, which can substitute for phosgene and other dangerous chemicals such as methylene chloride, and can serve as a component of reformulated fuel.

Carbon dioxide (CO2) has been used as an alternative to phosgene in the synthesis of various compounds such as carbamates, organic carbonates and polymers. Abundant in nature, CO2 poses few health hazards; its use has the added advantage of carbon sequestration (i.e., removing greenhouse gases from the atmosphere).[108]

A new process was recently developed in China that eliminates the use of phosgene in the production of polyurethane. Compared with the traditional polyurethane process using phosgene, this new method is reportedly more environmentally friendly and reduces costs by approximately 20%.[109]

Even Isochem, while still producing phosgene, is also developing phosgene alternatives based on amino acids and hydrazine derivatives for the pharmaceutical, agrochemical, and specialty chemical industries. It is drawing on its parent company SNPE's years of experience in the production of alkyl hydrazines for space propulsion.[110]

In addition, there are options for reducing the toxicity of isocyanates, which are a major concern in their own right. Isocyanates can be engineered chemically for reduced toxicity, for example by increasing their molecular weight to decrease their vapor pressure. There are also techniques for generating isocyanates in situ, avoiding the safety problems posed by storing large amounts of these dangerous chemicals; DuPont, for example, synthesizes methyl isocyanate on demand in order to avoid storage and shipping requirements.[111]

Polycarbonates, which are traditionally synthesized using phosgene, can also be produced by alternative methods. General Electric, for example, commercially produces polycarbonates without phosgene.[112]

In view of the astonishing toxicity of phosgene, and even of products such as isocyanates made from phosgene, elimination of this deadly chemical should be a top priority. The extensive experimentation with alternatives shows that it is feasible; indeed, the world's largest chemical companies are actively developing the alternatives. The surprise is that France, and Europe, still tolerate the production of vast quantities of such a needless, poisonous substance.

II. E. Case Study: Pesticides

A leading agricultural nation, France is also a leading producer and user of agricultural chemicals, including pesticides and fertilizers. It is no accident that some of these are toxic; indeed, pesticides are toxic by design. They are intended to kill unwanted organisms – whether these are insects, plants, or fungi. Many pesticides are harmful to human health for the same reasons that they are harmful to pests. For example, the commonly used organophosphate and carbamate classes of insecticides work by inhibiting cholinesterase, a crucial enzyme for insects that is also crucial in the human nervous system. (Many pesticides are also harmful to humans through different mechanisms that do not apply in pests.)

Pesticides have been detected in air, water and food.[113] They pose hazards to agricultural workers, to industrial workers who produce them, to nearby communities that may be accidentally exposed, and to consumers who either use pesticides in their homes or are exposed to them through food or other sources. Pesticide exposures among children are a particular concern, because even small exposures during critical windows of developmental vulnerability can produce life-long consequences.[114]

Some pesticides have been withdrawn from the market in response to requirements established under the EU Agricultural Pesticides Directive adopted in 1991. However, many highly hazardous pesticides continue to be produced and used in Europe. Policy options for pesticide regulation include systematic analysis of safer alternatives, used in different ways in Sweden and in the Canadian province of Québec, and taxes on pesticides based on both quantity and toxicity, as seen in several Scandinavian countries. Alternatives to toxic pesticides include substitution of safer chemicals, the family of techniques referred to as "integrated pest management," improved crop rotation practices, and other behavioral changes.

Health and Environmental Effects of Pesticides

Human health effects of pesticides can include cancer, developmental effects, reproductive effects, endocrine disruption, immunotoxicity, neurotoxicity, and toxicity to various organ systems. Much of the literature on toxic effects of pesticides refers to pesticide active ingredients, but the so-called “inert” ingredients of pesticide formulations can also be hazardous. There are an estimated 1 million pesticide poisonings in the world each year.[115]

Use of pesticides can work against the goal of boosting and sustaining agricultural yields because many pesticides kill natural predators as well as target organisms. Pesticides often kill beneficial insects as well as pest species. Harmful algal blooms can result from pesticides in agricultural runoff. Pesticides can harm pollinators, earthworms, and other organisms that are vital to sustainable agriculture. Prolonged use of herbicides can damage soil quality and increase vulnerability to erosion.[116]

Pesticide Hazards: Not Just for Farmers[117]

In June 2005, a massive fire occurred at SBM Formulation, a pesticide manufacturing factory in Béziers[118]. Firefighters reported smoke rising 500 m above the plant, and smoke from the fire was detected in Toulouse, 100 km away. The fire involved at least three buildings, although the plant's recently updated emergency plans considered only the possibility of fire in a single building.

Some 2,000 pesticides were stored at the facility at the time of the fire. No information about these products was available to the firefighters who responded to the emergency. Because the plant is located near a residential area, many local residents were exposed as they slept in their homes. There was no official warning to serve as the basis for an evacuation; a school in the area even remained open that morning, potentially leading to acute exposures among children.

Two weeks after the fire, the company released a limited list of products at the facility, indicating volumes of pesticides by chemical family only, not by individual substances. In addition, a trade union provided a list of substances that BASF had ordered from the facility; this included a banned pesticide that was probably intended for export abroad. As of September 2005, the company still has not provided a full list of substances made or stored at the facility.

Pesticide production in France

Pesticide producers operating in France include Bayer Agro, BASF, Calliope, Cerexagri, Monsanto, Aventis, Dupont, Syngenta, Novartis, and Dow Agro.

As of 2002, the most recent year for which figures are available, France had the highest expenditures on agrochemicals (excluding fertilizers) in all of Europe. The value of the agrochemical market in France was nearly €1.9 billion in 2002; Germany and Italy were the next largest (see Table 9).

France exports more pesticides than it imports, as shown in Table 10**.** In the 1990s, critics of the World Bank noted that French companies were heavily involved in production of pesticides for export to developing countries. [119]

Regulation of pesticides in Europe

The European Union Agricultural Pesticides Directive of 1991 was adopted in an effort to harmonize and regulate registration, sale, and approval of pesticides across Europe. Under this Directive, the European Commission and member states are involved in an on-going project to review the safety of all pesticides currently on the market. As of July 2003, only 46 pesticides had been reviewed through this process. Nearly half of these were refused inclusion to Annex 1, the list of active ingredients considered acceptable.[120]

Under the Directive, either a company or a member state can sponsor a pesticide active ingredient. The sponsor must collect and provide data on the identity, physical and chemical properties, health effects, environmental fate and behavior, and other information for the pesticide. If the standards are not met, the pesticide must be withdrawn from the EU market. Some pesticides have been withdrawn by their manufacturers because their profitability is too low to justify the costs of demonstrating safety.[121]

However, many pesticides that raise serious health concerns have not yet been reviewed under the Agricultural Pesticides Directive, and remain on the market. A number of countries have adopted additional policies to address such pesticides. For example, regulation of pesticides in Sweden incorporates the "substitution principle" which aims to ensure that less hazardous products and processes are adopted in place of more toxic ones whenever possible.[122] Using the substitution principle, the regulating authority in Sweden has withdrawn or refused approval for a number of pesticides, based on the demonstrated availability of safer alternatives. Manufacturers have cooperated in many cases by withdrawing highly hazardous and/or poorly studied pesticides from the market voluntarily.

A similar philosophy motivates regulation in the Canadian province of Québec, where the Pesticide Management Code, adopted in 2004, effectively bans the sale of consumer products containing any of twenty active ingredients. The list was based on existing lists of recognized carcinogens and endocrine disruptors. For every active ingredient on this list, the province verified that at least one alternative product is available to fulfill the same purpose as the listed chemical, thus ensuring that no essential products are prohibited.[123]

Pesticide taxes are another effective option for reducing total pesticide use, adopted in Denmark, Norway, Sweden, and Finland. In Norway, under a system put in place in 1999, tax rates on pesticides are differentiated according to health and environmental classifications. The tax on a given pesticide is worked out through a formula that takes into account both area treated and the health and environmental profile of the chemical. Differentiation based on toxicity is important; a tax based solely on the quantity of chemicals used might encourage a shift toward more concentrated and more toxic chemicals. The Norwegian taxes apply to all categories of pesticide use, including non-commercial and home uses as well as agricultural and horticultural uses.[124]

Table 9. Agrochemical markets in Europe, 2002

	Value of sales (€1000)	Volume of active ingredients (tonnes)
Austria	76,786	2,694
Belgium	147,286	5,017
Denmark	80,961	2,719
Finland	58,000	1,633
France	1,869,000	82,456
Germany	1,133,000	26,635
Greece	168,900	11,852
Netherlands	263,480	8,073
Ireland	59,831	1,551
Italy	674,911	42,112
Norway	22,690	819
Portugal	113,878	25,754
Spain	636,109	40,727
Sweden	50,762	1,836
Switzerland	84,190	1,526
Turkey	158,005	27,834
UK	575,315	21,114

Source: European Crop Protection Association Statistical Review, 2002 (Excludes fertilizers)

Pesticides of Concern

Among the pesticides produced in France, more than a dozen are characterized by particular health concerns and/or have been severely restricted or banned in some countries. Table 11 shows selected active ingredients of high concern that are produced in France, along with a partial listing of countries in which each of these active ingredients are banned, restricted, or not registered for use.

Herbicide active ingredients of concern that continue to be produced in France include alachlor, diuron, glyphosate, isoproturon, and trifluraline.

Alachlor, produced by Bayer Agro, BASF, Calliope, Cerexagri, and Monsanto, is considered a likely carcinogen at high doses, a developmental toxicant, and a probable endocrine disruptor, and has been detected as a contaminant in groundwater.[125] It is either banned or not registered for use in a number of countries, including Australia, Austria, Canada, Denmark, Finland, Germany, the Netherlands, and the UK.

Table 10: Pesticides Trade Balance, 2001-2003

French exports minus imports (in US $1000)

	2001	2002	2003
Fungicides	(15,128)	(49,215)	(17,253)
Herbicides	206,564	271,488	344,694
Insecticides	135,144	118,871	129,491
Disinfectants	(26,791)	(27,102)	(25,216)
Total	299,791	314,042	431,716

Source: FAOStat database

Diuron, produced by Bayer France, Aventis Cropscience, Calliope, Cerexagri, Dow Agro, DuPont, and Monsanto, is classified as a known or likely carcinogen by the US Environmental Protection Agency and as posing hazards of reproductive or developmental toxicity (as listed in the US Toxics Releases Inventory). It is not registered for use in Sweden and Finland.

Insecticide active ingredients of concern include the organophosphates azinphos-methyl, fenitrotion, malathion, and phosmet and the bioaccumulative organochlorine endosulfan, as well as fipronil and imidacloprid.

Organophosphates vary significantly in their level of acute toxicity, but all exert toxic effects through a common mechanism, blocking the action of a key enzyme in the human nervous system. In addition, some organophosphates pose other health hazards as well. For example, malathion is a possible carcinogen, a potential ground water contaminant, and a suspected endocrine disruptor.[126] Malathion is included in the list of active ingredients effectively banned in Quebec.

Substantial concerns have been raised in the US regarding health effects suffered by workers exposed to azinphos-methyl and phosmet. The US Environmental Protection Agency has allowed the registration of azinphos-methyl to expire for many existing uses, granting provisional registration for continued use in only a small subset of applications.[127] Azinphos-methyl is banned in India, Indonesia, and Thailand, and is not registered for use in Denmark, Germany, the Netherlands, and the UK.[128] Phosmet, which is classified as having suggestive evidence of carcinogenicity[129], is not registered for use in Denmark, Finland, Germany, the Netherlands, the Philippines, the UK, and New Zealand, as well as in many African countries.

Endosulfan, an organochlorine insecticide, affects the central nervous system. Acute exposures can produce nausea, dizziness, headache, or convulsions, and, at high levels, can be fatal. Endosulfan can bioaccumulate; and laboratory tests suggest that long term exposure may also damage the kidneys, testes, liver, and immune system.[130] Endosulfan has been implicated in an epidemic of devastating birth defects, as well as other disorders, among populations exposed to it in agricultural runoff in India. It is banned in Germany, the Netherlands, Sweden, the UK, and the USA, as well as several countries in Latin America, Asia, and the Middle East. Its use is severely restricted in more than 20 other countries. Health and environmental advocates have suggested that endosulfan should be added to the list of persistent organic pollutants targeted for elimination world-wide under the Stockholm Convention.[131]

Table 11: Active Ingredients of Concern

	Banned or not registered for use in countries or regions including:
Herbicides	
Diuron	Angola, Finland, Sweden
Alachlor	Australia, Austria, Canada, Denmark, Finland, Germany, Netherlands, UK
Isoproturon	Australia, Canada, Denmark, Finland, Philippines, USA
Trifluraline	Denmark, Netherlands, Norway, Philippines, Sweden
Glyphosate	Finland, India
Insecticides	
Fipronil	Cameroon, Canada, Portugal, Germany, UK
Azinphos-methyl	Denmark, Germany, India, Indonesia, Netherlands, Thailand, UK
Fenitrotion	Germany, Netherlands, Portugal
Endosulfan	Belize, Denmark, Germany, Netherlands, Norway, Sri Lanka, Sweden
Imidacloprid	Restricted in France
Phosmet	Denmark, Finland, Germany, Philippines, Netherlands, New Zealand, UK
Malathion	Germany
Fungicides	
Pendimethaline	Uganda, Finland
Cyprodinil	Holland; also restricted in UK
Fenpropimorph	Australia, India, Netherlands, Philippines, USA
Chlorthalonil	Netherlands, Sweden

Sources: Greenpeace France, Pesticide Action Network. Country lists are not exhaustive.

Fipronil is classified as a possible carcinogen by the US Environmental Protection Agency.[132] Countries in which fipronil is not registered for use include Canada, Germany, Portugal, and the UK. The French government suspended authorization of many uses of this active ingredient in February 2004 due to its toxic effects on bees as well as uncertainties about its effects on human health.

In April 2005, two government agencies[133] issued a report on the human health risks of exposure to fipronil and determined that while the risks to adults were within the current safety limits, children's exposure could exceed those limits. The report also indicates that there remain large uncertainties with regards to this pesticide, particularly with regards to workers' exposure (both in the manufacture and application) and its impacts on thyroid function. [134]

Alternatives

Safer alternatives are available in every area in which hazardous pesticides are employed. In some cases, the alternative is to use a safer chemical for a similar purpose; for example, the worst organophosphate insecticides can often be replaced with less hazardous substances. In some cases, it is a matter of developing or adopting alternative products, such as chemicals that interfere with a specific life stage of a target insect, without affecting other organisms.

In other cases, the best alternative to using toxic pesticides is to convert to sustainable agricultural practices; in many instances, toxic pesticides can be replaced by mechanical pest controls, by integrated pest management (IPM) techniques, or by techniques such as crop rotation.

IPM is a methodology for minimizing pesticide use by increasing understanding of crops, pests, and the broader ecological system of which a crop forms a part. A key tool for IPM is regular monitoring of pest populations. When pest levels rise above an established threshold, steps are taken to control their populations. These steps may include use of predatory insects or other natural predators, and can include targeted use of pesticides where appropriate. Pesticide application is designed to use the least harmful and most species-specific materials, with applications only in the areas where pest populations are high.[135] IPM is effective in reducing pesticide use in urban settings as well as in agriculture.

Some plant species produce natural insect repellents. For example, extracts from the neem tree, native to India, are effective in deterring feeding and disrupting mating behavior in many insect species. Garlic extracts are also an effective replacement for organophosphate insecticides in some applications.[136]

Alternatives to azinphos methyl in fruit cultivation that have been applied in the US include use of Kaolin clay and pheromone disruption. Spraying fruit with kaolin clay, a naturally occurring, non-toxic material, repels insects without damaging the fruit.[137] Pheromone disruption, using dispensers known as “puffers,” controls major insect pests with little or no chemical use. Although initially more expensive than chemical controls, over time mating disruption became more cost effective than the conventional approach due to effects on secondary pests.[138]

Alternatives for France will draw on local knowledge and conditions, not necessarily transplanting foreign examples. For example, an IPM strategy for wheat farming in Picardy, developed by Alternatech IPM, includes the following recommendations:

- choose varieties resistant to disease and other problems;
- avoid risky preceding crops (wheat, maize);
- delay sowing date to 20 October; reduce sowing densities by 30%;
- follow the treatment thresholds used in IPM;
- fertilization should aim to maximize yield in alternate years and stagger inputs; and
- weeding should use conventional practices that prioritize anti-disease measures.[139]

III. REACH and beyond: risk, regulation, and chemical safety

Individual workers and consumers, acting on their own, cannot protect themselves against the chemical hazards created by modern industry. Protective regulation is essential; it is quite literally a matter of life and death. At present, a complicated patchwork of regulations provides only partial protection, leaving thousands of widely used chemicals untested and effectively unregulated. REACH, the European Union's proposed new chemicals policy, is designed to fill that gap. It calls for an 11 year process of registration and testing of all chemicals used in industry in volumes of one tonne per year or more, with testing requirements that become progressively stricter as volumes increase. Although debate continues about amendments, some form of REACH is likely to be adopted soon, and to go into effect in 2007.

Ever since REACH was formally proposed in 2001, it has been a subject of intense debate. While many European government agencies and environmental organizations have supported REACH, many industry groups, and foreign observers such as the US government, have opposed or sharply criticized it. The debate has raised fundamental issues about the impacts and philosophy of regulation, which will remain important even after the final votes are taken on REACH. Here we discuss three aspects of the debate, addressing three basic questions:

- How great is the economic burden of REACH?
- Would regulation such as REACH be unfair to small and medium enterprises (SMEs)?
- Would a new set of risk-based priorities lead to better regulation?

III. A. The costs of REACH: very large or very small?

Implementation of REACH will not be free; among other things, it requires thousands of laboratory tests. Will the costs of REACH crush European industry, or will they barely be noticed? Studies have come out on both sides of this question. Interestingly, almost no one has come out in the middle: researchers either believe that the cost is very large or very small. Industry sponsored studies have found large costs, while government and NGO studies have found small costs.

Under REACH, some 30,000 existing chemicals will be registered and tested; it is usually anticipated that a handful of those will be restricted or withdrawn from use, while almost all will be approved. New chemicals used in volumes of one tonne per year or more will be subject to the same tests; typically, a few hundred such chemicals are introduced in Europe each year. For these new chemicals, which are already subject to strict testing requirements, REACH will be somewhat less stringent than current regulations.

The disagreement about the costs of REACH is not primarily about the direct costs of registration and testing. Industry sponsored studies tend to use somewhat higher estimates for these costs, but usually only 2-3 times the figures used in other studies.[140] The latest estimates suggest an 11 year total cost, for the EU as a whole, of €2 billion-€4 billion. Rather, the principal disagreement is about the indirect costs that result from the process of registration and testing of chemicals.

In the government and NGO studies, the indirect costs of REACH are no more than 1-6 times as large as the direct costs. Costs of this magnitude, totaling a few billion euros spread over 11 years, are easily outweighed by the health-care savings of even a small reduction in occupational illness, or by the savings on reduced cleanup costs for hazardous chemical waste in the future. In short, it is clear that the benefits greatly exceed the costs.[141]

Two major industry studies came to a very different conclusion, finding unacceptably large losses from REACH. One study was done by the consulting firm Arthur D. Little, for Bundesverband der Deutschen Industrie (BDI), the German industry federation. Its most widely quoted, midrange scenario suggested that Germany's GDP would be reduced by 2.4% as a result of REACH; industrial output would suffer most of the losses, declining by 7.7%. Another study, by Mercer Management Consulting, was done for UIC, the French chemical industry trade association. Its original estimate was even more extreme, projecting a loss of 3.2% of GDP and 670,000 jobs in France.[142] In two updates, reflecting the revisions to REACH in 2003, Mercer lowered its estimate, with the final version reducing the forecast to losses of "only" 1.6% of GDP and 360,000 jobs.[143]

The Arthur D. Little estimate, a 2.4% loss of GDP, if projected across the entire EU, implies that the indirect losses caused by REACH would be 650 times the direct costs of registration and testing.[144] The updated Mercer estimate of a 1.6% loss of GDP, if projected across the entire EU, similarly implies that indirect losses caused by REACH would be more than 400 times the direct costs. These ratios are simply implausible; in a modern industrial economy, regulations do not cause indirect effects of hundreds of times their direct costs. Indeed, the enormous losses from tiny direct costs, in both the Arthur D. Little and Mercer studies, are based on long chains of implausible reasoning.

The Arthur D. Little study is the more impressive and detailed of the two. With more than 200 pages of text, a 16-equation mathematical model, and evidence of extensive data collection and analysis, it seems imposing and rigorous at first glance. However, closer inspection shows that it is based on exaggerations and misrepresentations throughout. Among its more glaring mistakes are:

- a misreading of economic theory about market power and pricing, which led to inappropriately multiplying all losses by a factor of 9;
- an assumption that all costs of REACH will be incurred in 7 years, not 11;
- confusion of assumed losses from the applications of REACH to existing and new chemicals, both of which are exaggerated and both of which are assumed to intensify each other; and
- the assumption that REACH will delay the introduction of *all* new products involving chemicals by nine months, causing losses of up to 70% of sales in some branches of industry.[145]

These and other mistakes render the Arthur D. Little study worthless as an estimate of the impacts of REACH.

In contrast, the Mercer study has never been published, except as a PowerPoint slide show. It, too, suggests that extensive data analysis was done, but it presents only the shortest summaries of that analysis. The reader can only wonder why Mercer's estimate of a 1.2% increase in the costs of paint production will lead to a 20% drop in sales (slide 26), or why a 0.8% increase in costs for electronics manufacturers leads them, too, to lose 20% of their sales (slide 27).[146] These sectors have sales losses of 16 to 25 times the size of their cost increases, a ratio that seems implausible. On the other hand, pharmaceutical companies, who are said to face an 8.8% cost increase, lose a very similar amount, 21.6% of their sales (slide 23). Here the sales loss is only 2.5 times the cost increase.

How could pharmaceutical companies possibly face a cost increase of 8.8% as a result of REACH? The registration and testing costs of €4 billion or less will be spread out over the entire European economy over a period of 11 years; there is no way that the share of REACH costs attributable to pharmaceuticals could approach 8.8% of the industry's operating costs. One pharmaceutical company, Sanofi-Aventis, had European revenues of over €11 billion in 2004. If that one company alone had to pay all the costs of REACH, for all chemicals and sectors, over the next 11 years, it would amount to about 3% of their turnover in Europe.[147] Of course, in reality Sanofi-Aventis does not have to pay the entire costs of REACH; other industries and other pharmaceutical companies will pay their share. Thus the correct figure for the cost increase in pharmaceuticals should be much, much smaller than 3%, not 8.8%.

Other strange figures abound throughout the Mercer study, and cannot be explained within the confines of the report's cryptically brief and undocumented PowerPoint format. Why, for example, should 25% of the costs of the substitution of chrome pigments in the iron and steel industry consist of litigation (slide 39)? Chromium is the pollutant featured in the movie *Erin Brockovich*, and in the real-life tragedy that it describes. It has been known for 80 years that chromium causes elevated levels of cancer in workers who are exposed to it.[148] If, as Mercer seems to assume, REACH leads to the elimination of chromium from some industries, the industries' money might be better spent on researching safer alternatives, rather than on litigation.

Both Arthur D. Little and Mercer have performed additional studies following up on their original work. Arthur D. Little has continued to use its same model, with all its flaws, and hence has produced an updated stream of equally flawed numbers. Mercer has produced a subsequent study, also for UIC, of the impact of REACH on four downstream industries (this time including 13 pages of text, but no citations to data sources, publications, or experts other than themselves).[149] In each of the industries -- semiconductors, finished textiles, windscreen wipers for automobiles, and cold rolled steel -- the story is the same: each product line requires vast numbers of chemicals, different from the ones used in other, very similar products; quite a few of these chemicals are known to be hazardous and would therefore be regulated under REACH; the burden of registering and testing so many different chemicals would pose an unbearable economic burden to the industry.

Again, the stories are difficult to evaluate without additional documentation. It is interesting to learn that computer chip manufacturing requires more than 150 chemical substances and formulations. But does every new chip require the introduction of 150 new, different chemicals, as the study assumes? Likewise, does every new windscreen wiper require different chemicals from the last one? After a change in chemicals used to produce windscreen wipers, does it really take three months to one year of tests, as assumed by Mercer, to determine that the windscreen is still being wiped clean? The study is a series of unsupported assertions of this sort, strung together to produce frighteningly big, hypothetical losses for downstream industries.

For example, take the story of cold rolled steel. The final phase of shaping steel sheets involves running them between cylinders which squeeze and flatten the steel. Rolling oils are needed to allow smooth operation at the high speeds of a typical rolling mill. Some of the oils are said to contain toxic ingredients that might be prohibited under

REACH. Mercer calculates that a change in rolling oils caused by REACH could increase costs by €2.40 per tonne, or 0.6% of the average sale price of €400 per tonne.

However, almost all of the cost increase (€2.20) comes from Mercer's assumption that the rolling mill will decrease its speed by 1% as a result of the change in rolling oil, and that the lower speed will last for a full year. What happens if the steel and chemical industries are innovative and resourceful enough to come up with nontoxic rolling oils that do not decrease the speed of the mill? Then Mercer's remaining cost increases, for implementation, testing, and the additional cost of the oil, amount to €0.19 per tonne of steel, or 0.05% of the sales price. This is remarkably similar to estimates of the impact of REACH from government studies, though far below the catastrophic level foreseen by Mercer and Arthur D. Little.[150]

III. B. Can SMEs survive regulation?

More recently, the discussion about the expected impacts of REACH has shifted away from estimating aggregate costs, toward impacts on particular sectors and types of businesses. Some studies have tried to anticipate specific problems, bottlenecks, and bureaucratic obstacles that may arise when REACH is implemented. The Strategic Partnership on REACH Testing (SPORT), a collaboration of the European Commission, member states, and industry, performed pilot trials of the steps required by REACH in order to test its workability; it identified many minor adjustments and reorganizations that could smooth the process of implementing REACH.[151] Another assessment of the impacts of REACH, jointly sponsored by the Commission and industry groups, also found that REACH will have moderate economic impacts, while identifying many details for further discussion.[152] Studies of this sort have confirmed that REACH is, or can easily be made to be, workable for industry as a whole.

Criticism of REACH has nonetheless continued, notably involving the suggestion that some groups of businesses will face unacceptable costs. The most frequently mentioned potential victims of the regulation are small and medium enterprises (SMEs). Lacking the financial and technical resources of larger firms, and using chemicals in smaller volumes, they are said to face a proportionately greater burden from REACH, or any chemical regulation. It is common, in debates about regulation in general, to hear arguments that SMEs are a crucial part of the economy, and will be unable to bear any new regulatory burdens.

Given the importance of SMEs to the discussion, it is worth being clear on what this category includes. The European Commission's official definition of SMEs requires that they have no more than 250 employees, and fall below the threshold of either €50 million annual turnover, or €43 million on their annual balance sheet. Moreover, they cannot be linked to other, larger businesses, for instance as subsidiaries.[153] Informally, SMEs are usually defined solely by employment -- normally, any business with less than 250 employees, though businesses up to 500 employees are at times included.

There are two reasons why discussion of SMEs frequently overstates the importance and autonomy of this group of enterprises: first, many are subcontractors to larger firms; and second, when national employment alone is used as a criterion, some apparent SMEs are in fact subsidiaries of large foreign corporations.

There are, indeed, independent small businesses, which might find regulations to be a burden and have limited ability to comply with them, but there are not nearly as many of these businesses as it appears. As we saw in part 1, an academic study found that more than half of the SMEs in France were subcontractors to larger businesses as of 1990. The corporate restructuring that began in the 1980s led big businesses to make sharply increased use of small subcontractors; this expanded the appearance, but not the reality, of the independent role of small businesses in the economy. The fortunes of subcontractors depend on the larger businesses that they work for, not just on their own, more limited resources. The ability of subcontractors to respond to new technical requirements, and to absorb and pass on regulatory costs, has more to do with the size of the dominant firm than with the subcontractor. Subcontractors which are not subsidiaries of the parent company would normally meet the European Commission definition of SMEs, even though they are not in reality economically autonomous forces.

In addition, as UIC points out (see part 1), some apparently small French businesses are branches of foreign enterprises. The figures on the UIC web site, which seem to describe the role of small businesses in the chemical industry, are based solely on employment in France; by this standard, multinational businesses with moderate sized operations in France will appear to be SMEs.

This is not just true of the chemical industry. In 2003, enterprises with less than 250 employees in France included MGM, Samsung-France, Pratt et Whitney, Fox Entertainment-France, SmithKline Beecham Sante et Hygiene, Warner Music-France, and BASF Agro. The most expansive discussions of SMEs include enterprises with up to 500 employees; multinational enterprises with operations in France that slip in under that standard include Hitachi Computer Products-Europe, NEC Computers-France, Coca-Cola Production, GE Capital Fleet Services, Sony Music Entertainment-France, MCI WorldCom, and the chemical companies Dow Agroscience, Lyondell Chimie-France, Solvin-France (one of the PVC producers discussed in part 2), and Henkel Surface Technologies-France.[154]

All of these "small and medium subsidiaries" would of course fail to satisfy the European Commission's formal definition, since they are linked to larger enterprises elsewhere. But if employment is used as the sole criterion, as is common in informal discussion, then MGM, Warner Music, SmithKline Beecham, and BASF Agro are SMEs.

Despite these two major qualifications, there are truly independent SMEs that are neither subcontractors nor subsidiaries of foreign firms. Some of them may even need assistance in coping with regulations such as REACH. It is important, however, to recognize that there are fewer independent SMEs than is commonly believed. This is useful in avoiding an exaggerated notion of the role which small businesses play in the modern corporate economy. And it also demonstrates that there would be only limited costs to providing assistance to those independent SMEs that genuinely need help in coping with the burdens of new regulation.

Significant steps have already been taken to help genuine SMEs, and more may well be needed in the future. The revisions to REACH in 2003 substantially eased the registration and testing requirements for chemicals in the volume range between one and ten tonnes, in part because the European Commission believed that SMEs would have had difficulty complying with the original, stricter requirements. Further modification of the treatment of the lowest-volume chemicals is still under discussion, for the same reason.

Even for SMEs, new regulations are not always bad. SMEs are more important among the "downstream users," the industries that use chemicals, rather than the chemical industry itself. For the downstream users, REACH provides important benefits: it provides assurance that the chemicals that are produced and sold are safe to use, eliminating potential hazards and liabilities that the downstream users might otherwise face.[155]

There is no reason to roll back regulations because of their potential effects on an exaggerated population of small businesses. Health, safety, and environmental regulations do not represent an impossible burden for SMEs. Moreover, regulations such as REACH are not intended to be business assistance programs, and should not be judged primarily on their effects on the smallest enterprises. Most industrial workers do not work for SMEs; most chemical hazards are not produced or used by SMEs. Workers and consumers need protection from the very real chemical hazards that are most often produced by very large companies. REACH is designed to provide protection from those hazards; other policies should be designed to address the needs of independent SMEs.

III. C. Are new risk-based priorities needed?

In the debate over chemicals policy, a new note has been sounded recently by industry representatives. They have accepted the need for REACH in some form, but call for setting priorities based on risk assessment, so that the riskiest chemicals are tested and regulated first. CEFIC, the European chemical industry trade association, offered its "New proposals to improve workability of REACH" in early 2005; one of its main points was that "Risk, not the annual volume alone, is the suitable criterion for identifying substances of high concern. Therefore, the registration process should include a system for prioritization of substances based on risk."[156]

The proposal to rely on risk assessment sounds at first like a sensible, objective way to use additional information and create smarter regulation. But in reality it is neither necessary nor feasible, and would inhibit the straightforward, workable procedures now built into REACH.

The starting point for understanding this debate is the distinction between *hazards* and *risks*. The term *hazard* refers to the inherent danger of exposure to a chemical. Standard laboratory tests, of the kind called for under REACH and other regulations, are designed to determine the hazards associated with chemicals. In the simplest terms, hazard answers the question, will a chemical make you sick if you swallow it (or inhale it, or get it on your skin, etc.)? And if so, how much of it does it take to make you sick?[157] In contrast, *risk* refers to the expected amount of damage that a pollutant will do, depending on where it is released and how many people come into contact with it. A chemical with the same degree of hazard to human health will cause much more risk if it is released in the middle of a big city, rather than on an uninhabited island. Risk depends on both the hazard of a pollutant, and the exposure of people to emissions of that pollutant.

There are three related problems with the proposal to set priorities for chemical regulation based on risk:

- there is no need for these priorities;
- it is impossible to carry out the proposed volume of risk assessments; and
- in practice, risk assessment is not a straightforward, objective process that advances our understanding of how to reduce the harm caused by chemicals.

New risk-based priorities are not needed

REACH already sets clear priorities for registration and testing of chemicals, based on volume of use, and on known hazardous properties: it will start with the highest volume chemicals, and the ones that are known to be carcinogens, mutagens, reproductive toxins, and/or persistent bioaccumulative toxins. Why are additional, or different, priorities needed?

The industry proposals to set priorities within REACH are based on the assumed urgency of reducing the costs of registration and testing. Verband der Chemischen Industrie (VCI), the German chemical industry trade association, offered a version of the CEFIC proposal with the clearly stated goal of reducing by about 70% the long-term tests required by REACH.[158] If the costs of REACH were as high as the frightening forecasts produced by Arthur D. Little and Mercer, then reducing the costs would be a matter of great importance. However, as we have seen, those forecasts are absurd overestimates.

On the more reasonable forecasts produced by other studies, the registration and testing costs of a few billion euros, spread over the entire European economy over a period of 11 years, appear entirely bearable, even minimal in the aggregate. A moderate strengthening of REACH, restoring some of the desirable features that were eliminated by earlier amendments, would add only slightly to the cost; an enhanced REACH would remain thoroughly affordable.[159] With or without such enhancements, the costs of REACH are both so low that comparatively little can be saved by further prioritizing the testing effort. The greater danger is that a complicated new formula and bureaucratic procedure for prioritization could cause confusion and disruption of the generally well-designed REACH process.

The required risk assessments cannot be carried out at reasonable cost

Risk assessment requires an enormous amount of data and analysis. It involves not only the information on hazards, which REACH is designed to determine, but also calculations of exposures: where is the chemical emitted, what are the patterns of transportation through air, water, food chains, etc., and how many people are exposed to how much of it through each possible pathway?

In short, risk assessment tries to get precise answers to numerous complicated questions. The exposure questions are often much harder to answer than the hazard questions. For this reason, a risk assessment of any individual chemical can take many years to be completed. In 1994, the European Commission drew up a list of 141 top-priority chemicals to be assessed for human health and environmental effects. As of 2003, risk assessment reports had been prepared for just 113 of these chemicals.[160] In other words, risk assessments for these priority chemicals have been carried out at a rate of about 13 per year. At this rate, it would take more than 2,000 years to complete risk analyses for the 30,000 chemicals currently on the market.

The advocates of risk-based prioritization presumably know that adequate risk assessments are time-consuming and expensive. Industry statements often begin by invoking the scientific authority of risk assessment, suggesting that sophisticated analysis will lead to more information and better decisions than called for under REACH. But in practice, industry proposals call for simplistic approximations of risk based on minimal information.

CEFIC proposes that for any substance produced in quantities above 10 tonnes per year, companies would only need to prepare a limited "Information Set," containing much less information than is required by REACH. According to CEFIC, "The Information Set would be used as the basis for prioritization and registration." For substances produced in quantities between 1 and 10 tonnes per year, even less would be required, perhaps limited to whatever happens to be available: "in order to make REACH more user-friendly for SMEs, appropriate available information for prioritization would be produced... instead of a full Information Set."[161] The CEFIC proposal would thus produce much less, not more, information about chemical hazards and risks than the testing called for by REACH.

Similarly, the VCI proposal called for estimation of risk based on simple testing of short run affects, combined with thresholds for concentration, below which chemicals would be assumed to be risk-free. The German Environment Ministry rejected these criteria as obviously failing to accurately reflect the state of knowledge about chemical hazards and risks: some long-term hazards are not particularly dangerous on short-term tests; and some chemicals are extremely hazardous even at very low concentrations.[162]

Ad hoc estimation of risk based on limited information is not a scientific advance over REACH, no matter how grand a theoretical preamble is attached to the idea. What the industry proposals would do is to drastically reduce the testing required, and the information about toxicity that would be available, for chemicals on the market. It would also place heavy demands on the new EU Chemicals Agency, which would be continually involved in assessing risk on the basis of limited information, and defending its judgments against criticism. With so little information available, it would be all too easy for industry or others to criticize the agency's judgments.

As environmental advocates have maintained throughout the debate, risk assessment is frequently impossible because exposure data is lacking; but it puts the burden of proof back on the public sector, which has the time-consuming task of proving that risk exceeds a threshold before action can be taken. (It is much easier to determine whether *hazard* exceeds a dangerous level, using the information collected under REACH.) Thus an insistence on risk assessment amounts to "paralysis by analysis," sabotaging the precautionary approach that is embodied in REACH and other environmental policies.[163]

Risk assessment answers the wrong question

Even if it were somehow possible, risk assessment of all the chemicals in use today would not necessarily be helpful. Risk assessment is not an objective process that has a single, definitive endpoint. And it can be a distraction from answering more important questions about how to reduce harm from hazardous chemicals.

Risk assessments are based on numerous assumptions about exposures, human behavior, chemical effects, and chemical fate; these assumptions may or may not be explicit. The outcomes of risk assessments depend heavily on these assumptions. In one risk assessment exercise, eleven different European risk assessment groups reached eleven different conclusions on the same question, with numerical answers differing by as much as a million to one. The organizers concluded that “at any step of a risk analysis, many assumptions are introduced by the analyst and it must be recognized that the numerical results are strongly dependent on these assumptions.”[164]

Consider the case of trichloroethylene (TCE), a chlorinated solvent used in high volumes in much of the industrialized world. Several studies have suggested that TCE can cause cancers, especially in the liver and kidney. At least fourteen long-term carcinogenicity experiments have been carried out on TCE, as well as at least eight major epidemiological studies. We know more about TCE than we do about most industrial chemicals; it will never be possible to gather this much information about every chemical.

With all this information, one might expect that risk assessors would be able to agree on an evaluation of TCE. But a study of thirty different risk assessments found that they did not come to a consensus on the carcinogenic potential of TCE. The study concluded that "even if an enormous amount of resources are spent on testing of individual substances, significant uncertainty about their potential to cause harm may still remain. … Scientific uncertainty in risk assessment of chemicals can thus only partly be eliminated by data generation. Therefore there is an urgent need for methods to make preliminary and precautionary risk assessments of chemicals on the basis of incomplete knowledge."[165]

The important question is not, how can we come to a more perfectly precise estimate of exactly how much harm is caused by TCE? Since we know that there are good reasons to suspect TCE is harmful, the question that matters is, how hard is it to replace it with safer alternatives? Here there is extensive and encouraging evidence: Germany, Sweden, and Norway, applying different regulatory strategies, all achieved sharp reductions in TCE use in the 1990s; substitution of other chemicals and processes for TCE was usually achieved at relatively low cost.[166] In the US, the state of Massachusetts has also been able to significantly reduce the use of TCE, and has produced a helpful guide to some of the alternative technologies.[167]

More and better risk assessment is not what is needed to protect workers and consumers, in France or elsewhere. It is much more important to identify the available alternatives, and to move forward in implementing them. The companies that switch to less toxic products will avoid future liability for chemical hazards, and will gain a head start in the race to market new, safer products around the world. The French chemical industry, which is already succeeding in the global marketplace, has the resources and the ability to succeed as well in creating a safer, healthier environment.

Endnotes

All of the web sites included in the endnotes were viewed by the authors during June-September 2005.

---

[1] Data from INSEE web site.

[2] Data available through 2003, on Eurostat web site.

[3] Bruno Amable and Bob Hancké, "Innovation and Industrial Renewal in France in Comparative Perspective," *Industry and Innovation* 8 (2), 2001, 113-133. Investment rates from Figure 4, on 118. See also Eurostat Yearbook 2004, chapter 3.

[4] The trade balance was barely positive in 2004, since the French economy grew faster than many of its leading export markets, while energy prices rose sharply. These short-term reverses do not represent a long-term loss of competitiveness. See INSEE, "The French Economy 2005-2006" at http://www.insee.fr/en/indicateur/cnat_annu/base_2000/documentation/publications/overview.pdf.

[5] Amable and Hancké 2001, 119.

[6] For an impassioned argument that France has done much worse than several northern European countries in solving these problems, see Timothy B. Smith, *France in Crisis: Welfare, Inequality, and Globalization since 1980* (Cambridge University Press, 2004). For a recent economic analysis, advocating increased reliance on market-based policies, see OECD, *Economic Survey of France, 2005*.

[7] Hart Hodges, “Falling Prices: Cost of Complying With Environmental Regulations Almost Always Less Than Advertised,” Economic Policy Institute (1997) (http://epinet.org); Winston Harrington, Richard D. Morgenstern, and Peter Nelson, “On the Accuracy of Regulatory Cost Estimates,” *Journal of Policy Analysis and Management* 19 no. 2 (Spring 2000), pp.297-322.

[8] Cheminfo Services, *A Retrospective Evaluation of Control Measures for Chlorinated Substances (Case Studies of Ex-Ante/Ex-Post Socioeconomic Effects)*, report to Environment Canada and Ontario Ministry of Energy, Science and Technology (March, 2000).

[9] International Chemical Secretariat, “Cry Wolf: Predicted Costs by Industry in the Face of New Regulations,” April 2004

[10] Our estimate, in a study for the Nordic Council of Ministers, was €3.5 billion. See Frank Ackerman and Rachel Massey, "The True Costs of REACH," 2004. The European Commission's estimate was even lower, €2.3 billion. The discussion of the impacts of REACH on chemical prices is based on the €3.5 billion estimate; the Commission's estimate would imply even lower price impacts.

[11] Ursula Triebswetter and David Hitchens, "The impact of environmental regulation on competitiveness in the German manufacturing industry -- a comparison with other countries of the European Union," *Journal of Cleaner Production* 13 (2005), 733-745.

[12] World Trade Organization (WTO) web site.

[13] Exports in US dollars, and population, both in 2003, from WTO country profiles.

[14] Chemical industry worldwide sales of €1776 billion, from CEFIC web site, converted at average 2004 exchange rate of $1 = €0.804; world GDP of $40.9 trillion, from World Development Indicators database, World Bank web site.

[15] "Environmental Outlook for the Chemicals Industry," OECD Environment Directorate, 2001, figure 9, page 35.

---

[16] The US had a small trade deficit in chemicals in 2002 and 2003, and essentially equal chemical imports and exports in 2004. The US in earlier years, and the EU and Japan in all recent years, have chemical exports exceeding imports. See *Chemical & Engineering News*, July 11, 2005, and CEFIC web site.

[17] Data for 1970, 1980, 1990, 1998 from OECD, "Environmental Outlook," Annex 2, page 111. Data for 2004 from CEFIC web site.

[18] OECD, "Environmental Outlook," page 24.

[19] Unofficial EU data, from the European Commission, cited from a source published in 2000; OECD, "Environmental Outlook," page 26.

[20] UIC web site.

[21] CEFIC web site.

[22] INSEE, Comptes nationaux - Base 2000, table 2.204, shows employment in industry was 4.463 million in 1990, falling to 3.688 million in 2004. Full-time equivalent employment in industry (same source, table 2.205) also shows a 1.4% annual decline over the same years.

[23] Amable and Hancké, "Innovation and Industrial Renewal," Table 7, page 127.

[24] Keith Chapman and Helen Edmond, "Mergers/Acquisitions and Restructuring in the EU Chemical Industry: Patterns and Applications," *Regional Studies* 34 no. 8 (2000), 753-767.

[25] *Chemical & Engineering News*, July 11, 2005.

[26] Quoted from the Air Liquide web site.

[27] Toulouse Presentation given by a representative of the French Environment Ministry at the CCA6 - "6th Meeting of the Committee of the Competent Authorities responsible for the implementation of Directive 96/82/EC", in Antwerp, Belgium, 10-12 October, 2001, http://www.uneptie.org/pc/apell/disasters/toulouse/pdffiles/frenchpresentationCCABelgium.pdf

[28] Ministere de l'ecologie et du developpement durable, “Bilan des Accidents Technologiques 1992-2004," http://barpipdf.geniecube.info/plaquette_20_06_05.pdf

[29] www.liberation.fr/page.php?Article= 325536

[30] Florence Menegaux and Jacqueline Clavel, "Nonoccupational exposure to pesticides and childhood acute leukemia," Children with Leukemia conference, London, September 2004, http://www.leukaemiaconference.org/programme/posters/day4-menegauxclavel.pdf

[31] JF Viel and B Challier, "Bladder cancer among French farmers: does exposure to pesticides in vineyards play a part?," *Occupational and Environmental Medicine* 52 (1995), 587-592.

[32] Reseau SCOP 93, "Occupational cancer in a Paris suburb: First results of a proactive research study in Seine Saint-Denis," *International Journal of Occupational and Environmental Health* 11 (2005), 263-275.

[33] Ellen Imbernon, "Estimate of the number of cases of certain types of cancer that are attributable to occupational factors in France," Institut de Veille Sanitaire, 2005, http://www.invs.sante.fr/publications/2005/cancer_240205/rapport.pdf

[34] CGT, "Faire reculer les cancers, c’est possible!", 2004, http://docsite.cgt.fr/1081338933.pdf.

[35] European Industrial Relations Observatory Online, 2002, http://www.eiro.eurofound.eu.int/2002/04/feature/fr0204105f.htm

[36] Case study databases are available at http://www.emcentre.com/unepweb/tec_case/ (for case studies collected by UNEP) and https://www.unido.org/NCPC/Sector/Sectors.cfm (for case studies collected by UNIDO).

---

[37] UNEP case studies available at http://www.emcentre.com/unepweb/tec_case/; follow the links for "manufacturing" and "chemicals and chemical products".

[38] Adapted from Rachel Massey, "Building a Healthy Economy: Chemicals Risk Management as a Driver of Development," Swedish Chemicals Inspectorate (KemI Report No. 2/05), September 2005.

[39] The following overview reflects the principles of green chemistry as developed by Paul Anastas and John Warner, in *Green Chemistry: Theory and Practice* (Oxford: Oxford University Press, 1998). This summary is drawn from http://www.epa.gov/greenchemistry/whats_gc.html.

[40] This discussion of VOCs is based on Mike Lancaster, *Green Chemistry* (Cambridge: Royal Society of Chemistry, 2002).

[41] United Nations Economic Commission for Europe, Aarhus Clearinghouse for Environmental Democracy, information available at http://aarhusclearinghouse.unece.org/.

[42] United Nations Economic Commission for Europe, Aarhus Clearinghouse for Environmental Democracy, Spotlight: France, available at http://aarhusclearinghouse.unece.org/resources.cfm?c=1000004,1000043.

[43] US Toxics Release Inventory: http://www.epa.gov/tri/

[44] For success stories of companies that have successfully reduced use of toxics (while, in most cases, also saving money in the process), see TURA case studies collected at http://www.state.ma.us/ota.

[45] Joe Thornton, *Environmental Impacts of Polyvinyl Chloride Building Materials*, 2003, http://www.healthybuilding.net/pvc/Thornton_Enviro_Impacts_of_PVC.pdf.

[46] Eric Linak with Kazuo Yagi, *CEH Product Review: Vinyl Chloride Monomer (VCM)* (Chemical Economics Handbook – SRI International, October 2003).

[47] Eric Linak with Kazuo Yagi, *CEH Marketing Research Report: Polyvinyl Chloride (PVC) Resins* (Chemical Economics Handbook – SRI International, September 2003).

[48] Information on VCM transportation from Greenpeace France research.

[49] Thornton 2003.

[50] Information based on research by Greenpeace France.

[51] See http://www.arkemagroup.com/arkema/GB/produits/d_marques.cfm?idmarque=72.

[52] Frank Ackerman and Rachel Massey, "The Economics of Phasing Out PVC," 2003, http://ase.tufts.edu/gdae/Pubs/rp/Economics_of_PVC.pdf.

[53] Ackerman and Massey 2003.

[54] Ackerman and Massey 2003; Jamie Harvie and Tom Lent, "PVC-Free Pipe Purchasers' Report," 2002, http://www.healthybuilding.net/pvc/pipes_report.pdf.

[55] See, among others, the examples cited at http://www.advantica.biz/hardware_licensing/swagelining/water.htm, http://www.borealisgroup.com/public/news/press_releases/articles/article_70.html

[56] "Arkema functional polyolefins for cable compounds," 2002, http://www.arkemagroup.com/Service/Tele/DownLoad/grp1/545.pdf.

[57] Ackerman and Massey 2003.

[58] On respiratory health concerns, see Jouri J. K. Jaakola et al., "Interior Surfaced Materials in the Home and the Development of Bronchial Obstruction in Young Children in Oslo, Norway," *American Journal of Public Health* 89:2 (February 1999), 188-192.

[59] http://www.arkemagroup.com/arkema/GB/produits/d_marques.cfm?idmarque=72.

---

[60] Ackerman and Massey 2003.

[61] "Focus on Phthalates," *Chemistry and the Consumer Newsletter* 4 (July 2005), available at http://www.chemsoc.org/pdf/gcn/GC&Cnewsletter4.pdf.

[62] Duty et al. (2005) Personal Care Product Use Predicts Urinary Concentrations of Some Phthalate Monoesters, http://ehp.niehs.nih.gov/members/2005/8083/8083.pdf

[63] Swan et al., (2005) "Decrease in Anogenital Distance among Male Infants with Prenatal Phthalate Exposure," *Environmental Health Perspectives* Volume 113, Number 8 http://ehp.niehs.nih.gov/docs/2005/8100/abstract.html

[64] Chemistry and the Consumer Newsletter (July 2005) Issue 4, "Focus on Phthalates".

[65] Chemistry and the Consumer Newsletter, "Focus on Phthalates." Also see http://europa.eu.int/rapid/pressReleasesAction.do?reference=IP/05/838&fo

[66] Cosmetics Directive (76/768/EEC).

[67] Information from industry website: http://www.ethers-de-glycol.org/english/c9.html#eins.

[68] Henry Chinn with Uwe Löchner and Kazuo Yagi, "CEH Marketing Research Report: Glycol Ethers," *Chemical Economics Handbook* (SRI Consulting, July 2004), p. 663.5000 D.

[69] "Malgré les risques, les éthers de glycol sont encore fabriqués," *Actu Environnement* (January 8, 2005), http://www.actu-environnement.com/ae/news/879.php4.

[70] P. de Kettenis, "The Historic and Current Use of Glycol Ethers: A Picture of Change." *Toxicology Letters* 156 (2005), 5-11. Commercial preparations of methoxy-1-propanol-2 contain, as an impurity, the isomer methoxy-2-propanol-1 (the β isomer). In pure form, this β isomer is classified as a category 2 reproductive toxicant. See Oxygenated Solvents Producers Association (OSPA)'s Glycol Ethers Charter (March 1, 2005) http://www.ethers-de-glycol.com/english/downloads/French%20Glycol%20Ethers%20Charter%20english.doc.

[71] Crouzillacq, Francis (2000) Ether de glycol: IBM au coeur de la polemique. 01net., August 10, 2000. http://www.01net.com/article/116471.html, and European Industrial Relations Observatory (EIRO) (2000) on the European Foundation for the Improvement of Living and Working Conditions' web site "Occupational illnesses and industrial solvents in the spotlight." http://www.eiro.eurofound.eu.int/2000/09/inbrief/fr0009189n.html.

[72] Confédération Générale du Travail (CGT) (2001) « Ethers de glycol: Les cas de malformations et de cancers observes dans les usines IBM aux Etats-Unis et en France, » http://www.cgt.fr/internet/html/lire/?id_doc=211, viewed September 2005.

[73] [73] Crouzillacq, Francis (2000) Ether de glycol: IBM au coeur de la polemique. 01net., August 10, 2000. http://www.01net.com/article/116471.html, viewed September 2005,

[74] Chinn et al., "CEH Marketing Research Report: Glycol Ethers," p. 663.5000 E.

[75] Chinn et al., "CEH Marketing Research Report: Glycol Ethers," p. 663.5000 D.

[76] Chinn et al., "CEH Marketing Research Report: Glycol Ethers," p. 663.5003 B.

[77] Directives 94/60/CE, 2003/36/CE, and 2003/34/CE (amendments to 76/769/EEC regarding CMRs) and 67/548/CEE (dangerous substances directive).

[78] Ministère de la Santé et des Solidarités (November 2002) Questions/Réponses sur les éthers de glycol http://www.sante.gouv.fr/htm/pointsur/ethersglycol/index.htm. Two decisions both on August 24, 1999 by l'Agence Française de Sécurité Sanitaire des Produits de Santé (AFSSAPS), banned them from use in human medications in cosmetics.

[79] Conseil Supérieur d'Hygiène Publique de France (CSHPF) (november 2002) « Les éthers de glycol dans les produits de consommation et la santé » http://www.ladocumentationfrancaise.fr/rapports-publics/034000013/index.shtml

---

[80] 67/548/CEE and 88/379/CEE, adopted in French law by l'arrêté du 20 avril 1994 modifié and l'arrêté du 21 février 1990 modifié, respectively ; Ministere de la Sante et des Solidarites (November 2002) Questions/Réponses sur les éthers de glycol.

[81] Actu-Environnement (Aout 2005) Malgre les risques, les ethers de glycol sont encore fabriques. http://www.actu-environnement.com/ae/news/879.php4

[82] Oxygenated Solvents Producers Association (OSPA)'s Glycol Ethers Charter (March 1, 2005) http://www.ethers-de-glycol.com/english/downloads/French%20Glycol%20Ethers%20Charter%20english.doc.

[83] INSERM (October 1999) Ethers de glycol. Quels Risques pour la Sante? http://ist.inserm.fr/BASIS/elgis/fqmr/rapp/DDD/687.pdf

[84] "Décret du 1er février 2001 relatif à la protection des travailleurs exposés à des agents cancérigènes, mutagènes ou toxiques pour la reproduction (ou agents CMR)"

[85] CGT (January 2004) Faire reculer les cancers, c'est possible! http://docsite.cgt.fr/1081338933.pdf

[86] CGT, Faire reculer les cancers, c'est possible!, p. 13.

[87] CGT, Faire reculer les cancers, c'est possible!, p. 13.

[88] Environment Canada (May 2003) Current Use Patterns in Canada, Toxicology Profiles of Alternatives, and the Feasibility of Performing an Exposure Assessment Study http://www.ec.gc.ca/toxics/docs/2be-2me/EN/profiles.cfm

[89] http://www.xandex.com/Products/inker/remover.htm

[90] Sarah Sexton, "The Reproductive Hazards of Industrial Chemicals: The Politics of Protection," *The Corner House* (November 1993), http://www.thecornerhouse.org.uk/item.shtml?x=52198.

[91] Information about SUBSPRINT is available at http://www.rrz.uni-hamburg.de/kooperationsstelle-hh/content/arbeitsgebiete/ersatzstoffe/praxis/subsprint/uk/welcome.html

[92] For example, see the vendor list of cleaners for metals at http://www.p2pays.org/ref/22/21484.pdf

[93] Lyondell offers P-series as replacement for E-series glycol ethers; see http://www.lyondell.com/html/products/techlit/2653.pdf.

[94] ADF Systems web site, http://www.adfsystems.com/index.html

[95] Church & Dwight systems, http://www.churchdwight.com/

[96] Michael P. Malveda, "CEH Product Review: Phosgene," *Chemical Economics Handbook – SRI International* (August 2003), p. 687.1000A.

[97] Anastas & Williamson (1996) *Green Chemistry: Designing Chemistry for the Environment*. American Chemicals Society.

[98] CDC (Feb 2005), "Facts about Phosgene," http://www.bt.cdc.gov/agent/phosgene/basics/pdf/phosgene-facts.pdf

[99] ATSDR (2004), "Medical Management Guidelines (MMGs) for Phosgene ($COCl_2$)," http://www.atsdr.cdc.gov/MHMI/mmg176.html

[100] US Environmental Protection Agency (EPA), "Phosgene: Hazard Summary," http://www.epa.gov/ttn/atw/hlthef/phosgene.html.

[101] ATSDR (2004) Medical Management Guidelines for Phosgene

[102] CDC NIOSH Safety and Health Topic: Isocyanates, http://www.cdc.gov/niosh/topics/isocyanates/

[103] Malveda 2003.

[104] Malveda 2003.

---

[105] CDC NIOSH Safety and Health Topic: Isocyanates

[106] "Doing Without Phosgene" in Albert S. Matlack, *Introduction to Green Chemistry* (New York: Marcel Dekker, 2001), pp. 27-42.

[107] Except where otherwise noted, these examples are from Anastas & Williamson (1996) *Green Chemistry: Designing Chemistry for the Environment*. American Chemicals Society.

[108] Aresta & Quaranta (1997) "Carbon dioxide: a substitute for phosgene," *ChemTech*, March 1997 v27 n3 pp. 32-40; McGhee et al. (1995) "Carbon dioxide as a phosgene replacement: synthesis and mechanistic studies of urethanes from amines, CO2, and alkyl chlorides," *Journal of Organic Chemistry*. Vol 60 n.9 pp. 2820 - 2830

[109] *China Chemical Reporter*, March 26, 2005. p. 15.

[110] "Isochem Expands its Range of Advanced Fine Chemical Solutions," *Chemical Week* 166:2 (January 21, 2004), p. 40

[111] Matlack, "Doing Without Phosgene".

[112] Matlack, "Doing Without Phosgene".

[113] On pesticides in air, see Carol Bedos et al., "Occurrence of Pesticides in the Atmosphere in France," *Agronomie* 22 (2002), 35-49, available at http://www.fymy.ucl.ac.be/crp/fichiers/Occurrence%20of%20pesticides.pdf.

[114] Ted Schettler et al., *In Harm's Way: Toxic Threats to Child Development* (Cambridge, MA: Greater Boston Physicians for Social Responsibility, 2000).

[115] "Agrochemicals," in Albert S. Matlack, *Introduction to Green Chemistry* (New York: Marcel Dekker, 2001), pp. 319-348.

[116] Matlack 2001, pp. 319-348.

[117] Research by Greenpeace France.

[118] ***This site was formerly operated by Union Carbide, later by Rhône Poulenc, and more recently by executives from Rhône Poulenc. Greenpeace, "Béziers soufré," (August 18, 2005)*** http://www.greenpeace.org/france/news/beziers-soufre.

[119] Mimi Kleiner and Marcia Ishii-Eiteman, "Poison Profits: The G-7 Pesticide Industry's Stake in the World Bank," 50 Years is Enough Network, 1997, available at http://www.50years.org/factsheets/pesticide.html.

[120] David Buffin et al., "Breaking the Pesticide Chain: The Alternatives to Pesticides Coming Off the European Union Market," (Friends of the Earth and Pesticide Action Network UK, 2003).

[121] Buffin et al., 2003.

[122] Pesticide Action Network UK, "Sweden Enters UK with Environmental Attitude," *Pesticide News* 26 (1994), available at http://www.pan-uk.org/pestnews/pn26/pn26p18.htm. Another, more recent, description of the process is available in Vibeke Bernson, Swedish National Chemicals Inspectorate, "Comparative Risk Assessment: Substitution: How Will It Work?" (Power point slides prepared January 2003).

[123] For details on the law see http://www.mddep.gouv.qc.ca/pesticides/permis/code-gestion/code-enbref.htm

[124] Jesper Schou and Jens C. Streibig, "Pesticide Taxes in Scandinavia," available at http://www.foes-ev.de/downloads/scandinaviastudy.pdf. Also see Mikael Skou Andersen et al., "An Evaluation of the Impact of Green Taxes in the Nordic Countries (Aarhus University and Nordic Council of Ministers, 2000), available at http://www.norden.org/pub/miljo/ekonomi/sk/2001-566.pdf.

---

[125] Unless otherwise noted, all health effects information is drawn from the PANNA On-line Database at http://www.pesticideinfo.org/Index.html.

[126] PANNA On-line Database at http://www.pesticideinfo.org/Index.html.

[127] US Environmental Protection Agency, http://www.epa.gov/oppsrrd1/op/azm.htm.

[128] PANNA On-line Database at http://www.pesticideinfo.org/Index.html.

[129] US Environmental Protection Agency, listed in PANNA On-line Database at http://www.pesticideinfo.org/Index.html.

[130] US Agency for Toxic Substances and Disease Registry (ATSDR), "ToxFAQs for Endosulfan," February 2001, available at http://www.atsdr.cdc.gov/tfacts41.html.

[131] Environmental Justice Foundation, *End of the Road for Endosulfan* (London: Environmental Justice Foundation, 2002). Available at http://www.ejfoundation.org/pdfs/end_of_the_road.pdf.

[132] PANNA On-line Database at http://www.pesticideinfo.org/Index.html.

[133] L'Agence française de sécurité sanitaire des aliments (Afssa) and l'Agence française de sécurité sanitaire environnementale (Afsse).

[134] http://www.afssa.fr/ftp/afssa/basedoc/Rapportfipro.pdf; http://www.afsse.fr/documents/Rapport_FIPRONIL.pdf;

summary at http://www.actu-environnement.com/ae/news/1069.php4;

[135] Matlack 2001, pp. 319-348.

[136] Buffin et al., 2003.

[137] Richard Earles et al., "Organic and Low-Spray Apple Production," *Appropriate Technology Transfer for Rural Areas* (October 1999).

[138] C. O. Calkins, "Review of the Codling Moth Areawide Suppression Program in the Western United States." *Journal of Agricultural Entomology* 15:4 (October 1998), 327-333.

[139] Pesticides News 2003, available at http://www.pan-uk.org/pestnews/pn61/pn61p17.htm.

[140] For example, the Mercer study discussed below estimates registration and testing costs (in thousands of euros per chemical), in the four volume tiers, of 34, 209, 456, and 898 (Mercer's slide 15); the comparable figures from a recent study for the Commission and other stakeholders, are 15, 163, 282, and 323 (KPMG, "REACH -- further work on impact assessment: a case study approach," April 2005, executive summary, page 7). The Mercer study was based on an earlier version of REACH with more demanding testing requirements, particularly for the lowest volume tier.

[141] See the discussion in Ackerman and Massey 2004.

[142] Mercer Management Consulting, "Study of the impact of the future chemicals policy: final report," April 24, 2003. This "report" is a PowerPoint slide show with 95 slides; it is apparently the most detailed form of the study that has been published.

[143] Mercer Management Consulting, "Study of the impact of the future chemicals policy: additional REACH implementation scenario," June 24, 2003; "Etude d'impact de la future politique dans le domaine des substances chimiques: Étude complémentaire suite à la proposition de réglementation du 29 octobre 2003," April 8, 2004.

[144] Ackerman and Massey 2004, 43-44.

[145] See the detailed critique of the Arthur D. Little study in Ackerman and Massey 2004, 65-70.

[146] All references here are to the April 2003 PowerPoint version, rather than the even shorter updates.

[147] Total costs of REACH assumed to be €3.5 billion over 11 years, from Ackerman and Massey 2004; Sanofi-Aventis European revenues of €11.1 billion in 2004, from their web site, assumed to

---

continue unchanged for 11 years. On these assumptions, the total costs of REACH are 2.9% of the 11 year revenue total.

[148] Cheryl Pellerin and Susan M. Booker, "Reflections on hexavalent chromium: health hazards of an industrial heavyweight," *Environmental Health Perspectives*, September 2000, volume 108 (9), A402-407.

[149] Mercer Management Consulting, "Study of the impact of the future chemicals policy: four examples of the impacts of the regulation proposal on downstream industries," April 2004. The results are also summarized in the second of the Mercer updates cited above.

[150] Ackerman and Massey 2004 estimated that REACH would cause an average cost increase of 0.06% for chemicals sold in the EU.

[151] Andreas Ahrens, Dirk Jepsen, Kerstin Heitmann, and Frank Claus, "The SPORT report: making REACH work in practice," July 2005.

[152] KPMG Business Advisory Services, "REACH -- further work on impact assessment: a case study approach," April 2005.

[153] European Commission, "The new SME definition: user guide and model definition," 2003.

[154] *L'Expansion* web site, www.lexpansion.com.

[155] Rachel Massey, *Surviving REACH: A Guide for Companies That Use Chemicals*, International Chemical Secretariat, Gothenburg, Sweden, 2005.

[156] CEFIC, "New proposals to improve workability of REACH," February 24, 2005; emphasis in original.

[157] This discussion of hazard, and the subsequent discussion of risk, omit questions of ecotoxicity and focus solely on human impacts, purely for simplicity of exposition. For completeness, a parallel discussion of impacts on other species and ecosystems should be included.

[158] German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, "Is This Truly a 'Better REACH'? Evaluation of the VCI/CEFIC Proposals," draft, March 2005.

[159] See the "REACH Plus" scenario described in Ackerman and Massey 2004.

[160] Jack de Bruijn, Bjorn Hansen, and Sharon Munn, “Role of the precautionary principle in the EU risk assessment process on industrial chemicals,” *Pure and Applied Chemistry*, Vol. 75, Nos. 11-12 (2003), 2535-2541.

[161] CEFIC, "New proposals to improve workability of REACH," 6; emphasis in original.

[162] German Environment Ministry, "Is this truly a 'Better REACH'?", 15-17.

[163] Inger Shörling, "The Greens perspective on EU chemicals regulation and the White Paper," *Risk Analysis* 23 no. 2 (2003), 405-409.

[164] S. Contini, A. Amendola, and I. Ziomas, *Benchmark Exercise on Major Hazard Analysis*, Ispra, Italy: Commission of the European Communities Joint Research Center, 1991, as cited by Joel Tickner.

[165] Christina Ruden, “From Data to Decision: A Case Study of Controversies in Cancer Risk Assessment,” Doctoral Thesis, Institute of Environmental Medicine, Karolinsta Institutet, Stockholm, Sweden, 2002.

[166] Daniel Slunge and Thomas Sterner, "Implementation of policy instruments for chlorinated solvents. A comparison of design standards, bans and taxes to phase out trichloroethylene," *European Environment* 11 no. 5 (2001), 281-296; Julia von Grote et al., " Reduction of occupational exposure to perchloroethylene and trichloroethylene in metal degreasing over the last 30 years: influences of technology innovation and legislation," *Journal of Exposure Analysis and Environmental Epidemiology* 13 no. 5 (2003), 325-340.

---

[167] Karen Thomas, John LaPlante, and Alan Buckley, "Guidebook of Part Cleaning Alternatives:

'Making Cleaning Greener in Massachusetts'," 1997, http://www.mass.gov/envir/ota/pubs/partsguide.pdf.