Green Chemistry: Cornerstone to a Sustainable California: A Critical Analytic Review

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February 27, 2008

Abstract

In January 2008, Michael Wilson and colleagues issued a report on "green chemistry," the second such report in two years. Some (but not all) of the scientific and analytic foundations and data in this report are critically examined, and they are found seriously wanting. The report is founded on the crucial unsubstantiated premise that existing federal chemicals regulation results in substantial adverse human health and environmental effects because innovators and manufacturers are not required to prove safety in advance. It then attempts to prove this point by incoherently relying on alleged safety risks from pesticides, for which the report itself acknowledges that prior proof of safety is in fact statutorily required. As a policy remedy for this and equally nebulous problems, the report proposes that the State of California mandate radical but unspecified new informational demands, without any reproducible framework for what information would be satisfactory, and no consideration at all about its value for public or private decision-making. The authors propose to ban the production or use of any chemical for which the informational database is subjectively judged after the fact to be inadequate. Substances, technologies, manufacturing processes, and products that earn the authors' blessing as examples of "green" chemistry apparently would be exempted from these informational demands, leading to perhaps the world's largest ever uncontrolled human chemistry experiment. As an advocacy document, the report is lavishly produced and pleasingly illustrated, and unusually well referenced. This turns out to presage its own downfall, for the report's references turn out to be dominated by the work of fellow activists and a handful of selected studies generally removed from the scientific context in which they appeared. In several critical instances, the report cites scientific claims incorrectly and makes scientific assertions that are neither supported nor factually credible. Because of increasing interest in green chemistry, including proposals such as this one for radical regulatory mandates, a genuine scientific review would have been welcome, and perhaps is long overdue.

Qualifications

Richard B. Belzer is an independent consultant on regulatory matters involving economics, policy, risk assessment and information quality. From 1988 to 1998, he served as an economist at the U.S. Office of Management and Budget's Office of Information and Regulatory Affairs. At OMB he reviewed dozens of major proposed and draft final rulemakings, and their supporting risk- and economic analyses, initiated by several agencies and Executive branch departments. He earned multiple performance awards for the quality of his work. He left OMB to become Visiting Professor of Public Policy at Washington University in St. Louis, and Regulatory Program Manager for the Weidenbaum Center on the Economy, Business and Public Policy.

Dr. Belzer is a member of the American Economics Association and the Society for Risk Analysis. The AEA is the premier professional society for economists, while the SRA is an interdisciplinary association of about 2,000 professionals involved in the assessment and management of health, safety and environmental risks. He was elected Treasurer of SRA in 1998, re-elected in 2000, and served on its Executive Committee from 1998 through 2003. He earned SRA's Outstanding Service Award in 2003.

In addition holding a doctorate in public policy from Harvard University, Dr. Belzer earned BS and MS degrees in agricultural economics from the University of California at Davis, and the MPP from the John F. Kennedy School of Government.

Acknowledgements

This review was funded by a grant from the American Chemistry Council. The analysis presented herein is solely the work product of the author and does not necessarily reflect the views of ACC or its member companies.

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I. Introduction

For much of the public, science is a mysterious thing that takes place behind ivy-covered walls in university laboratories and classrooms. Scientists are widely accorded respect and oftentimes regarded with awe. Policy advocacy is fundamentally different. In the United States, anyone can become an activist. There are no minimum educational standards required, no tests to pass, and no peer review panels that guard the door to the publishing house. The public understands that activists have agendas, and whereas they may find it hard to dismiss the work of scientists, they have little trouble rejecting activists with whom they disagree.

Normally, scientists and activists are relatively easy to separate. Science is the methodical and painstaking study if what *is*. Activism is argumentation in the political sphere about what *ought to be*. Still, public confusion arises because universities employ both scientists and activists. Sometimes, the same individuals play both roles. When scientists act as activists, the public can find it especially challenging to discern where science ends and advocacy begins.

Although it was sponsored by the University of California, the recent report by Michael Wilson and colleagues is a work of political and policy activism, hereinafter referred to as *Wilson II* to distinguish it from an earlier work of political and policy advocacy (*Wilson I*).[1] Neither of these documents are scientific work products. Thus, it would be unfair to expect them to meet even minimal scientific standards, such as rigorous and independent peer review, and indeed, they do not. Still, to be credible an advocacy report must meet treat facts with care, begin with factual premises, and sustain a logical argument from premise to conclusion. Wilson II does not meet these standards.

First, even if it is assumed arguendo that the authors' premises are factually supported, Wilson II builds on this foundation a structure of scientific claims that is unsupported, incorrect, or irrelevant, and links them together with arguments that are often tautological. Second, the policy recommendations in Wilson II have dubious merit even if these errors also are ignored. Wilson II assumes away the most daunting challenges facing their proposal to radically restructure chemistry: proving in advance that its preferred inputs, technologies, manufacturing processes, and products are free of health, safety and environmental risk. Third, Wilson II ignores the potentially staggering opportunity costs of its policy recommendations, including adverse effects on health, safety and the environment. There is no way to know whether the legislative adoption of these recommendations would save hundreds of lives or result in the premature death of thousands.

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[1] For *Wilson II*, see **Wilson, Michael P.; Schwarzman, Megan R.; Malloy, Timothy F.; Fanning, Elinor W. and Sinsheimer, Peter J.** "Green Chemistry: Cornerstone to a Sustainable California," Berkeley, Calif.: Center for Occupational and Environmental Health, University of California, 2008, 26. For *Wilson I*, see **Wilson, Michael P.; Chai, Daniel A. and Ehlers, Bryan C.** "Green Chemistry in California: A Framework for Leadership in Chemicals Policy and Innovation," Berkeley, Calif.: California Policy Research Center, University of California, 2006, 131.

In Section II, a few of the many definitions of "green chemistry" are compared and contrasted. No position is taken with respect to which definition is the *right* one, for ultimately this is a matter of values and preferences rather than science because the distinguishing attributes of green chemistry, however it is defined, are inherently nonscientific. Wilson II adopts the practice of never clearly defining exactly what is meant by "green chemistry," thus allowing different readers to impute their own preferred definition. Once readers focus intently on what the authors actually say, it becomes clear that they have adopted an extreme definition even while relying on mainstream language.

In Section III, Wilson II's premises and assumptions are fit into a logical and generally accepted scientific framework – what economists call "market failure."[2] This framework is hinted at in the report, but otherwise it is generally missing and no other scientific superstructure can be found. When organized this way, it is clear that the report begins with a fundamentally flawed understanding of how markets work (including markets for information) and how workers and consumers make decisions (especially decisions in the face of uncertainty about risk). These errors are compounded by others -- inconsistent and biased treatment of the external benefits and costs of conventional versus green chemistry, and populist definitions of risk that clash with all of the scientific literature.

In Section IV, the Wilson II is shown to have incorrectly characterized the "economic consequences" of conventional chemicals production and use. Two of the three types of consequences that are identified concern historic activities that cannot be influenced by policy changes today. In the language of economics, these are "sunk costs." Decision theory counsels that sunk costs be ignored when making forward-looking decisions. In addition, the report does not even acknowledge that among the "economic consequences" of conventional chemicals production and use are huge increases in individual and family welfare, including the reduction and elimination of a host of biological, chemical, environmental, and safety risks. By ignoring these benefits, Wilson II presents the most one-sided view of economic consequences imaginable.

In Section V, Wilson II is shown to have demonstrated the superiority of its favored proposals by magical thinking. Because the authors define green chemistry to exclude any substance, technology, manufacturing process, or product that is not risk-free, they assume that the innovations they desire would be exempt from the informational burdens that they would impose on others. Further, pretend that State mandates would not cause massive reductions in material welfare for all Californians, and especially its low-income residents. Ironically, for anything to qualify under the

[2] The concept of *market failure* is often used incorrectly by non-economists. Economists use the term to describe any departure from a perfectly competitive equilibrium, and do not intend it to imply any normative judgment about whether a particular market is "good" or "bad." Activists, however, typically intend market failure to be a normative judgment that a market is "bad" or produces "bad" outcomes. In this paper the terms *market failure* and *government failure* are used in the same, nonjudgmental way that economists (who invented the terms) use them. They are explained in more detail in Sections III and VI, respectively.

authors' extreme definition of green chemistry must endure a much greater data burden – proving scientifically that it is risk-free.

In Section VI, Wilson II is shown to have ignored a crucial element of the problems besetting modern chemistry: the problem of "governmental failure." Like market failure, "government failure" is a nonjudgmental term of art used by economists to describe discrepancies between the idealized model of government action and its actual performance, which like the market, always departs from the ideal. Government failure arises for several reasons, including the inherent inability of regulators to gain superior (much less perfect) knowledge about what they seek to control and the inherent limits of enforcement. Regulatory intervention is often proposed as the solution for market imperfections with the unrealistic expectation that regulation will be both perfectly effective and efficient, and costless to enforce. This never happens. Policy-makers can choose only between imperfect markets and imperfect governments. The challenge, as always, is to discern the optimal mix of market forces and governmental guidance.

Finally, it is readily apparent from Wilson II that a disconnect exists between the way scientists approach issues involving risk and the orientation and policy objectives of the report's activist authors. Risk assessment is the universally recognized basis for providing scientific input to the private and public management of health and environmental risk.[3] It is part of the foundation for training in environmental health, both at the undergraduate level and in graduate programs in public health.[4] However, none of the report's authors appears to teach or practice human health risk assessment and the lead author is on record opposing it.[5]

A scholarly, objective analysis of the risks and benefits of green chemistry would be a welcome addition to the current policy debate. Unfortunately, this report is hopelessly inadequate on both margins. At a minimum, the authors would have needed to supplement their small group with more diverse expertise and secure rigorous, independent scholarly peer review to ensure that they had not allowed their personal values and political agendas to color their scientific analysis.

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[3] See, e.g., **National Research Council.** *Risk Assessment in the Federal Government: Managing the Process*. Washington, D.C.: National Academies Press, 1983, **____.** *Science and Judgment in Risk Assessment*. Washington, D.C.: National Academies Press, 1994, **____.** *Understanding Risk: Informing Decisions in a Democratic Society*. Washington, D.C.: National Academies Press, 1996, **Presidential/Congressional Commission on Risk Assessment and Risk Management.** "Framework for Environmental Health Risk Management," Washington, D.C., 1997, **Presidential/Congressional Commission on Risk Assessment and Risk Management and Risk Management.** "Risk Assessment and Risk Management in Regulatory Decision-Making," Washington, D.C., 1997..

[4] See, e.g., **Klaassen, Curtis D.** ed**.** *Casarett & Doull's Toxicology: The Basic Science of Poisons*. New York: McGraw-Hill Medical Publishing Division, 2001. This textbook is the single required reading for UC Berkeley's *undergraduate* course in toxicology (Nutritional Sciences and Toxicology 110P). See http://nutrition.berkeley.edu/undergrad_class/nst-110/.

[5] Wilson I at 84-86. See also West Berkeley Alliance for Clean Air and Safe Jobs, *Media Release: Health Risk Assessment or Toxic Use Reduction?*, October 2007 ("Dr. Michael Wilson of the University of California at Berkeley School of Public Health has said that Health Risk Assessment is not an effective tool, while Toxic Use Reduction has proven much more promising.") (http://www.westberkeleyalliance.org/docs/mediarelease/hra_release_10_11_07.pdf).

II. What is (or Isn't) Green Chemistry?

"Green chemistry" as a term of art appears to date from the mid-1990s. A number of definitions are available, and although they are very similar, there are important differences among them. For example:

- How are each of the generally accepted criteria defined in practice? There is widespread agreement on a set of "12 principles," but there appears to have been little debate about what these principles mean in practice.
- How are each of the generally accepted criteria measured? Many of them are defined subjectively, so consensus on definitions requires prior agreement on values.
- How are tradeoffs made among these criteria? Even of all 12 are easily measured, they cannot be simultaneously maximized.
- What is the role of cost-effectiveness? Green chemistry first appeared within U.S. EPA's statutorily based pollution prevention hierarchy, which has an explicit role for cost-effectiveness. Subsequent versions differ, with some invoking cost-effectiveness and others denying any role at all for the consideration of cost.
- How is opportunity cost taken into account? The term *opportunity cost* is economics jargon for the value of benefits that must be foregone in order to obtain something else of value. Just as it is said, "there is no such thing as a free lunch," the resources that are devoted to green chemistry must come from somewhere. It is essential to know the location of this place called Somewhere so that the benefits that much be given up can be properly tallied.
- What is the role of science? The criteria are founded on certain premises that are presumed to be factual. It is not clear what happens if any of these premises is refuted by science.

For any discussion of green chemistry to be informative, it must be transparent about how each of these issues will be resolved.

A. U.S. EPA's pollution prevention hierarchy

Before the term "green chemistry" appeared, the U.S. EPA was directed by Congress to implement the Pollution Prevention Act of 1990 (PPA).[6] The PPA established as national policy a hierarchy of waste management that emphasized *source reduction*:

> The Congress hereby declares it to be the national policy of the United States that pollution should be prevented or reduced at the source whenever feasible; pollution that cannot be prevented should be recycled in an environmentally safe manner, whenever feasible; pollution that cannot be prevented or recycled should be treated in an

[6] 42 U.S.C. 13101 et seq.

> environmentally safe manner whenever feasible; and disposal or other release into the environment should be employed only as a last resort and should be conducted in an environmentally safe manner.[7]

Congress gave the term *source reduction* a definition:

> (A) The term "source reduction" means any practice which—
>
> > (i) reduces the amount of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment (including fugitive emissions) prior to recycling, treatment, or disposal; and
> >
> > (ii) reduces the hazards to public health and the environment associated with the release of such substances, pollutants, or contaminants.[8]
>
> The term includes equipment or technology modifications, process or procedure modifications, reformulation or redesign of products, substitution of raw materials, and improvements in housekeeping, maintenance, training, or inventory control.
>
> (B) The term "source reduction" does not include any practice which alters the physical, chemical, or biological characteristics or the volume of a hazardous substance, pollutant, or contaminant through a process or activity which itself is not integral to and necessary for the production of a product or the providing of a service.

Source reduction means reduction, not elimination, and reductions in mass and hazard both qualify, but reductions in risk achieved by waste treatment do not qualify. Implicitly, source reduction also includes what is now called green chemistry (e.g., "reformulation or redesign of products"). The definition also includes a host of activities that are not part of green chemistry (e.g., "improvements in housekeeping, maintenance, training, or inventory control").[9]

Congress' commitment to this policy appears to have been largely hortatory, however. It did not delegate significant rulemaking authority to U.S. EPA. Rather, it authorized the EPA Administrator to "establish in the Agency an office to carry out the functions" set forth in the law "independent of the Agency's single-medium program offices," and with "the authority to review and advise such offices on their activities to promote a multi-media approach to source reduction."[10] This new office would be able to advise the single-medium program offices but not overrule their decisions. The law gave the office 13 functions to perform, none of which is expressly regulatory. [11]

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[7] 42 U.S.C. 13101(b).

[8] 42 U.S.C. 13102(5)(A).

[9] Id.

[10] 42 U.S.C. 13103(a).

[11] 42 U.S.C. 13103(b).

Congress appears to have assumed and expected that source reduction would be cost-effective relative to end-of-pipe treatment or pollution control. This is evident from its findings, in which it is stated:

> There are significant opportunities for industry to reduce or prevent pollution at the source through cost-effective changes in production, operation, and raw materials use. Such changes offer industry substantial savings in reduced raw material, pollution control, and liability costs as well as help protect the environment and reduce risks to worker health and safety.[12]

Source reduction might occupy the highest rung on the pollution prevention ladder, but options that are not cost-effective do not qualify as pollution prevention.

U.S. EPA appears to have first linked source reduction with the nascent concept of green chemistry in a 1998 research plan:

> The goal of this research effort is to improve existing chemical design practices by developing more environmentally benign chemical synthesis (i.e., green chemistry) and safer commercial substances. Green chemistry research was established to promote fundamental and innovative chemical methodologies that accomplish pollution prevention and have broad application in the industrial sector. It is the use of chemistry for source reduction, the highest tier of the risk management hierarchy.[13]

Sometime later, the Agency altered its Pollution Prevention Hierarchy by renaming it a "Sustained Chemistry Hierarchy" and replacing the term *source reduction* with *green chemistry*.[14] Perhaps recognizing that its statutory authority is limited to the Pollution Prevention Act, its definition retains the PPA's bow toward cost-effectiveness:

> Green chemistry, also known as sustainable chemistry, refers to environmentally friendly chemicals and processes that result in: reduced waste, eliminating costly end-of-the-pipe treatments; safer products; and reduced use of energy and resources—all improving the competitiveness of chemical manufacturers and their customers.[15]

This makes sense because without cost-effectiveness, green chemistry cannot "improve[] the competitiveness of chemical manufacturers and their customers." Firms facing competition will not voluntarily adopt methods that fail a cost-effectiveness test, and Congress did not give U.S. EPA the authority to require that they do.

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[12] 42 U.S.C. 13101(a)(2).

[13] **U.S. Environmental Protection Agency, Office of Research and Development.** "Pollution Prevention Research Strategy," U.S. Environmental Protection Agency, Washington, D.C., 1998, 46.

[14] U.S. Environmental Protection Agency, *Green Chemistry: Basic Information* (http://www.epa.gov/greenchemistry/pubs/whats_gc.html).

[15] U.S. Environmental Protection Agency, *Green Chemistry* (http://www.epa.gov/greenchemistry/).

It is also worth noting that government failure (discussed in greater in Section VI) loomed large in the description of the problem Congress directed EPA to solve through the Pollution Prevention Act:

> The opportunities for source reduction are often not realized because existing regulations, and the industrial resources they require for compliance, focus upon treatment and disposal, rather than source reduction; existing regulations do not emphasize multi-media management of pollution; and businesses need information and technical assistance to overcome institutional barriers to the adoption of source reduction practices.

Congress seems to have recognized that adherence to media-specific pollution control regulations, mandated by Congress and implemented by EPA, was responsible for much of the problem.

B. Anastas & Warner (1998)

In a 1998 book, Anastas and Warner (A & W) first elucidated what are known as the "12 Principles of Green Chemistry."[16] Since 1998, these principles have experienced little evolutionary change. These principles have been adopted literally by several organizations[17] and adjusted a bit at the margin by others.[18] At the time, Anastas was a U.S. EPA employee who presumably had a significant role in replacing "source reduction" with "green chemistry" in the pollution prevention hierarchy. However, the Pollution Prevention Act makes only a cameo appearance in the book (p. 7).

A & W acknowledge that risk is a function of hazard *and* exposure, but they assert that reducing hazard ought to always be preferred.[19] By focusing entirely on

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[16] **Anastas, Paul T. and Warner, John C.** *Green Chemistry: Theory and Practice*. New York: Oxford University Press, 1998.

[17] See, e.g., the Center for Green Chemistry and Engineering at Yale University, which Anastas directs (http://greenchemistry.yale.edu/definitions/); the Warner Babcock Institute for Green Chemistry, which Warner directs (http://www.beyondbenign.org/greenchemistry/greenchem.html); the American Chemical Society's Green Chemistry Institute (ACS/GCI) (http://portal.acs.org:80/portal/acs/corg/content?_nfpb=true&_pageLabel=PP_ARTICLEMAIN&node_id=1415&content_id=WPCP_007504&use_sec=true&sec_url_var=region1). Anastas has proposed a companion set of 12 Principles for Green Engineering (http://greenchemistry.yale.edu/definitions/), which ACS/GCI has adopted (http://portal.acs.org:80/portal/acs/corg/content?_nfpb=true&_pageLabel=PP_ARTICLEMAIN&node_id=1415&content_id=WPCP_007505&use_sec=true&sec_url_var=region1). These principles are not examined further in this report because they are neither contained nor referenced in Wilson II or companion Cal EPA documents.

[18] See, e.g., U.S. EPA (http://www.epa.gov/greenchemistry/pubs/principles.html). The Warner Babcock center's restatement of the 12 Principles includes three overarching constraints not found in the original or in the Yale version: Green chemistry must be "more environmentally benign," "more economically viable," and "must functionally outperform" the alternatives. Although "environmentally benign" is not clearly defined, it could be inferred to mean "less risky" rather than simply "less toxic." See http://www.beyondbenign.org/pdf/gengc12p.pdf.

[19] **Anastas, Paul T. and Warner, John C.** *Green Chemistry: Theory and Practice*. New York: Oxford University Press, 1998. at 14.

hazard, "the concept of a level of acceptable risk is eliminated as a target and replaced with the optimal goal of environmentally benign." This goal is not optimal, however, if risk reduction is what is intended. It cannot be optimal because it is either ineffective, inefficient, or both.[20] If there is no level of risk that is acceptable, effort to reduce risk cannot cease until zero risk is achieved.

The overarching principle of cost-effectiveness, found in the Pollution Prevention Act, is thus missing from what A & W call the "theory and practice of green chemistry." This is troubling as a matter of theory, for the reasons already set forth, but it is also an impractical way to inculcate green-chemistry principles. Where cost-effectiveness appears at all, it is more a matter of conviction or hope than empirically observed science,[21] and unlike the Pollution Prevention Act it is never stated as a condition that must (or even should) be met.

Indeed, none of the 12 principles contains any mention of cost-effectiveness. Two of these principles are presented as absolutes: Prevention is always superior to treatment or cleanup, and catalytic reagents are always superior to stoichiometric reagents.[22] Returning to the five questions raised at the beginning of this section on page 8, none of them is satisfactorily answered. It is not clear how these 12 principles are to be applied in practice, how they are to be measured, how tradeoffs among them are to be made, or what role science has if any of the foundational premises turn out to be refuted.[23] If taken literally, several of these principles could lead to undesirable outcomes, as Table 1 beginning on page 20 suggests.

The lack of attention to cost-effectiveness, tradeoffs, and opportunity costs are surely the most glaring theoretical and practical weaknesses in this exposition. Innovations that are not cost-effective will not be voluntarily adopted, either by firms or by consumers. Tradeoffs among the 12 Principles are inevitable in practice, but green-chemistry theory does not provide any guidance concerning how to weight each of them

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[20] It is ineffective because it achieves less risk reduction for any fixed resource commitment, and it is inefficient because it requires the expenditure of excess resources to achieve any fixed level of risk reduction. The optimal level risk reduction is achieved when marginal benefits equals marginal cost for expenditures on hazard reduction and on exposure control.

[21] **Anastas, Paul T. and Warner, John C.** *Green Chemistry: Theory and Practice*. New York: Oxford University Press, 1998. at 10: "A synthetic chemist who develops a 'green chemistry' synthesis is likely to produce a more cost-effective product when all direct and indirect costs are accounted for."

[22] Ibid. at 30. See also p. 32 for a transparently false analogy: ("The damage and the costs of fixing a problem are always greater than those of preventing it, whether it be appendicitis or toxic chemicals.") If it is true that preventing appendicitis is always preferred, then everyone's healthy appendix must be prophylactically removed by surgery at the earliest possible moment. The remaining 10 principles are conditions that *should* apply, which allows for circumstances in which the principle does not apply.

[23] Ibid. at 56-61(Fig. 5.1 through Fig. 5.3), generic examples of how to account for human toxicity). However, in each of these examples the "green chemistry" option is clearly dominant. Principle #7 says that "renewable" feedstocks should always be preferred to "depletable" feedstocks, but the presumed advantages of the former are susceptible to scientific refutation. For example, corn-based ethanol is clearly renewable but its net environmental and human health benefits may be negative. Similarly, extensive reliance on agricultural materials likely would result in significant expansion of land cultivation, with attendant environmental consequences.

at the margin. Unless prospective green-chemistry innovations are subjected to careful analysis of their opportunity costs, it cannot be responsibly assumed that their adoption increases the sum total of human welfare.

However, the issues posed at the outset of this section remain largely unexamined in the green chemistry literature. A more recent handbook on green chemistry by Manahan is illustrative.[24] The handbook's policy recommendations extend into a host of scientific areas beyond the author's expertise; he is dismissive of both the scientific content of other disciplines and scientific evidence that dos not support his policy views. To give just one obvious example, Manahan relates the famous bet between Paul Ehrlich and Julian Simon (which Simon won) but denies both its relevance and implications.[25]

For green chemistry to succeed without having to rely on governmental coercion, its advocates will need to incorporate scientific knowledge with which they are unfamiliar and uncomfortable – most notably, economics. This is made more difficult by the degree to which much of what green chemistry advocates "know" about economics is false.[26]

C. California Environmental Protection Agency

California appears poised to make exactly this transition in favor of coercion. The process was helped along in part by Wilson I, a consulting report prepared for the California legislature.[27] The report recommends that California adopt a comprehensive and mandatory program of toxic use reduction (TUR). The California Environmental Protection Agency has followed up with a Green Chemistry Initiative than appears to have been predestined to lead to TUR. Wilson II appeared in this context, as a marketing brochure for TUR that, interestingly, never uses TUR language.

1. Wilson I

Wilson I "evaluated six state and four federal chemicals policies to determine whether and to what extent they represent models that address the Data, Safety, and Technology Gaps engendered by TSCA," the Toxic Substances Control Act. Thus, it was a foundational premise that TSCA constituted a failed public policy; this premise would be carried over to Wilson II.

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[24] **Manahan, Stanley E.** *Green Chemistry and the Ten Commandments of Sustainability*. Columbia, Mo.: ChemChar Research, Inc., 2005.

[25] Ibid. In a debate over whether the world was running out of resources, Simon proposed a bet concerning the future price of five natural resources to be selected by Ehrlich. Ehrlich would win if prices rose (the expected result if economic scarcity had increased) and Simon would win if they did not. Prices did in fact fall, but Manahan rejects the experiment as irrelevant because "common sense dictates that Earth's resources are finite." This ignores the vast literature on the economics of exhaustible resources.

[26] Ibid. "Unfortunately, the conventional economic view of resources often fails to consider the environmental harm done in exploiting additional resources." An additional problem arises with the selective use of data. Having rejected the market prices of a diversified basket of commodities as a measure of scarcity in the Ehrlich-Simon bet, Manahan then says crude oil prices circa 2005 are proof of scarcity.

[27] The report was funded by the University of California's Policy Research Center, the Northern California Center for Occupational and Environmental Health (COEH), and UC Toxic Substances Research and Training Program. The original sources of these funds are not disclosed.

Of the 10 state and federal policies said to have been evaluated, Wilson I discusses only one -- the Massachusetts Toxic Use Reduction Act of 1989 – and in highly complimentary tones:

> Based on this analysis, we concluded that the Massachusetts Toxics Use Reduction Act (TURA) of 1989, though limited, is a model that is relevant to the development of a comprehensive chemicals policy in California. TURA is unique among U.S. environmental statutes in that it requires firms to report their *use* of hazardous chemicals, rather than their *releases* of chemical pollutants, and it requires firms to evaluate their operations and plan for process improvements. It is the only statute that includes an institute -- funded with fees assessed against the use of a list of particularly hazardous chemicals -- to provide ongoing technical assistance, training, and research for Massachusetts businesses in toxics use reduction strategies. Together, these approaches have motivated continual innovation by firms in strategies to reduce their use of hazardous chemicals. TURA takes a few steps toward correcting the Data, Safety, and Technology Gaps. We believe California can learn from (and build on) the 16 years of experience by government and industry in Massachusetts under TURA. [28]

Wilson I makes clear that the purpose of the Massachusetts TUR program's information disclosure mandates was not to fill *scientific* data gaps, but to serve the instrumental purpose of empowering third parties to force toxic use reduction. TURA's data disclosure mandates are mass- rather than risk-based. All chemicals listed for disclosure are assumed to be "inherently hazardous" and their "use in processes should be steadily reduced or eliminated." Fees charged on the use of chemicals are intended to "disadvantage[] them in the market" and fund a university-based program (much like COEH in California).[29]

According to Wilson I, TURA's weaknesses are stark. First, it lacks universal coverage and

> regulatory tools to compel recalcitrant firms to implement their toxics use reduction plans. The lack of a regulatory "hammer" may be allowing some companies to gain a competitive advantage in Massachusetts through poor environmental performance.[30]

The report is silent on the matter of whether TURA has rendered firms covered by he law less competitive.

According to Wilson I, the second major weakness in TURA is that it

> does not oblige manufacturers, retailers, or suppliers to evaluate the toxicity and ecotoxicity of chemicals used in intermediate or final

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[28] Wilson I at 67.

[29] Wilson I at 68

[30] Wilson I at 70.

> consumer and commercial products, or to disclose this information to consumers, workers, businesses, and industry. It does not require business and industrial buyers of chemicals to evaluate the toxicity and ecotoxicity of the chemicals they use, including those introduced into consumer and commercial products. It therefore does not support U.S. firms that are attempting to "clean" their supply chains.[31]

Wilson I endorses the coercive nature of TURA and advocated that it be applied, in much expanded form, in California. To close the "data gap," Wilson I calls for laws and regulations mandating that producers generate and disseminate "a more extensive set of toxicity data than is currently being gathered under the HPV [High Production Volume] program, along with basic exposure data."[32] California "could also consider adopting the battery of tests required under REACH," the European Union's Registration, Evaluation, Authorization and Restriction of Chemicals program.[33] The report advocates California impose REACH-like testing requirements on producers for at least the 30,000 chemicals targeted by REACH,[34] but preferably, all 80,000+ chemicals in the TSCA inventory.[35] In addition, the report recommends that producers be required to obtain yet more data from consumers about how they use chemicals and products.[36] These data requirements, even if technically feasible, would increase the cost of chemical manufacture and use, and thus consumer prices, though this appears to be precisely the intent.

Wilson I offers some insight concerning how these data would be used:

> [I]nformation should be made available to the public in a platform that will allow trade associations and public-interest groups to access it and develop it into forms that are useful for consumers, workers, small-business owners, and so forth.[37]

In practice, this means using screening-level data as proxy estimates of human health and environmental risk[38] subject to chemical producers proving the absence of risk. Requiring proof of safety

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[31] Wilson I at 70-71.

[32] Wilson I at 77. Given the doctrine in Wilson I, only mass and hazard matter. Thus, the purpose served by exposure data is unclear.

[33] **Wilson, Michael P.; Chai, Daniel A. and Ehlers, Bryan C.** "Green Chemistry in California: A Framework for Leadership in Chemicals Policy and Innovation," Berkeley, Calif.: California Policy Research Center, University of California, 2006, 131.

[34] Wilson I at 76.

[35] Wilson I at 75-76.

[36] Wilson I at 74.

[37] Wilson I at 78.

[38] Wilson I at 80-82.

> creates a compelling incentive for the producer to either generate chemical toxicity and exposure information for these chemicals or remove them from commercial circulation.[39]

Risk assessment could not be used to provide proof of safety. Mere "scientific suspicion of risk" would be sufficient to warrant a ban.[40] Bans would be achieved indirectly through a combination of regulatory instruments, the strongest of which would be a legal prohibition on the use of chemicals for which proof of safety had not been supplied to the government.[41]

2. The Cal EPA Green Chemistry Initiative

In April 2007, the California Environmental Protection Agency (Cal EPA) established a "Green Chemistry Initiative" with the stated purpose of

> develop[ing] a coordinated, comprehensive strategy designed to foster the development of information on the hazards posed by chemicals, ways to reduce exposure to dangerous substances, approaches that encourage cleaner and less polluting industrial processes, and strategies to encourage manufacturers to take greater responsibility for the products they produce.[42]

Whereas previous green-chemistry initiatives have been voluntary, this text clearly implies a planned coercive regulatory component. The purpose of the initiative thus appears to have been to identify regulatory tools for, and a political consensus if favor of, legislatively imposing TUR mandates.

This might not have been immediately apparent because TUR does not explicitly appear in the policy directive that lead to the initiative, and it was constrained by the outset by implicit expectations for both cost-effectiveness and scientific integrity:

> Our goal must be to significantly reduce public health and environment impacts, as well as costs, by affecting the redesign of product formulations and manufacturing processes. Our strategy, and the policy that it champions, must have at its core and be governed by sound science.[43]

A process called the "Conversation with California" was established by the Department of Toxic Substances control (DTSC), a subordinate agency of Cal EPA,

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[39] Wilson I at 79.

[40] Wilson I at 84.

[41] Wilson I at 86-88.

[42] Memorandum from Linda S. Adams, Secretary for Environmental Protection, to Chairpersons and Directors, Boards, Departments and Office, *California Environmental Protection Agency (Cal/EPA) Green Chemistry Initiative,* April 7, 2007 (http://www.dtsc.ca.gov/PollutionPrevention/GreenChemistryInitiative/upload/CalEPA_Green_Chemistry_Initiative_Memo.pdf).

[43] Ibid. at 2.

consisting of a "consultation with other government agencies, industry and affected stakeholders" that would produce

> a baseline assessment of existing programs, expertise and approaches related to the health and environmental effects of toxic chemicals and their sources, the identification of missing elements or "gaps" in how exposure to toxic chemicals is prevented or controlled, and the analysis of multi-media impacts.[44]

After this "Conversation," DTSC and other Cal/EPA entities would "develop lists of options the state could consider in filling the gaps identified in the baseline assessment." These options "should, at a minimum, be able to answer" a range of scientific and technical questions, including:

- toxicity of chemicals found in products, processes and commerce;
- physical and chemical properties of chemicals and their potential to leach or migrate from wherever they may be found;
- fate and transport of the chemicals in the environment;
- the health and environmental risks posed by those chemicals;
- the economic and technical feasibility of chemical and non-chemical alternatives to the use of particular chemicals; and
- the health and environmental risks posed by alternatives to those chemicals.[45]

This is both the first and he last place in the Initiative where these scientific and technical questions are asked.

3. The Options Report *Options*

This process yielded "818 options on ways to reduce the effects of toxic chemicals on people and the environment,"[46] though actual effects on people and the environment do not appear in the descriptions of the options themselves. The 818 options were then summarized into an Options Report by a Green Chemistry Initiative Team consisting of 49 state employees, which also did not identify scientifically credible estimates of effects on people and the environment.[47]

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[44] Id.

[45] Id.

[46] California Department of Toxic Substances Control, *Green Chemistry Initiative: Key Documents*, http://www.dtsc.ca.gov/PollutionPrevention/GreenChemistryInitiative/KeyDocs.cfm; California Department of Toxic Substances Control, *Green Chemistry Initiative:* California Green Chemistry Initiative; Phase 1—A Compilation of Options, January 2008 (http://www.dtsc.ca.gov/PollutionPrevention/GreenChemistryInitiative/upload/Phase_1_Options_Report_Chapters.pdf).

[47] California Department of Toxic Substances Control, *Green Chemistry Initiative: Phase One — Options Report; Acknowledgements,* January 2008 (http://www.dtsc.ca.gov/PollutionPrevention/GreenChemistryInitiative/upload/Acknowledgements.pdf).

This Options report includes:

- 6 data collection options;
- 5 economic incentive options;
- 12 statutory and regulatory options;
- 3 voluntary measures options;
- 3 education and outreach options;
- 3 research and technology options;
- 3 technical assistance options;
- 3 recognition, award, and certification options

It is worth noting that at least 12 of the 37 options proposed are regulatory mandates. Although the Options Report summarizes the public input Cal EPA received, the essential scientific and technical questions, listed above as the foundation fort the project, were not addressed.

4. The Options Report *Executive Summary*

The Executive Summary is largely distinct from the catalog of alternatives presented in the Options Report. Like the Options Report, it too does not address the scientific and technical questions posed at the outset. Most of its text consists of a restatement of the 12 Principles set forth by A &W in 1998. It relies extensively on the proposition that green chemistry is more revolutionary than evolutionary:

> Green Chemistry is a strategy to reduce the use of toxic substances so that they do not harm the public or contaminate the environment. It seeks to fundamentally remake the way we make things via the design and manufacture of products with little or no hazardous substances. It reduces the overall "footprint" of goods and processes.[48]

Thus, Cal EPA intends its Green Chemistry Initiative to "fundamentally remake" chemistry in a way that essentially eliminates hazard, not reduce *risk*. These inferences are reinforced by a "do no harm" philosophy believed by its proponents to be a radical change from generations, if not centuries, of chemistry practice.

> Much like the Hippocratic code in medicine, Green Chemistry promotes chemicals and processes that do no harm or reduce harm to human health and the environment. Green Chemistry seeks to transform industrial activity to create a zero-waste society.[49]

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[48] California Department of Toxic Substances Control, *Green Chemistry Initiative: Phase One — Options Report; Executive Summary*, January 2008, p. ii (http://www.dtsc.ca.gov/PollutionPrevention/GreenChemistryInitiative/upload/Executive_Summary.pdf).

[49] Ibid at iii. Cf. **Anastas, Paul T. and Warner, John C.** *Green Chemistry: Theory and Practice*. New York: Oxford University Press, 1998. at 12: "Much like the Hippocratic procedures and protocols, a synthetic chemical methodology, to be truly elegant, mist 'first do no harm'."

A "zero-waste society" is truly a radical idea. Cal EPA would abandon the longstanding notion that risks and benefits both matter and that they should be managed or balanced. The position taken here is that only hazard and mass matter, and both should be avoided at all cost. The policy directive that started the initiative may have prescribed that costs be taken into account, but this appears to have been quickly abandoned.

5. Wilson II

It is in this context that Wilson II simultaneously appeared in January 2008. Despite its university branding, it is essentially a promotional brochure for the Options Report Executive Summary. It does not analyze any of the 37 policy options containing 818 elements. Rather, it provides a scientific veneer for the Executive Summary.[50] With respect to the definition of green chemistry, Wilson II mimics the Executive Summary by defining it in terms of abandoning chemistry as it has been practiced for hundreds of years in favor of a radical, new approach in which only mass and hazard (but not risk) matter.

More importantly, Wilson II takes the next step of advocating that green chemistry become the new vessel for marketing toxic use reduction as public policy. The generation of waste per se must be eliminated. This cannot be achieved without a highly coercive regulatory footprint, so the State of California must enact laws authorizing Cal EPA to design and enforce such a comprehensive regulatory presence.

Because of these significant differences in past usage of the term "green chemistry," in the remainder of this report Wilson II is described as a promoting set of policy recommendations for statutorily mandating toxic use reduction. Green chemistry has instrumental value for advancing TUR, but TUR rather than green chemistry is the authors' objective.

[50] Five funding sources are listed: (1) Cal DTSC; (2) California Policy Research Center, UC Office of the President; (3) UC Centers for Occupational and Environmental Health; and (4) the National Institute for Occupational Safety and Health; and (5) the U.S. Centers for Disease Control and Prevention.

Table 1: The 12 Principles of Green Chemistry: Theory and Practice

Theory	Practice
1. It is better to prevent waste than to treat or clean up waste after it has been created.	• What if prevention is technically impossible? What if prevention is not technically impossible, but extraordinarily expensive? • Does the principle apply if prevention is not cost-effective, even after all costs and benefits are accounted for?
2. Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product	• If atom economy is per se desirable, then atoms must be scarce. • What if the incorporation of all materials used in the process yields a riskier final product?
3. Wherever practicable, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment.	• Where risk is more readily reduced by exposure control, this invites suboptimal risk minimization.
4. Chemical products should be designed to effect their desired function while minimizing their toxicity.	• What if efficacy of function must be compromised to achieve reduced toxicity?
5. The use of auxiliary substances (e.g., solvents, separation agents, etc.) should be made unnecessary wherever possible and innocuous when used.	• What if a comprehensive risk assessment shows that an auxiliary substance is technically necessary? • What if the alternative to an auxiliary substance results in greater risks to human health and the environment?
6. Energy requirements of chemical processes should be recognized for their environmental and economic impacts and should be minimized. If possible, synthetic methods should be conducted at ambient temperature and pressure.	• What if the application of energy results in lower risks to human health and the environment than other alternatives?
7. A raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable.	• What if the environmental and human health risks associated with a renewable feedstock exceed the environmental and human health risks associated with a depletable feedstock? • What does "economically practicable" mean?
8. Unnecessary derivatization (use of blocking groups, protection/ deprotection, temporary modification of physical/chemical processes) should be minimized or avoided if possible, because such steps require additional reagents and can generate waste.	• How is "unnecessary" derivitazation defined, and who decides? • What if derivitazation reduces risks to human health and the environment?

Theory	Practice
9. Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.	• What if catalytic reagents result in greater risks to human health and the environment?
10. Chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment.	• What if degradation byproducts turn out not to be innocuous? How much "non-innocuousness" is acceptable, and who decides? • What if environmental persistence is not accompanied by increased risk?
11. Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.	• What if the availability of real-time data invites the use of process control technologies that increase risks to human health and the environment?
12. Substances and the form of a substance used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions, and fires.	• The potential for accidents and releases is literally "minimized" only if the process is prohibited. Is that what is intended? • If not, then this potential can only be minimized subject to defined constraints. Which constraints are considered, and which are not?
Source: Anastas & Warner (1998) at 30.	

III. Market Failure

Market failure is the technical term in economics for the condition where differences exist between the private and social costs or benefits of a good, service, or activity. It dates from no later than 1958.[51] Gaps between private and social costs are called *externalities*. A *negative externality* arises if a voluntary exchange between buyer and seller adversely affects a third party. A positive externality occurs if the exchange makes a third party better off. In the former case, costs are imposed on the third party without his consent. In the latter case, the third party obtains a benefit without having to pay for it. Where negative externalities arise, there will be too much of the good, service or activity in the market, and its market price will be too low. Conversely, *positive externalities* mean that there is too little of the good, service or activity in the market, and the market price is too high.

Understood in a market failure framework, Wilson I and II both imply that chemical production and use per se *always* results in significant *negative* externalities – in particular, massive adverse effects on human health and the environment. However, the report fails to provide a scientifically credible story why any such causal relationship might actually exist. Instead, it notes the co-existence of chemicals and a selected list of ailments accompanying modern life in the richest nation in the history of the world, and simply assumes causality. More tellingly, the report does not even consider the possibility that innovation in conventional chemistry has generated significant *positive* externalities, such as benefits to human health and the environment, as if such an outcome is technically infeasible. Yet, there is no scientific reason to assume that the balance of externalities from conventional chemical production or use is always or usually negative. This can only be ascertained by objective, scholarly empirical research.

It is also important to note that not all pollution is an externality. Environmental risks usually are negative externalities, but they are not if they are the products of economically efficient taxes or permit schemes. Pollution taxes or permits internalize environmental costs such that the optimal level of pollution remains.[52] Command-and-control regulation, which by all accounts is extensive with respect to chemical production and use, is intended to significantly reduce the creation of negative externalities. Nevertheless, the much-smaller level of pollution that remains after command-and-control regulation is still a negative externality because no price is paid for its generation.[53]

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[51] **Bator, Francis M.** "The Anatomy of Market Failure." *Quarterly Journal of Economics*, 1958, *72*, pp. 351-79.

[52] Wilson I rejects economic incentives that fully internalize externalities because the objective of TUR is to minimize the manufacture and use of chemicals having a "scientific suspicion of risk" (p. 84). In contrast, the objective of economic incentives is to maximize the net social benefits from the production and use of chemicals, taking account of all human health and environmental risk.

[53] To be clear, waste disposal that is paid for is not a negative externality. Emissions and effluents that are *not* paid for are externalities except in the case where emissions or effluents do not escape the property boundary.

Human health risks follow this pattern. Risks that result from occupational exposure to hazards are negative externalities if employment is involuntary or workers are ignorant of the risks they bear, or if they are not fully compensated for risk-bearing.[54] Consumer products also may have associated negative externalities if consumers are not aware of the risks from intended use.[55]

A. Imperfect information is not necessarily market failure

There is no market in which consumers have perfect information about the products they buy, and there is no market in which sellers have perfect information about the tastes and desires of consumers. Furthermore, there are always asymmetries in information between buyers and sellers. These asymmetries can work to the extreme disadvantage of buyers in some cases (e.g., homes, used cars), but they can significantly favor buyers in others (e.g., insurance, antiques). Yet, markets for each of these goods still exist, and even thrive, because the party possessing superior information has strong incentives to reveal it to secure a better deal.[56]

Lessons from the rich literature in the economics of information are nowhere to be found in Wilson II. The report adopts instead a simplistic view in which it is assumed that imperfect information about chemicals is inherently a severe defect in the marketplace, and one that operates to workers and consumers disadvantage. The report states:

> Manufacturers and businesses can sell a chemical or product without generating or disclosing adequate information about its potential health or environmental hazards.[57]

This alleged market failure prevents consumers from choosing products "on the basis of their potential health and environmental impacts," prevents businesses and manufacturers

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[54] There is an extensive economics literature concerning wage premiums for bearing occupational risks. See, e.g., **Viscusi, W. Kip.** *Fatal Tradeoffs: Public and Private Responsibilities for Risk*. New York: Oxford University Press, 1992, ____**.** *Rational Risk Policy*. Oxford: Clarendon Press, 1988, ____**.** *Risk by Choice: Regulating Health and Safety in the Workplace*. Cambridge, Mass.: Harvard University Press, 1983.

[55] A different form of externality arises in cases where producers are held liable for adverse effects resulting from *unintended* uses, or firms are held liable for illness that was not caused by employment. Product liability usually is strict, and there are well known examples in which the effect (if not the purpose) of product liability litigation was rentseeking. See, e.g., **Angell, Marcia.** *Science on Trial*. New York: W.W. Norton, 1997, **Schuck, Peter H.** *Agent Orange on Trial: Mass Toxic Disasters in the Courtroom*. Cambridge, Mass.: Belknap Press, 1986..

[56] This idea is neither new nor controversial. The seminal article in the literature is almost 40 years old. See: **Akerlof, George.** "The Market for Lemons: Quality Uncertainty and the Market Mechanism." *Quarterly Journal of Economics*, 1970, *84*(3), pp. 13.. In 2001, Akerlof won a share of the Nobel Prize in economics for this and related scholarship.

[57] Wilson II at 2. See also 85, acknowledging that perfect information is infeasible: "[B]ecause 'perfect information' is unobtainable (especially with regard to the health or environmental effects of chemicals), policy decisions must inevitably be made under conditions of uncertainty." According to Wilson I, imperfect information is a defect of markets that has instrumental value for the purpose of using governmental power to drive chemicals out of the marketplace.

from "identify[ing] and eliminat[ing] hazardous chemicals and products in their supply chains," and undermines the "deterrent function of the product liability and workers' compensation systems."[58] Although imperfect information constitutes a market failure whose solution is government regulation, the fact that government can neither produce nor mandate perfect information is not considered a defect of regulatory intervention.

Although Wilson II states that the amount of information currently generated and disclosed is *in*adequate, it does not reveal what additional information would *be* adequate.[59] The report glosses over what additional information would remedy this defect[60] but confidently proposes that the State can effectively demand that it be produced anyway. The report never discusses what value additional data would have for private or public decision-making.[61]

Even if Wilson II is correct that there is too little information in the marketplace about risk as a product attribute, it does not follow that the result is excess adverse health or environmental effects. Such a conclusion ignores a fundamental principle of decision theory: in the presence of uncertainty about the riskiness of a substance, process or product, normal risk-aversion will lead individuals (and firms) to *reduce* their risk exposure, not to accept or increase it.[62] For example, workers with acrophobia will decline jobs that present even the appearance of a falling risk irrespective of the degree to which that risk has been technically managed. They are almost certain not to choose skydiving as a hobby even though the average fatality risk is less than 1 in 100,000.[63] This is the geometric mean of the risk range that U.S. EPA uses to define *de minimis* risk,

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[58] Wilson II at 7. Strict liability undermines the deterrent effects of the product liability and workers' compensation systems. Consumer products are more expensive because users who follow directions subsidize consumers who don't. Workers who gain from dubious settlements and judgments raise the effective price of labor, and thus reduce the wages of workers generally.

[59] Hints are provide elsewhere. See, e.g., Wilson I at 74-78, and Section II.C.1 beginning on page 13. Also, the "Solutions" chapter of Wilson II says "[c]hemical producers and product manufacturers should be required to provide hazard and tracking data as a condition of use or sale in California. Chemical and product distributors should also be required to contribute tracking data." There is a wide variety of tests that could be construed as "hazard data"; which tests yield information with the greatest value? Which tests have *any* value? The report appears to be concerned about chemicals at the molecular level. Do scientists (much less the public) know how to objectively, accurately and without uncertainty interpret molecular information?

[60] Wilson II at 20: "California should identify the best available toxicity testing methods and support research and development of new methods."

[61] If every chemical or consumer product in the marketplace had, say, an LD_{50} or similar statistic, what would consumers do with this information?

[62] See, e.g., **Raiffa, Howard.** *Decision Analysis: Introductory Lectures on Choices under Uncertainty*. Reading, Mass.: Addison-Wesley, 1979. Wilson II presumes the opposite – that in the face of uncertainty about risk, decision-makers will be risk-loving.

[63] In 2006, there were 21 non-military fatalities reported in the U.S. out of at least 2.2 million jumps. See United States Parachute Association, *Accident Statistics* (http://www.uspa.org/about/page2/relative_safety.htm).

but most people – even those without a hint of acrophobia -- are likely to think that there is nothing *de minimis* about the risk of jumping out of a perfectly good airplane.[64]

One reason the public may perceive chemical risks to be much greater than they actually are is because conventional chemical risk assessment methods strive not to understate risk, and thus almost certainly overstate it, often by orders of magnitude.[65] If people incorrectly believe these risk estimates are unbiased, normal risk aversion will lead them to behave much more cautiously than they would if they had either unbiased estimates or perfect information. Adding new objective information about chemical risks generally diminishes risk perceptions and public concern; it does not increase it.[66]

B. External benefits are presumed large for green chemistry, but ignored for conventional chemistry

Markets also do not perform efficiently when they generate external *benefits* that are not captured in market prices. When this occurs it means that *too little* of the good, service, or activity is available and that market prices are *too high*. Correcting this market failure generally requires identifying a way to tax passive beneficiaries or (because that is often infeasible) subsidizing the production of the good, service, or activity that generates the external benefits. This is the longstanding justification for government funding of basic research.[67]

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[64] Accident reports are available for each of the 21 fatalities. Sixteen cases involved experienced parachutists who committed operator errors or were attempting high performance maneuvers. Two were students whose fatalities appear attributable to instructor errors (the instructors also were killed). One was a novice who was not properly secured to her instructor's tandem. Excluding experienced parachutists who are most knowledgeable about risk, the fatality risk is about 1 in 1 million. See http://www.dropzone.com/fatalities/2006/North_America/index.shtml).

[65] **U.S. Environmental Protection Agency Office of the Science Advisor.** "An Examination of EPA Risk Assessment Principles and Practices," Washington, D.C., 2004.

[66] There is a rich literature in risk perception, also not found in this report or its 2006 antecedent, which tries to explain, among other things, why lay risk perceptions often exceed expert risk estimates by wide margins. See, e.g., **Slovic, Paul** ed**.** *The Perception of Risk*. London: Earthscan, 2000. Researchers have identified a number of social factors that amplify risk perceptions, including activism intended to increase risk perceptions. See **Pidgeon, Nick; Kasperson, Roger E. and Slovic, Paul** eds**.** *The Social Amplification of Risk*. Cambridge: Cambridge University Press, 2003.

[67] Advocates of *applied* research often use the same argument to seek subsidies. However, the more applied the research activity, the less credible is the argument that it will produce positive externalities. Patent ownership is a simple test of the capacity for any research endeavor to capture most (if not all) of the value of an invention, thereby limiting the scope and scale of positive externalities. A total of 6,164 U.S. patents issued since 1976 are assigned to the Regents of the University of California, which sponsored Wilson I and II. See http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&u=%2Fnetahtml%2FPTO%2Fsearch-adv.htm&r=0&p=1&f=S&l=50&Query=an%2F%28regents+and+university+and+California%29&d=PTXT. A total of 2,151 patent applications are pending that list the Regents as the assignee. See http://appft1.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&u=%2Fnetahtml%2FPTO%2Fsearch-adv.html&r=0&p=1&f=S&l=50&Query=an%2F%28regents+and+university+and+california%29&d=PG01.

Wilson II takes the position that green chemistry *will someday produce* vast external social benefits. For example, in a text box analogizing green chemistry to energy efficiency, the report makes the following claim:

> A new chemicals policy that supports green chemistry could produce similar benefits, opening new business and employment opportunities in safer chemicals and products while also improving human health and environmental protection.[68]

However, the report ignores the external benefits from conventional chemistry that Californians *enjoy right now.* To take just one example, the substitution of plastic for metal and glass has virtually eliminated public sector costs associated with tending to laceration injuries from breakage, significantly reduced petroleum consumption in transportation, and dramatically curtailed communicable foodborne illness and death from pathogenic organisms.[69] These any many other external benefits from conventional chemistry could be lost if green chemistry mandates were enacted.

C. External costs are presumed large for conventional chemistry, but ignored for green chemistry

Wilson I adopted the conventional model in which risk is a function of hazard and exposure.[70] Exposure can be tricky because duration matters but usually is not accounted for empirically. For some chemicals, exposure today cannot have consequences days or

[68] Wilson II at 22. The report asserts, but provides no supporting evidence for the assumption, that the benefits of energy efficiency innovations are positive externalities – that is, that they are not captured by market sellers or buyers. Moreover, the items listed are not necessarily social benefits. For example, a policy that creates thousands of unskilled jobs by disemploying productive capital and skilled labor is unlikely to qualify. In addition, California's energy efficiency has been achieved in part by suppressing supply and relying on imports from other states. In 2006, the state had 16.2% of U.S. crude oil reserves but produced 11.8% of U.S. output. See Energy Information Administration, *California State Energy Profile*, March 13, 2008 (http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=CA#Datum). In 2007, California generated 5.3% of U.S. electricity but in 2006 consumed 9.7% of U.S. production. See Id. and *State Data for Consumption & Sales*, April 5, 2007 (http://www.eia.doe.gov/cneaf/electricity/epa/sales_state.xls).

[69] Plastic packaging has been credited with significantly reducing the amount of food waste in the United States. See, e.g., **Tierney, John.** "Recycling Is Garbage," *New York Times Magazine.* New York, N.Y.: New York Times, 1996. ("Plastic packaging and fast-food containers may seem wasteful, but they actually save resources and reduce trash. The typical household in Mexico City buys fewer packaged goods than an American household, but it produces one-third more garbage, chiefly because Mexicans buy fresh foods in bulk and throw away large portions that are unused, spoiled or stale.") (Plastic packaging and fast-food containers may seem wasteful, but they actually save resources and reduce trash. The typical household in Mexico City buys fewer packaged goods than an American household, but it produces one-third more garbage, chiefly because Mexicans buy fresh foods in bulk and throw away large portions that are unused, spoiled or stale.") (http://query.nytimes.com/gst/fullpage.html?res=990CE1DF1339F933A05755C0A960958260&sec=&spon=&pagewanted=all).

[70] Wilson I at 6. It is conventionally assumed, for example, that carcinogens pose lifetime cancer risks proportional to lifetime dose. This is based on the assumption that all carcinogens operate through a genotoxic mechanism.

even hours later.[71] In Wilson II, however, this accepted framework is abandoned in favor of a pair of demonstrably incorrect but popularly appealing risk measures – units of mass and aggregate incidence of selected health effects irrespective of their cause.

1. Risk measured in units of mass

The report's adoption of this odd definition is evident from an early figure comparing the growth of global population relative to growth in chemicals production.[72] These figures are meaningful only if mass causes risk. However, the report makes no attempt to even show an *association* between mass and risk; rather, the argument begins and ends with the recognition that global chemicals production is rising faster than global population. The report does not even consider the possibility that increases in chemicals production are an indicator of rising worldwide wealth, especially wealth among the world's poor.

By measuring risk in units of mass, the report also makes no risk-based distinctions among chemicals. This is odd; elsewhere the report highlights chemicals that the authors believe pose especially grave risks, such as persistent organic pollutants and metals. Global chemicals production could be rising because larger quantities of less- or non-toxic chemicals are now made or used instead. If so, then by equating mass with risk, the report is condemning the solution to the problem it seeks to fix.

Wilson II voices grave concern that worldwide chemical production is "rapidly outpacing population growth,"[73] but why this should be a concern is not clearly stated. If chemicals production and wealth were not positively correlated (as they appear to be), then growth in per capita chemical production could be reduced either by simply restricting chemical production or by encouraging fertility. There is no evidence suggesting that the authors believe population growth would be a good thing, and some evidence that they believe it would be bad.[74] Therefore, comparisons of the relative pace of growth are irrelevant phenomena even if at first blush they seem intuitively appealing. Whatever is the problem that the report seeks to address, simply changing the rate of growth in chemicals production, population, or both, cannot be the solution.[75]

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[71] The classic example of this phenomenon is perchlorate, a reactive anion of significant interest in California. Perchlorate is not directly toxic, it is not stored in the body or metabolized, and it is excreted in a matter of hours. Exposures less than about 250 ppb in drinking water has been shown not to cause even nonadverse biological effects in healthy adults. See **National Research Council.** "Health Implications of Perchlorate Ingestion," Washington, D.C.: National Academies Press, 2005.

[72] Wilson II at 1 (Figure 1, showing population growth rising at 0.77% per year and chemicals production rising at 3% per year).

[73] Wilson II at 2. The construction "rapidly outpacing" is inherently pejorative irrespective of the phenomena being compared.

[74] Wilson I at 9 ("By 2050, California's population is expected to grow by about 50%, from 36 to 55 million residents. This expansion will be accompanied by a growing set of social, economic, and environmental problems…").

[75] As a thought experiment, imagine that tomorrow 50% of the mass of conventional chemicals production were instantaneously replaced by green chemicals. Worldwide chemical production would still be "rapidly outpacing population growth."

2. Risk measured as health effects incidence irrespective of cause

Wilson II also includes a purported "Index of Annual California Health and Environmental Indicators."[76] This index, which consists of 13 selected statistics among thousands available, is meaningful only if the items in the index are both measures of risk *and* they are the result of current chemicals production or use. None of these statistics qualifies.

Of the 13 numbers reported, four are measures of mass and have the inherent defects described above. Three are measures of incidence. None is a measure of risk, or even a recognized component of risk, such as hazard or exposure. Statistics on plastic waste are unrelated to risk, and they are conveniently reported in small units (pounds, not tons) to make them appear larger.[77] The incidence statistics purport to show annual cases of chronic disease (208,000) and premature deaths (4.400) attributable to "workplace chemical exposures."[78] The source of these estimates is an unfinished, unpublished, and non-peer reviewed work product co-authored by two of the five authors of Wilson II.[79] Likewise, the five listed "community health" measures have an odd mix of units: mass, percentages, dollars, and incidence. The mass "emission" statistic is insufficiently documented and likely to be wrong by about a factor of seven.[80] One of the dollar-denominated figures comes from the authors' own unfinished, unpublished and non-peer reviewed work; the other is an undocumented adjustment of an estimate published in 1992 concerning pesticides, which elsewhere the report says do not even have a "safety gap" for green chemistry to solve.[81] Finally, the incidence statistic in this group is unrelated to chemical production or use.[82]

3. Other erroneous risk definitions used in the report

For a market failure to be occurring *now* due to human health or environmental risks posed by chemicals production or use *today*, there must be evidence of human health or environmental harm (or at least biomarkers of such effects) that can be reliably

[76] Wilson II at 2.

[77] Totals need to be divided by population to account for the size of the California market. For per capita amounts, divide by about 36 million.

[78] Wilson II at 2 ("Index of Annual California Health and Environmental Indicators").

[79] Cited in the report as Leigh P, Wilson M, Schwarzman M. Costs of Toxic Chemical-induced Occupational Diseases Among Adults in California (2008), *in preparation*. These estimates are discussed in greater detail in Section IV.C beginning on page 39.

[80] The U.S. EPA's TRI Explorer (http://www.epa.gov/triexplorer/, accessed February 23, 2008) fact sheet for California 2006 shows 3,465,346 pounds of fugitive air emissions, 13,310,651 pounds of point source air emissions, and 5,026,690 pounds of surface water discharges – a total of 21,793,687 pounds of reportable emissions and effluent, which is 14% of the value given in the report.

[81] Wilson II at 8: "*With the exception of pesticides and pharmaceuticals*, laws governing chemicals in the U.S. and California generally require public agencies, not producers, to carry the burden of proof that a chemical or product causes unreasonable harm to human health or the environment before the agency can implement protective measures" (emphasis added, footnote omitted).

[82] The issue of methylmercury is addressed in more detail in the subsection below beginning on page 30.

attributed to chemicals exposure resulting from *past examples of current market transactions or activities* involving chemicals. Extinct market transactions and activities are irrelevant; innovations made today or tomorrow in green chemistry generally will not affect them.[83]

Many of the claims made in the report concerning adverse health and environmental effects that are irrelevant to green chemistry for reasons other than the temporal disconnect described above, or they involve risks that may not actually exist. However green chemistry is defined, innovations tomorrow cannot affect risks associated with extinct market transactions and activities, or reduce or eliminate speculative risks.

i. Extinct market transactions and activities

Wilson II relies on numerous statistics that purport to be relevant to current market transactions but in fact are not. For example, the report claims that 72% of "the state's largest hazardous waste sites [are] leaking toxic material into groundwater."[84] This claim appears to involve sites constructed before the promulgation, over a decade ago, of extremely stringent design and operating standards for hazardous waste disposal facilities. It is hard to follow why such a large fraction of new California waste sites leak "toxic material" given that such leaks are strictly prohibited by regulation. The most likely explanation is that these leaks come from legacy waste sites that no longer have operating permits.

Wilson II also provides a statistic purporting to measure the environmental burden posed by *current* hazardous waste generation. According to the report, U.S. EPA "estimates that the country will require 217,000 new hazardous waste sites by 2033," Presumably to manage future hazardous waste generation.[85] However, the U.S. EPA document cited in Wilson II says no such thing. It's a 20-year old, unsubstantiated estimate of the number of *legacy* hazardous waste sites *yet to be found*.[86]

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[83] To the extent that legacy contamination involves chemicals that are no longer marketed, no *current* market failure exists. Nevertheless, green-chemistry innovations may have significant value if they can achieve greater, faster, or less expensive remediation of legacy contamination.

[84] Wilson II at p. 2 ("Index of Annual California Health and Environmental Indicators").

[85] Wilson II at 10.

[86] U.S. EPA, Office of Solid Waste and Emergency Response, *Cleaning Up the Nation's Waste Sites: Markets and Technology Trends; 2004 Edition* (EPA 542-R-04-015) at 1-4 (embedded citations omitted):

> Under current regulatory requirements and practices, an estimated 294,000 sites (range 235,000 - 355,000) in the seven market segments will need to be cleaned up. This estimate does not include sites where cleanup is completed or ongoing.
>
> …
>
> The 294,000 sites estimate includes 77,000 sites that have already been discovered plus an estimated 217,000 sites estimated to be discovered in the future. The estimate of the number of future sites is based on the rate of new site discoveries in recent years and is expected to be highly variable from year to year. Future discoveries could very well turn out to be higher or lower than in the past. Most of these "future" sites would be managed under the UST [underground storage tank] and state mandatory and voluntary cleanup programs, including brownfields.

ii. Irrelevant market transactions or activities

At several places, Wilson II emphasizes adverse human health effects that have nothing to do with chemical production or use. These health and environmental effects, even if genuine, are irrelevant to green chemistry.

Example #1: Methlymercury. The report claims that 1 million women of reproductive age have blood mercury levels above "what U.S. EPA considers safe."[87] These figures are controversial for a number of reasons, including U.S. EPA's reliance on only a subset of the available epidemiologic data and the highly precautionary risk management preferences of its scientific staff.[88] More importantly, human methylmercury exposure (especially in California) is driven by the consumption of ocean fish caught thousands of miles away. It has nothing at all to do with chemical production or use in California, and it won't be affected at all by even a green chemistry "Manhattan Project."

Example #2: Pesticides. The foundational premise of the report is that the Toxic Substances Control Act (TSCA) has been ineffective and that mandatory toxic use reduction is therefore desirable and justified. Thus, one might reasonably expect that the report would exclude matters unrelated to TSCA, and especially, matters for which the alleged defects of TSCA do not exist. Yet, the report devotes considerable attention to alleged health risks from pesticides even though pesticides are regulated under entirely different statutory authorities that have none of the structural flaws alleged to be found in TSCA.[89] The report asserts that TSCA has failed because producers do not have to first prove that their products meet regulatory standards for safety, and then claims that pesticide regulation also has failed even though registrants have precisely this legal obligation.

Example #3: Air pollution. The report claims that in 2004, an estimated 237,363 California residents developed asthma because of "chemical substances in food, water,

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U.S. EPA acknowledges that this forecast was based on generous assumptions:

> This analysis assumes that EPA will add new sites to the [National Priorities List] for another 10 years, UST site discoveries will continue for 10 years, and new state and private party site discoveries will continue for 30 years.

The origin of U.S. EPA's 217,000 estimate is not clear. The same estimate also is reported, without reproducible derivation, in the 1996 edition of this series. See U.S. EPA, Office of Solid Waste and Emergency Response, *Cleaning Up the Nation's Waste Sites: Markets and Technology Trends; 1996 Edition* (EPA 542-R-96-005) at 1-2 (http://www.epa.gov/tio/download/market/market.pdf).

[87] Wilson II at 2 ("Index of Annual California Health and Environmental Indicators"). This figure is derived from a personal PowerPoint slide presentation, not a scientific document.

[88] "Safety" is a policy determination that is supposed to be made by Agency officials based on scientific and other inputs. The safety threshold alluded to in Wilson II is a policy judgment made by Agency scientists based on their personal views concerning how much risk is too much.

[89] See footnote 81 for a clear acknowledgement in Wilson II that whatever "safety gap" might exist with respect to TSCA, it does not exist with respect to pesticides because manufacturers have a statutory burden to prove safety. For additional references to pesticides, see Wilson II at 11, 13, 15, 16, and 19.

air, soil, the home and community."[90] The source for this estimate is the authors' unfinished, unpublished, and non-peer reviewed work "in preparation." None of the data or methods they used is disclosed. What are the likely sources of these asthma cases? U.S. EPA and the California Air Resources Board say the environmental causes of asthma are predominantly tropospheric ozone and particulate matter. Ground level ozone and particulates are environmental problems almost always associated with fuel combustion. Why asthma appears in a report criticizing TSCA is hard to follow.

iii. Speculative risks

The report devotes a great deal of attention to biomarkers of exposure (not effect) and implies that they are sound indicators of human health risk.[91] They provide little supporting scientific evidence, however. According to the report's "mass equals risk" model, however, it is sufficient to show the presence of any amount of mass rather than a significant amount of risk. Consistent with the authors' decision to ignore the social benefits of chemicals, they pay no attention to the extent to which products made from the chemicals they target have reduced human health risk or saved lives.[92]

iv. Nonexistent risks

The report asserts that there is a "[r]ising incidence of some cancers, asthma, and developmental disorders," and that these health effects "may be due in part to chemical exposures, particularly in young children."[93] The scientific basis for these claims is exceptionally weak. It consists of a generalized and unspecific reference to a federal cancer registry, a pair of literature reviews, and one research article. None of the references cited has anything to do with asthma. The author of the cited research article did not even find the effects that the report claims were "rising," much less show that they are associated with chemicals.[94] One of the literature reviews does not concern

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[90] Wilson II at 18 (Figure 2).

[91] Wilson II at 12-13. Biomarkers of *exposure* are not the same as biomarkers of *effect.* Biomarkers of effect may not be sensitive but at least they are selective, and thus they convey potentially useful information for decision-making. Biomarkers of exposure typically are sensitive but rarely are sensitive. Thus, biomarkers of exposure are excellent examples of scientific information with low value for decision-making.

[92] To give three examples, Wilson II characterizes polybrominated diphenyl ethers (PBDEs), phthalates, and bisphenol A as "toxic substances" because they have been detected in human blood or tissue (p. 13). But while the adverse health effects from these exposures remains speculative, each of these products has demonstrable health and safety benefits: PDBEs are flame retardants, phthalates enable the production of highly flexible plastic products including medical devices, and polycarbonate baby bottles avoid glass breakage.

[93] Wilson II at 14-15. Note the repeated use of qualifying adjectives in the text: "some" effects, "may be due, but only "in part." These qualifiers empty the claim of scientific content.

[94] The research article is an international comparison of selected data from 29 birth defect registries from seven European countries and the United States. Each registry's methods differed, making all comparisons fraught with uncertainty. Nevertheless, the results of this study are inconsistent with the claims in the report. With respect to severe hypospadias, the author reported no upward trend in incidence in California. With respect to cryptorchidism, the author reported a rise and fall in U.S. cases corresponding to changes in case definition. This is essentially a *negative exploratory data analysis*, but the report treats it as supporting the hypothesis that these developmental effects are rising due to chemical exposure. The author attempted

developmental disorders or include any analysis of possible causal factors for the reproductive effects analyzed,[95] and the other does not support the inferences made in the report.[96]

Nevertheless, the report reproduces a set of graphs purporting to show apparently significant decreases in sperm counts, and increases in hypospadias and certain childhood cancers.[97] Consistent with having misreported the results of the studies themselves, Wilson II also misuses these graphs. In the reference cited for the sperm count and hypospadias incidence graphs, it is clear that they were intended to be illustrative examples of data that have led to concern and research interest, not evidence of an association -- much less a causal relationship to chemicals. Indeed, the referenced scientists' conclusions, which the report does not quote, are exceedingly temperate.[98]

The third chart shows the percentage change in incidence in "children of leukemia and central nervous system tumors" rising from zero percent in 1975 to about 40 percent in 2000, but does not reveal how the chart was constructed. Figure 1 below shows the 25-year trend in incidence of all forms of leukemia in California. Figure 2 below shows the 25-year trend in childhood cancer in California. Both data sets convey a very different message. Whereas Wilson II claims leukemia incidence rose rapidly from 1975 to 2000, the actual 25-year trend is flat at 13 to 14 cases per 100,000 among whites, with a sudden and sharp recent decline. It declined from 12 to 10 cases per 100,000 among blacks.[99] Over 25 years the reported incidence of all childhood cancers has risen from about 13.5 to 16 among whites, but it has declined slightly within a range of 11 to 12 cases per 100,000 among blacks.[100] It is baffling how these data could be construed to imply that a

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only the barest of comparative analysis: he correlated birth defects with "the degree of industrialization," which he approximated by "group[ing them] into categories loosely based on their country's gross domestic product (GDP) in 1984."

[95] **Swann, Shanna H., Elkin, Eric P., and Fenster, Laura.** "The Question of Declining Sperm Density Revisited: An Analysis of 101 Studies Published 1934–1996." *Environmental Health Perspectives*, 2000, *108*(10), pp. 6.

[96] See footnote 40.

[97] Wilson II at 15 (Figure 1). The charts themselves are presented in a misleading manner. Though they all have the same horizontal size, they measure 22, 60, and 29 years, respectively.

[98] **Sharpe. Richard M. and Irvine, D. Stewart.** "How Strong Is the Evidence of a Link between Environmental Chemicals and Adverse Effects on Human Reproductive Health?" *British Medical Journal*, 2004, *328*, pp. 5 ("If environmental chemicals are exerting adverse health effects in humans, these are likely to be small in relation to those caused by our dietary and lifestyle changes, although these factors may interact").

[99] The discrepancy in incidence seems unlikely to be due to superior early detection among whites. That would affect mortality rates but not incidence, as childhood cancer is highly unlikely to be missed.

[100] All data are from the same source used in the report – the Surveillance Epidemiology and end Results (SEER) Program. Mortality rates for leukemia and childhood cancers also have declined. See http://statecancerprofiles.cancer.gov/cgi-bin/quickprofiles/profile.pl?06&090.

cancer crisis exists in California, and that the cause of this crisis is exposure to chemicals.[101]

[101] Elsewhere (p. 14), the report claims that there is an "inequitable distribution of toxic exposures" in California such that minority populations are at greater risk. If so, these exposures do not seem to be manifest in higher rates of leukemia or childhood cancer. Incidence rates among blacks have been declining for both.

Figure 1: Leukemia Incidence in California

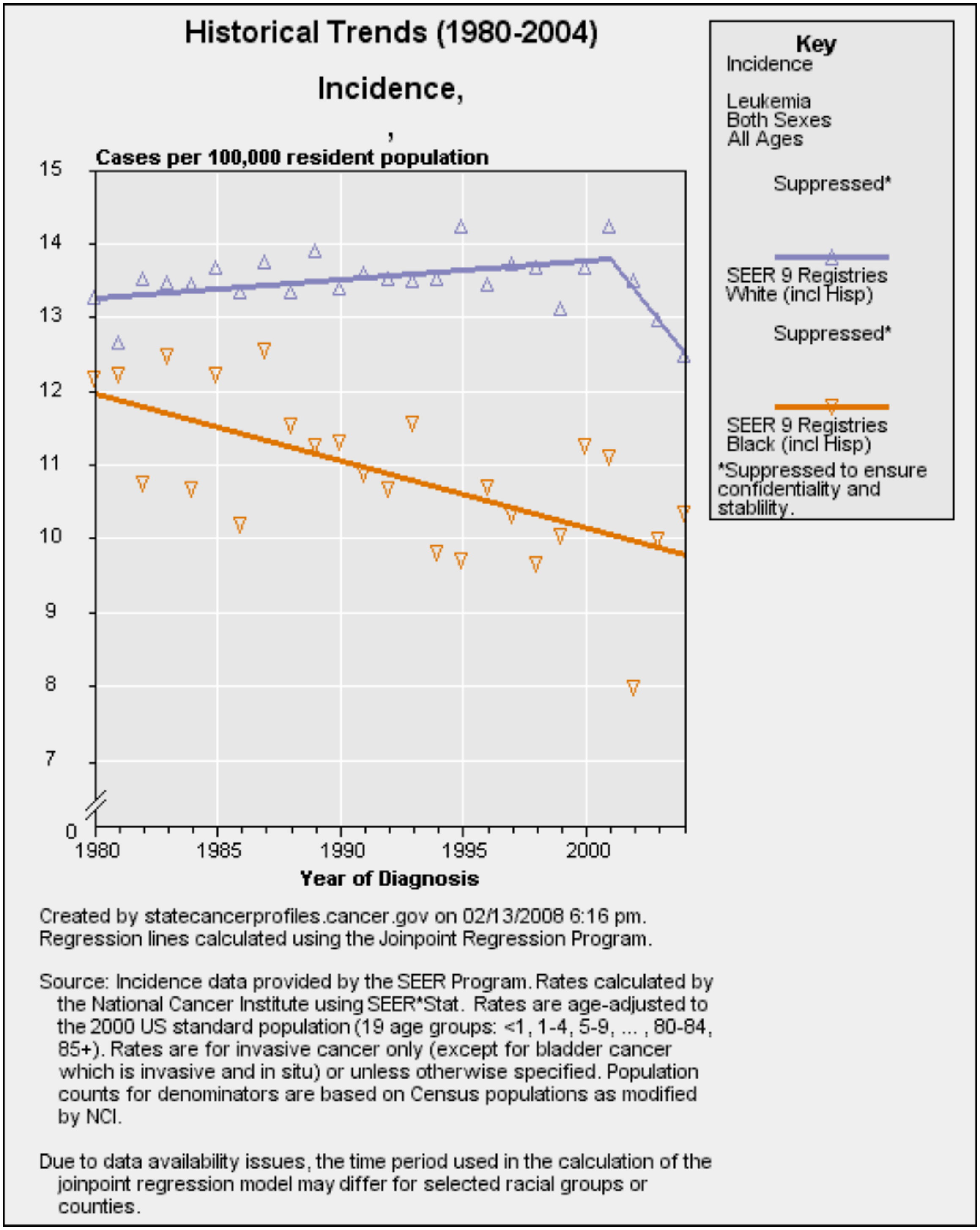
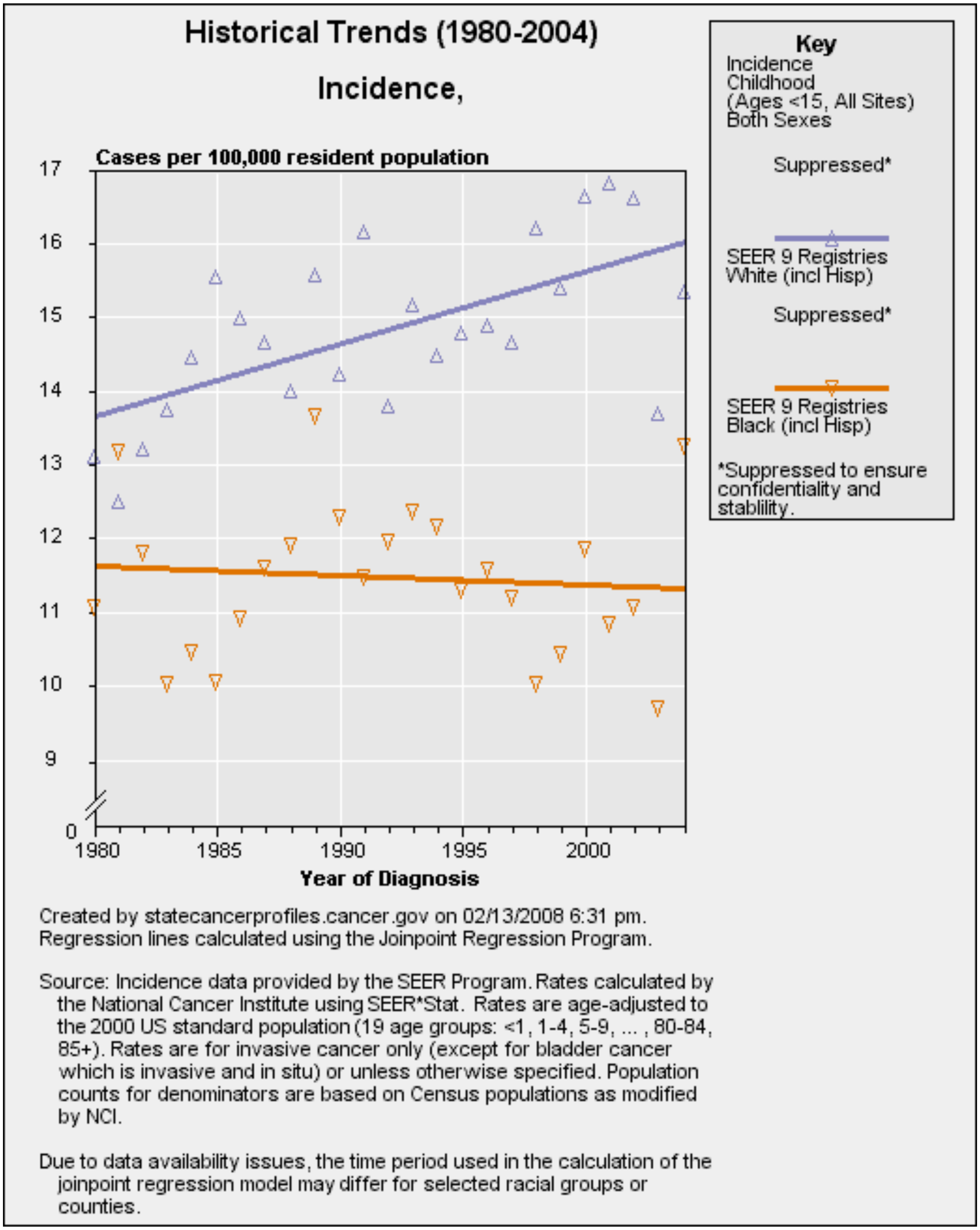


Figure 2: Childhood Cancer Incidence in California



IV. An Incomplete and Biased Characterization of "Economic Consequences"

Wilson II devotes an entire section to what is called the "economic consequences" of conventional chemistry.[102] Three such consequences are identified: adverse effects on human health, hazardous waste management, and non-hazardous waste disposal. The first of these *might* be a genuine external cost from chemicals production and use; the second and third are not. Each is addressed below.

First, it is important to note that the description of economic consequences in Wilson II is egregiously biased. It ignores the benefits of conventional chemicals, including benefits to human health and safety and environmental protection. These benefits are enjoyed by consumers every day and contribute to their welfare and satisfaction. They are among the product attributes that consumers use to decide which choices to make in the marketplace.[103] The report correctly states that consumers "choose chemicals and products primarily on the basis of their function, price, and performance"[104]; what the report fails to acknowledge is that health and safety features *are* performance attributes that consumers take seriously in decision-making. Presumably, the authors of the report believe that the weights they personally place on the health and safety attributes of consumer products are the "right" ones, but they have failed to articulate a reason why their preferences and values are superior to those of 36 million other Californians.

Throughout the report, the benefits that consumers obtain from chemicals and products are simply ignored -- including health and lifesaving benefits. The growth in global chemicals production is reported with alarm,[105] but the reasons why chemicals are produced and used are never addressed. Modern chemistry enables the manufacture of products that people want, including products that health professionals rely upon to save lives and reduce the consequences of disease and injury. The report discusses chemistry as if these social benefits do not (and indeed could not) exist. This bias results in an intellectually distorted description of the world around us.

A. Hazardous waste disposal

Wilson II cites figures for the aggregate cost of managing hazardous wastes, but it does not discriminate between the costs of managing *current* waste streams and the costs of managing *legacy* waste sites.[106] Neither green chemistry nor the policy recommendations made in the report would have any effect on legacy costs. Legacy costs themselves are exaggerated by regulations that require expenditures far beyond

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[102] Wilson II at 18-19.

[103] In section II.C beginning on page 7, it was noted that the report excludes any discussion of the *external benefits* provided by chemicals and chemical products. The existence of external benefits means that the market yields too *little* chemicals and chemical products, not too much.

[104] Wilson II at 1.

[105] Wilson II at 1 (Figure 1).

[106] Wilson II at 19. Each of the cost figures (which have not been independently validated) concerns *legacy* hazardous waste management.

what is necessary to eliminate actual risks.[107] With respect to *current* hazardous waste management costs, the report states: "It is necessary to account for these costs when evaluating the economic benefits of green chemistry alternatives." This view is eminently reasonable and fully consistent with economic principles. However, the report provides no evidence that these costs are not currently accounted for in production decisions. For current hazardous waste disposal to be a problem, the market price of legal disposal must be less than its full social cost, and the report gives no evidence that this is true, either.

A more plausible hypothesis is that, for companies and consumers who obey the law, the private cost of hazardous waste management significantly exceeds the social cost. That is, waste management and disposal regulations are so stringent that the market price more than covers any residual environmental harm. For small waste generators and especially consumers, the excessively high cost of legal waste management probably encourages widespread illegal waste disposal.[108]

To give just one example why this would be so, California's so-called universal waste regulations require consumers to deliver a wide variety of spent materials to a certified household hazardous waste collection facility. Covered wastes include:

- Common household batteries, such as AA, AAA, C, and D cells, and button-type batteries such as those used in hearing aids
- Fluorescent tubes and bulbs including mercury containing lamps, including new compact fluorescent bulbs that will soon be required everywhere in the United States[109]
- Electronic devices such as televisions, computers and computer monitors, printers, telephones and cell phones, telephones, radios and microwave ovens

In addition to fluorescent lamps, California's universal waste regulation covers virtually any consumer product containing mercury, such as pilot light sensors, gauges, thermometers and thermostats. The private cost of complying with these regulations undoubtedly exceeds the social costs of environmental harm.[110] In 2004, the Association of Lighting and Mercury Recyclers estimated that 76% of fluorescent bulbs were not recycled (i.e., they were illegally disposed).[111] California regulations even make it

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[107] See **Hamilton, James T. and Viscusi, W. Kip.** *Calculating Risks? The Spatial and Political Dimensions of Hazardous Waste Policy*. Cambridge, MA: MIT Press, 1999.

[108] See, e.g., **Viscusi, W. Kip and Zeckhauser, Richard J.** "Optimal Standards with Incomplete Enforcement." *Public Policy*, 1979, *27*, pp. 437-56.

[109] "On February 9, 2004, regulations took effect in California that classified all discarded fluorescent lamps as hazardous waste. This includes even low mercury lamps marketed as "TCLP passing" or "TTLC passing." **No one in California is allowed to discard their fluorescent lamps and batteries as non-hazardous solid waste (as ordinary trash)"** (emphasis in original). See California Integrated Waste Management Board, *Universal Waste* (http://www.ciwmb.ca.gov/WPIE/HazSub/UniWaste.htm).

[110] The text of the universal waste regulation reveals how costly it is to comply. See http://www.dtsc.ca.gov/LawsRegsPolicies/Regs/upload/OEARA_REGS_UWR_FinalText.pdf.

[111] National Mercury-Lamp Recycling Rate and Availability of Lamp Recycling Services in the U.S., November 2004 (http://www.nema.org/lamprecycle/docs/ALMR_capacity_statement.pdf).

difficult for concerned citizens to do the right thing.[112] One can only imagine what proportion of hearing aid batteries is actually transported to household hazardous waste collection centers.

The cost of universal waste disposal is exacerbated by the limited number of facilities qualified to take them. The City of Berkeley, the home of the University of California, has only two facilities licensed to accept household batteries, one that accepts used fluorescent light bulbs and electronics, and none authorized to accept other items containing mercury, paint, pesticides solvents, or car batteries.[113]

Given the high cost of legal hazardous waste management in California, there is an astoundingly strong economic incentive, at least for all but the smallest firms, to reduce hazardous waste generation. That incentive extends to the input and process substitutions proposed in the report and by other activists.[114]

B. Non-hazardous waste disposal

Wilson II includes an extensive discussion about plastics in the non-hazardous waste stream, but it does not allege that these wastes pose any human health risk.[115] Rather, the authors seem to be animated primarily by mass (even though plastics comprise a very small fraction of the waste stream[116]), the cost of legal disposal,[117] the limited fraction that is recycled, apparently irrespective of the health and environmental risks of recycling,[118] and the aesthetic impacts of improper disposal (which is encouraged by the high cost of *legal* disposal).

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[112] Fischer, Douglas. "Battery disposal effort overwhelmed," *Oakland Tribune*, April 3, 2006 (volunteer community household-battery recyclers hamstrung by 125-pound transport limit without a state permit).

[113] California's household hazardous waste program directs consumers to Earth911, located online at http://earth911.org/, where these figures were obtained.

[114] Conversely, these regulations create an astoundingly strong incentive for consumers to dispose covered wastes illegally.

[115] Wilson II at 19. The report's primary concerns are about "plastic debris on beaches" in California (p. 19) and in the oceans generally (p. 10). Green chemistry can reduce the future magnitude of this problem only if green-chemistry products are biodegradable and the by-products of biodegradation are non-toxic. To the extent that these products create unforseen environmental harms (the report exempts green chemistry products and processes from demonstrating proof of safety), or require the sacrifice of other benefits (including health and environmental benefits), the solution may turn out to be less desirable than in practice than it appears to be theory.

[116] It has been empirically estimated that plastic has historically comprised less than 20% of the municipal solid waste stream by volume. The volume is relatively constant but the percentage rises with aggressive paper recycling. See **Rathje, Wiliiam L. and Murphy, Cullen.** *Rubbish! The Archeology of Garbage*. Tuscon, Ariz.: University of Arizona Press, 2001.

[117] Wilson II displays uncommon ignorance about cost incidence, imagining that *governments* bear costs instead of passing them on to *taxpayers*: "*Municipal governments* are grappling with the costs of managing a growing stream of product waste. In 2003, the latest year for which data are available, *local governments* incurred the costs of handling 6 to 9 billion pounds of plastic waste, or about 160 to 260 pounds per California resident (footnote omitted, emphasis added)."

[118] Wilson II implies that plastic recycling has no environmental costs and that recycled plastic is a perfect substitute for new plastic. Both beliefs are false. Activists have long complained about the occupational and

In any case, mandatory toxic use reduction policies remain the solution because they

> can relieve the growing economic pressures created by hazardous and product waste and can reduce the burden of disease, improve the profitability of businesses, and provide the job opportunities necessary for a sustainable economy.[119]

Missing, however, is any scientific explanation for how this will work in practice.

C. Speculative claims about human health effects

Wilson II alleges that the primary "economic consequence" of existing markets for chemicals and products is an array of serious adverse human health and environmental effects. The market, it is said, "externalizes to the public many of the costs of health and environmental damage," including "direct and indirect costs of chemically related diseases among workers, as well as a portion of childhood diseases linked to environmental contaminants."[120] It is the authors' own quantitative (and monetized) estimates of health effects, which the report promotes as if they had withstood careful peer review, that have enjoyed the greatest resonance in the many news stories published about their report. These estimates cannot be examined, much less verified, because they are not yet published and Wilson II does not disclose the methods used to derive them.[121]

Still, some of the claims being made can be tested against other data to ascertain whether they are roughly plausible.

1. Occupational cancer cases

Wilson II claims that in 2004, 113,999 cancer cases were "attributable to chemical exposures in the workplace." [122] According to the National Cancer Institute's Surveillance Epidemiology and End Results (SEER) Program, there were on average 138,933 cancer cases reported per year in California during the 2000—2004 period.[123] For the figure in the report to be correct, more than 80 percent of *all* cancer cases in California must be due to occupational exposure to chemicals. There is no scientific basis for this attribution.

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environmental risks of plastics recycling. The Food and Drug Administration stringently regulates the use of recycled plastic in food packaging because it is concerned about contamination. See Food and Drug Administration, *Use of Recycled Plastics in Food Packaging: Chemistry Considerations* (August 2006) (http://www.cfsan.fda.gov/~dms/opa2cg3b.html).

[119] Wilson II at 19.

[120] Wilson II at 18.

[121] Report authors Wilson and Schwarzman are co-authors of the unpublished analysis that they cite as if it had been produced independently. They could have disclosed all the data and methods, but chose not to.

[122] Wilson II at 18 (Figure 1).

[123] National Cancer Institute, Surveillance Epidemiology and End Results (SEER) Program, *Incidence Rate Report for California by County*, http://statecancerprofiles.cancer.gov/cgi-bin/quickprofiles/profile.pl?06&001#incidence.

Wilson II also claims that in 2004, 3,845 cancer deaths were attributable to workplace chemical exposure. These deaths need not be (and probably are not) supposed to be a subset of the 113,999 cancer cases because many cancer cases that prove fatal do so subsequent to the calendar year in which they were diagnosed. For illustrative purposes, however, imagine that both cancer cases and cancer deaths in the SEER registry are steady-state figures. That would imply a cancer mortality rate of just 3%. According to SEER, during 2000--2004 there was an annual average of 53,848 deaths from cancer; the annual death rate was about 40% as large as the annual incidence rate.

Anther peculiarity about Wilson II's cancer estimates is worth noting. Although 113,999 cancer cases are attributed to occupational chemical exposure, only 8% (8,700) require hospitalization. If this were true, occupational cancer would be a mundane health effect, an implication with which no one who has experienced cancer would likely agree.

2. Cancer in children

Wilson II claims that in 2004, 690 cancer cases in children were "attributable to environmental exposures," defined in a footnote as "chemical substances in food, water, air, soil, the home and community.[124] SEER reports that during the 2000—2004 period, there were an annual average of 1,172 cancer cases in Californian children under 15 years old,[125] and 1,690 annual cases among Californian children under 20 years old.[126] Thus, Wilson II implies that between 40 percent and 60 percent of all childhood cancer cases are due to exposure to chemicals in the environment or in consumer products. There is no scientific basis for this attribution, either.

3. Cancer incidence generally

Finally, Wilson II alleges that the incidence "of some cancers" is rising in California, and this "may be due in part to chemical exposures."[127] This statement is technically true only because this textual construction is so vague that it is impossible to be false. Indeed, the statement would be true even if the number of cancer cases due to chemical exposure were exactly zero.

According to SEER, during 2000—2004 (the latest dates for which time-series data are reported) all-site cancer incidence in California *declined* at an annual rate of 1.7 percent, and this decline is significantly different from zero ($p < 0.05$). This means that the observed decline in all-site cancer incidence is almost certainly real. There is less than a 5% probability that it is due to chance. A decline in all-site cancer incidence is

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[124] Wilson II at 18 (Figure 2). The construction "environmental exposures" is highly ambiguous. In some taxonomies, all cancer that is not genetic is classified as environmental.

[125] National Cancer Institute, Surveillance Epidemiology and End Results (SEER) Program, *Incidence Rate Report for California by County, Ages < 15*, http://statecancerprofiles.cancer.gov/cgi-bin/quickprofiles/profile.pl?06&516#incidence.

[126] National Cancer Institute, Surveillance Epidemiology and End Results (SEER) Program, *Incidence Rate Report for California by County, Ages < 20,* http://statecancerprofiles.cancer.gov/cgi-bin/quickprofiles/profile.pl?06&515#incidence.

[127] Wilson II at 14-15.

inconsistent with the clear implication in Wilson II that cancer rates in California are rising.

Of course, it is still possible that the incidence of *some* cancers is rising in California. According to SEER, statistically significant increases in cancer are observed for the following sites:

- kidney and renal pelvis (3.9%)
- thyroid (4.7%)

SEER data show that the incidence in cancer of the kidney and renal pelvis rose from about 8 to 13 cases per 100,000 in white Californians from 1980—1995, and from about 8 to 16 cases per 100,000 among blacks. However, the mortality rate relative to the U.S. as a whole was not rising during this period except for cancer of the liver and bile duct.[128] For thyroid cancer, SEER data for 1980—2005 show that incidence rose at similar rates for both white and black Californians, with the rate higher for whites than for blacks rates high at similar rates. Until about 1997, rates for whites were about 50% greater than for blacks; since 1997, incidence among whites has risen sharply. Over the entire 25-year period, mortality rates have been either constant at around 0.5 case per 100,000, or falling very slightly.[129]

In any case, these are the only two cancer sites for which Wilson II's claim that cancer incidence in California is rising, and SEER reports that these rates are not rising in California relative to the United States as a whole.

How feasible is it that rising cancer incidence at these two sites is due to industrial or consumer exposure to chemicals? For kidney cancer, the suspected causes are inherited and acquired genetic mutations, chronic kidney disease, and certain environmental exposures – most notably, smoking. Among occupational exposures, cadmium is suspected to cause kidney cancer. Recent occupational exposure is unlikely to be an actual cause, however, because in 1992 the Occupational Safety and Health Administration dramatically reduced its permissible exposure limit.[130]

For thyroid cancer, chemical exposure isn't even on the short list:

> **What causes thyroid cancer?**
> Thyroid cancer is more common in people who have a history of

[128] National Cancer Institute, Surveillance Epidemiology and End Results (SEER) Program, *California State Cancer Profile: Kidney and Renal Pelvis* (http://statecancerprofiles.cancer.gov/cgi-bin/quickprofiles/profile.pl?06&072).

[129] National Cancer Institute, Surveillance Epidemiology and End Results (SEER) Program, *California State Cancer Profile: Thyroid* (http://statecancerprofiles.cancer.gov/cgi-bin/quickprofiles/profile.pl?06&080).

[130] See 29 C.F.R. 1926.1127. Causality is confounded because cadmium is a significant constituent in cigarette smoke.

> exposure of the thyroid gland to radiation, have a family history of thyroid cancer, and are older than 40 years of age.[131]

For a number of cancer sites, the claim of rising cancer incidence made in Wilson II is simply infeasible. Exposure to chemicals cannot be the cause of *rising* cancer incidence at sites where cancer incidence is *falling*. Statistically significant decreases in cancer incidence are observed for the following cancer sites:

- cervix (5.3%)
- breast (3.4%)
- colon and rectum (2.9%)
- lung and bronchus (2.8%)
- leukemia (2.8%)

For all other sites, upward or downward trends are not strong enough to be statistically significant.

At least until they reveal the data and methods upon which they based their claims, none of the estimates in Wilson II should be taken seriously. Their cancer estimates are so obviously peculiar that the other claims deserve similar skepticism.

V. The Uncounted Opportunity Costs of the Proposed Solutions

Wilson II proposes to solve this purported array of problems by mandating toxic use reduction, and on a scale that dwarfs any existing TUR program. To solve the "data gap," the report recommends that more data be generated and disclosed. To solve the "safety gap," the government would ban chemicals for which "adequate" data are not generated and disclosed. To solve the "technology gap," the report recommends subsidizing investments in research and development.

The report's descriptions of the private and social benefits of toxic use reduction (which is packaged as "green chemistry") are ethereal. Some examples:

- "Green chemistry technologies can contribute to a sustainable economy, relieving the economic pressures on state and local governments, improving the profitability of businesses using safer materials, providing job opportunities, and protecting human health and the environment."[132]
- "Green chemistry policies can relieve the growing economic pressures created by hazardous and product waste and can reduce the burden of disease, improve the profitability of businesses, and provide the job opportunities necessary for a sustainable economy."[133]

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[131] American Thyroid Association, *Cancer of the Thyroid FAQ* (http://www.thyroid.org/patients/faqs/cancer_of_thyroid.html).

[132] Wilson II at 19.

[133] Wilson II at 19.

- "California can close the technology gap by supporting green chemistry research, education and implementation."[134]

Although Wilson II implies that toxic use reduction would generate significant private and social benefits to Californians, neither theory nor evidence is provided suggesting why this would be so. The Wilson II definition of green chemistry is virtually free of health or environmental risk. Technology that isn't risk-free does not meet the definition. Wilson II also implies that there are no scientific, technical, or economic barriers to the development of risk-free technologies if only enough money is spent on research and development, and not coincidentally, conventional chemistry is banned or highly restricted.

In that last snippet of text lies a huge problem: there are huge opportunity costs associated with toxic use reduction that the report ignores.

A. Not all "data gaps" are worth filling

What exactly is a "data gap"? According to Wilson II, a data gap arises in any circumstance where perfect information is lacking. Yet, this describes the permanent and omnipresent state of the world since at least the dawn of mankind. Science never runs out of questions, so data gaps will be with us always. The mere existence of a perpetual gap between actual and perfect knowledge cannot be a rational basis for concluding that historic ways of trying to shrink it are fundamentally flawed, nor can it responsibly support a Draconian TUR regulatory program.

Moreover, not all data gaps are created equal. Many questions draw the attention of scientists because scientists are by nature curious people. However, trying to answer every question that intrigues scientists will not necessarily illuminate public or private decision-making. Only a (probably small) subset of these questions is important enough that answering them has high informational value. From the perspective of decision-making, these are the data gaps that deserve the greatest research attention. Wilson II makes no distinction between uncertainties that are valuable to fill and those that are not. It treats all uncertainties as data gaps, and assumes all data gaps as critical.

Recommending blindly that information be produced regardless of its value is a serious disservice to public and private decision-makers alike. Every risk management problem is characterized by incomplete data and uncertainty, and for that reason, an extensive effort has been made by scientists to develop tools for analyzing uncertainty and improving the capacity of risk managers to make decisions despite incomplete knowledge.[135] Wilson II makes no use of any of this scientific literature. Instead, the report advances the highly simplistic view that the solution to the problem of incomplete

[134] Wilson II at 22.

[135] A seminal reference in the field is **Morgan, M. Granger; Henrion, Max; and Small, Mitchell.** *Uncertainty: A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis*. New York, N.Y.: Cambridge University Press, 1990. Morgan currently serves as chairman of the U.S. EPA Science Advisory Board.

data is to mandate by regulation the production of more data, irrespective of its informational value.[136]

The task of ascertaining which scientific uncertainties are truly important, and which data gaps if filled would substantially reduce decision-makers' uncertainty, is much more difficult than Wilson II implies. The report approvingly cites the European Union's Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) program,[137] but this program has not yet been implemented and the EU has not yet figured out how it will utilize the test data that the program will require.[138]

There is an unmistakable instrumental reason why Wilson II argues for additional data mandates. The authors' objective is the removal of chemicals from the marketplace, and imposing expensive testing requirements will lead some conventional chemicals to be withdrawn from the market because their economic value is less than the cost of testing. Thus, it is tactically attractive to impose expensive testing requirements. The value of these new data are irrelevant; the more expensive they are to generate, the more conventional chemicals can be driven off the market.

Demanding new toxicological information with low informational value has another instrumental benefit to opponents of conventional chemistry. These data can be used to populate crude screening tests that have little or nothing to do with human health risk, but which are easily misinterpreted as suggestive evidence of significant risk.[139]

B. Bans require the public to do without things they value

Bans are the most extreme form of regulation imaginable. They are efficient policy tools only if the socially desirable amount of a good or service, or level of an activity, is zero. It is difficult to imagine what conventional chemicals might make this list. Generally, the only substances that would qualify have very high risks at any positive dose, there is no plausible benefit associated with using them, and they are inexpensive to replace.

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[136] It is not clear that the report's authors actually believe that more data are the "solution" to the "problem." As discussed in Section D on page 10, they also express dissatisfaction with pesticides despite the fact that registrants are legally required to generate vast quantities of test data. This ambivalence is further indicated by the absence of concrete suggestions concerning *what* new data collections ought to be mandated.

[137] Wilson II at 7

[138] The report also is ambiguous concerning what data producers and manufacturers would be required to generate. They punt that question to a future process in which the State of California would "identify the best available toxicity testing procedures and support research and development of new methods," but also require that they "produce consistent data, permitting comparison of chemical hazards." See p. 20.

[139] For honest advocates of green chemistry, this is a dangerous tactic. As discussed in Section V.C below, green chemistry cannot ethically or legally avoid the same testing requirements that apply to conventional chemistry. The expense of testing also will prevent many green chemistry innovations from reaching the market, and the same screening-level tests that could be used to demand the withdrawal of a conventional chemical also could be used to prevent the production of a green chemical with similar test results.

In economic terms, a ban results in the total abandonment of all producers' and consumers' surplus.[140] Yet that is what Wilson II criticizes TSCA for *failing* to achieve,[141] and it is what Wilson II recommends be adopted as California state policy.[142]

C. "Data gaps" in the Wilson II version of green chemistry

Wilson II carefully (and conveniently) defines green chemistry so that it is free of human health or environmental risk:

> Green chemistry is a fundamentally different approach that protects human and environmental health by replacing hazardous chemicals, processes, and products with safer alternatives.[143]

To qualify, chemicals must be formulated to be effective while reducing human and ecosystem toxicity, favor renewable materials over fossil fuel feedstocks where it provides a net ecological gain, and be designed to break down into innocuous substances after use. In manufacturing, qualifying requires using energy-efficient processes at minimal temperature and pressure, reusing chemical intermediates and producing minimal or no waste, and using biologically benign solvents. In use, qualifying requires "minimiz[ing] or eliminat[ing] the use of toxic, bioaccumulative and/or persistent chemicals in products," "maximiz[ing] the proportion of reused materials in new products," and "retain[ing] responsibility for products throughout their lifecycle from design to re-use." At disposal, "green chemistry" means "prevent[ing] the generation of hazardous chemical and product waste," "recycl[ing] chemicals and materials used in

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[140] *Producers' surplus* is the value to sellers of selling a good or service after all costs, including normal profit, have been subtracted. *Consumers' surplus* is the value to consumers of using a good or service net of the price they pay for it. For any normal good or service, consumers' surplus is positive. Producers' surplus is positive except under the textbook model of perfect competition.

[141] Wilson II at 9 ("TSCA has not provided an effective vehicle for the public, industry or government to either assess chemical hazards or control those of greatest concern"). See also Wilson I at xiii ("TSCA has not served as an effective vehicle for the public, industry, or government to *assess* the hazards of chemicals in commerce or *control* those of greatest concern" [emphasis in original]).

[142] The authors are not transparent about this, preferring to use language that is equivalent to banning substances and products but without using the word "ban." See, e.g., Wilson II at 20 ("Chemical producers and product manufacturers should be required to provide hazard and tracking *data as a condition of use or sale in California*" [emphasis added].); and 22 ("If a viable safer alternative exists, its adoption should be mandated and the chemical of concern should be phased out"). Though the word "ban" does not appear, both policies are equivalent to bans. The first policy would effectively ban substances for which the cost of producing and disseminating the required data exceeds producers' surplus. The second policy effectively bans any substance or product for which State regulators determine, based on subjective criteria, that an alternative is both "viable" and "safer." Wilson I is much more transparent. See, e.g., Wilson I at 72 (proposing a new policy that "[i]nclude[s] mechanisms for mandatory implementation of toxics use reduction strategies for priority chemicals, including product bans and phase-outs where appropriate"). Wilson I does not make clear what criteria would be "appropriate," but recommends "*product bans and limitations* to reduce the use of highest- and high-priority hazardous chemicals" (at 87, emphasis in original). "Highest-priority" and "high-priority" would be regulatory designations made after the application of unspecified criteria.

[143] Wilson II at 4-5.

manufacturing processes and products," and "recover[ing] products at the end of their useful life."[144]

In short, the cribbed Wilson II definition of green chemistry is chemistry that is virtually risk-free. This is a remarkably demanding set of requirements. Indeed, to legitimately meet this definition, a new chemical, technology, manufacturing process or product must be demonstrated to achieve each of these standards. Failing to achieve any one of them would be a fatal defect. This very strict definition of green chemistry is inconsistent with the principle that evolutionary reductions in health and environmental risk are desirable and that the perfect ought not be the enemy of the good.

To meet the Wilson II definition, a green-chemistry innovator must accomplish four demanding tasks.

First, he must show that that his product is as effective for the intended purpose as the product for which it substitutes; otherwise, the market for the new product will necessarily be limited. To demonstrate efficacy, innovators must prove that their new chemicals and products meet all the performance standards of the chemicals and products they are supposed to replace. That's a daunting analytic burden. If buyers discover that these substitutes have inferior performance, either they will decide not to buy them or they'll insist on paying lower prices. The recent history of "environmentally friendly" products has many examples in which market penetration was constrained by substandard performance. The federal government has policies in place that establish a preference for green products, but these policies do not require agencies to accept substandard performance.[145]

Second, the innovator must prove the absence of risk in all of its many dimensions. He will have to perform all of the laboratory tests that producers of conventional chemicals and products have to perform. Each test must yield an unambiguously negative result; positive or equivocal outcomes would raise questions about whether the innovation created new risks, just as occurs now in conventional chemicals testing. The difference is that conventional chemistry tolerates risks that are acceptable based on the specific application. The Wilson II definition of green chemistry is intolerant of any risk at all.

Third, the innovator must comply with Federal Trade Commission regulations (the "Green Guides") governing the marketing of products with environmental claims attached. These regulations require that all environmental claims be substantiated by

> competent and reliable scientific evidence, which is defined as tests, analyses, research, studies or other evidence based on the expertise of professionals in the relevant area conducted and evaluated in an

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[144] Wilson II at 5.

[145] A series of presidential Executive Orders has been issued, beginning in 1993, to encourage the procurement of "environmentally friendly" or "environmentally sound" products. Each directive has permitted agency heads to choose conventional products where "green" products do not achieve acceptable performance standards. See also Federal Acquisition Regulations; Environmentally Sound Products, 62 Fed. Reg. 44809-44813 (August 22, 1997).

> objective way by qualified people using procedures generally accepted in the profession to yield accurate and reliable results.[146]

It is certain that green-chemistry innovators will want to make environmental claims – how else could they distinguish themselves in the marketplace? – and every environmental claim must be rigorously documented with scientific evidence.

Finally, the innovator must be price-competitive. Some consumers will pay more for a green product than is justified by its performance because doing so provides intangible benefits, such as what economists call "warm glow" effects. The number of consumers so motivated always will be limited, as will be the amount of sacrifice they will agree to bear.

Wilson II proposes to overcome these burdens with a combination of mandatory toxic use reduction combined with plentiful public subsidies and financial penalties on conventional chemistry. The array of subsidies is extensive, including publicly funded research and development, the establishment of education and training programs, the provision of technical assistance grants and preferences, and "economic incentives" (i.e. direct and indirect subsidies in the form of preferential State procurement, loans, and tax credits).[147] The penalties on conventional chemistry consist of taxes on the manufacture and use of conventional chemicals.[148]

Even if it assumed that Wilson II describes a "better world," these proposals would be insufficient to achieve it. Data sufficient to prove safety still must be produced, and the State of California cannot exempt itself from federal regulations requiring those who market "green" products substantiate their claims scientifically.

D. Reckless substitution

Market forces, subject to the existing regulatory regime described above and product liability law, already permit (and indeed encourage) the development and marketing of green chemistry and green products. The high cost of safely managing hazardous inputs, intermediates, and wastes already creates a strong incentive for manufacturers to search for and identify alternative materials, technologies and manufacturing processes. Every one of the attributes of conventional chemistry that the report dislikes is an expensive cost that manufacturers would like to avoid.

Wilson II displays impatience with the pace of technical and economic evolution and insists that revolutionary change must be imposed by governmental fiat. Ironically, if the State took this advice, the most likely result of is not a sudden industrial

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[146] See, generally, 16 C.F.R. Part 260. These requirements are summarized at http://www.ftc.gov/bcp/conline/pubs/buspubs/greenguides.shtm. California cannot exempt Green Chemistry innovations that are marketed or advertised outside the State.

[147] Wilson II at 22-23.

[148] Subsidies are routinely proposed to support new technologies with the stated promise that they will be eliminated once the new technology is securely established in the marketplace. These promises are often not kept. Subsidies reward inefficiency and inculcate amongst beneficiaries a culture of dependency. Oftentimes, scarce resources are diverted from R&D to political lobbying to expand subsidies further or at least prevent them from being terminated.

transformation in the direction of green chemistry. Rather, it is reckless substitution. Wilson II implies what is made explicit in Wilson I – that the predictable result (indeed, the objective) is that many chemicals and products would be banned from the marketplace. If that were to happen, producers and consumers alike would be forced to substitute substances and products with less desirable performance properties and likely bear greater risks to human health and the environment.

Ironically, Wilson II provides what may be an excellent example showing shy forced substitution often is reckless substitution:

> Between 1995 and 2003, California auto repair workers were exposed to hexane, a well-known neurotoxic chemical found in automotive brake cleaners and many other commercial products. In 2000, several workers developed a neurological disorder that caused decreased function of their arms and legs. Each year, millions of cans of hexane-based products were sold in California as an alternative to chlorinated solvents, which were also hazardous but were more heavily regulated in the state.[149]

The use of passive voice disguises what actually happened. New environmental regulations effectively banned the use of solvents such as trichloroethylene (TCE), an alleged human carcinogen. However, auto repair workers still needed to clean automotive brakes, and hexane became the substitute. This substitution was more than just "regrettable," as the report calls it; it was reckless. Before banning TCE, regulators should have carefully analyzed how it would be replaced in each application – that is, they should have taken account of the opportunity costs of bans, including unintended new risks, before deciding how to proceed.

The report claims that the hexane case "highlights problems that are universal to current chemical and product management." That is misleading. The case shows what happens when one potentially hazardous product is banned without regard for the human health and environmental risks of its substitute.[150]

D. Stifled innovation

Market forces, especially during a period when the price of crude oil exceeds \$100 per barrel, provide powerful incentives to invest in green chemistry research and development. Currently, there are few governmental hurdles stifling R&D, and promising technologies and products face an eager marketplace driven by consumers who earnestly desire "green" things. That could come to an end if governments adopt coercive toxic use reduction laws to quicken the pace of technological change. Investments in green

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[149] Wilson II at 16 ("Hexane: A Neurotoxic Chemical in Widespread Use"), which the authors call a "regrettable substitution." This case study comprised Wilson's recent doctoral dissertation. For discussion purposes, it is assumed here that Wilson objectively characterized the risks from hexane. To be sure that the case involved reckless substitution, his dissertation would have to be examined carefully,

[150] For a wealth of empirical examples of risk-risk tradeoffs, see **Graham, John D. and Wiener, Jonathan Baert** eds**.** *Risk vs. Risk: Tradeoffs in Protecting Health and the Environment.* Cambridge, Mass.: Harvard University Press, 1995.

chemistry R&D likely would stop until implementing regulations are issued and their implications are fully analyzed. A considerable amount of effort would be devoted to just trying to conform to the new rules. If the regulations establish a pre-approval process in which the government must authorize new substances, technologies and products (a la REACH), green chemistry innovation will be set back many years. A reasonable worst-case can be imagined in which the bureaucratic approval process became as time-consuming an expensive and the existing federal regimes for pesticides and pharmaceuticals.

Whatever regulations are issued, they would likely remain unchanged for years. Regulatory agencies are not nimble. Changes can take years to promulgate, making it impossible for the regulatory agency to keep up with technological change. Market incumbents and political interest groups often use the regulatory system to exclude competitors, reduce competition, and protect their private interests against the public interest.[151] The result, ironically, would be less green chemistry – less R&D, less innovation, and fewer green-chemistry products delivered to the marketplace.

E. Transition costs of technology forcing

Embedded in the toxic use reduction ideology is the conviction that technology forcing is inherently desirable. Accepting evolutionary change prevents the achievement of a genuinely revolutionary conversion in industrial practice, and such a conversion is precisely what ought to occur.[152] Thus, it is essential to impose on manufacturers the regulatory burdens of proving safety and efficacy prior to marketing, and occupational, consumer, and environmental safety thereafter. Government must control by regulation the technology of production[153] because innovation is too important to be left to the marketplace.[154]

These acts will force firms to fundamentally change technology just to survive:

> [It] is now possible to fashion regulatory strategies for eliciting the best possible technological response to achieve specific health, safety, or environmental goals. A regulatory strategy aimed at stimulating technology change to achieve a significant level of pollution prevention rejects the premise of balance: that regulation must achieve a *balance* or compromise between environmental integrity and

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[151] George Stigler won the Nobel Prize in economics in 1982 for his work on the effect of government regulation on firm behavior. One of his durable insights is that firms and interest groups "capture" the levers of government use its coercive power in ways they find beneficial. See, e.g., **Stigler, George J.** "The Theory of Economic Regulation." *Bell Journal of Economics and Management Science*, 1971, *2*(1), pp. 3-21.

[152] See, e.g., **Ashford, Nicholas A.** "An Innovation-Based Strategy for the Environment," A. M. Finkel and D. Golding, *Worst Things First? The Debate over Risk-Based National Environmental Priorities*. Washington, D.C.: Resources for the Future, 1994, 275-314. at 293. Ashford is a longtime advocate of technology forcing.

[153] Ibid. at 295-296

[154] Ibid. at 305: "*[I]nnovation is more predictable and capable of being directed than invention or serendipitous discovery"* (emphasis in original).

industrial growth, or between job safety and competition in world markets.[155]

Moreover, the key to effective technology forcing is overwhelming regulatory stringency. Regulations that are only stringent enough to impose significant costs will not force technological change. Regulations must be so stringent that mere adaptation is technologically infeasible.

A common conceit among those who would radically remake the world is the costs of transition to their preferred technological equilibrium can be safely ignored. They assume that whatever pains might be associated with technology forcing are either irrelevant or ethically justifiable. Transition costs represent the consumption of real resources, and in less analytically sterile terms, real people.

Before embarking on the radical program of forced technology change advocated in Wilson II, it would be sensible to take seriously the magnitude of transition costs involved. Given the concern expressed in this report for environmental justice, it also would be worth examining whether the brunt of transition costs might be borne by low-income households. University faculties in chemistry, engineering and environmental health seem much more able to adapt, or even benefit handsomely from technology forcing.

VI. Government Failure

Wilson II is imbued with an assumption never seriously examined -- that government can establish and implement effective and efficient regulations, that it can do these things with little or no error, and that its actions will not have unintended consequences, including the creation or exacerbation of health and environmental risks. There is no empirical basis for this belief, and ample scholarship showing that government failure is an inevitable outcome with potentially significant ramifications.

The assumption also is contradicted by the report's essential premise -- that the Toxic Substances Control Act (a government intervention in the market) has failed to deliver what its advocates promised it would. If adopted, the recommendations in Wilson II would vividly illustrate the triumph of its authors' hope in the perfectibility of government over their actual experiences.

There is ample empirical data showing that when governments try to improve upon the market, things often go wrong. Economists who study this phenomenon call it *government failure*.[156] The symmetry in language with *market* failure is intentional. Just as markets can be described theoretically to work perfectly but departures from perfection cannot be avoided in practice, government regulation can be described theoretically to work perfectly but departures from perfection cannot be avoided in practice.

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[155] See, e.g., Ibid. at 293 Ashford is a longtime and dedicated advocate of technology forcing.

[156] See, e.g., **Tullock, Gordon; Seldon, Arthur and Brady, Gordon L.** *Government Failure*. Washington, D.C.: Cato Institute, 2002, **Winston, Clifford.** *Government Failure versus Market Failure*. Washington, D.C.: AEI-Brookings Joint Center for Regulatory Studies, 2006, **Wolf, Charles, Jr.** *Markets or Governments: Choosing Between Imperfect Alternatives*. Cambridge, Mass.: MIT Press, 1988. Wolf uses the term *nonmarket* failure.

The principle and significance of government failure is aptly summarized by Brookings Institution economist Clifford Winston:

> Government failure … arises when government has created inefficiencies because it should not have intervened in the first place or when it could have solved a given problem or set of problems more efficiently, that is, by generating greater net benefits… From a policy perspective, market failure should be a matter of concern when market performance significantly deviates from the appropriate efficiency benchmark. Similarly, government failure should call a government intervention into question when economic welfare is actually reduced or when resources are allocated in a manner that significantly deviates from an appropriate efficiency benchmark.[157]

Government failure has a number of predictable sources. First, unlike markets, governments are never disciplined by the price system. When consumer demand for a market good or service declines, prices and quantities both fall. Producers adapt; some exit the business. Consumer demand ultimately may vanish as better products come onto the market. In contrast, governments do not adjust well when demand for their "products" declines. They are susceptible to the temptation to use coercive powers that are unique to government and require consumers to buy what they sell, and at whatever price they want to charge. Once government intervenes in a market, it rarely withdraws even when the public would it them to do so or when its purpose has become superfluous.[158]

Second, while it is routinely observed that dissatisfaction with market outcomes often leads to government intervention, dissatisfaction with governmental outcomes rarely results in market allocation. Almost without exception, the adopted prescription for government failure is more government.[159] `

Third, while large firms and governments alike suffer from the inefficiencies of bureaucracy, firms can and do merge, reorganize, streamline or downsize to reduce these burdens. In contrast, governmental reorganization often involves little more than "moving boxes around" on an organization chart. Firms can hire and fire based on job performance, except insofar as they are constrained by union contracts, but incompetent government employees are protected by civil service rules.

Fourth, governments are uniquely susceptible to political interference and rentseeking.[160] These phenomena are inherent to the process of building support for

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[157] **Winston, Clifford.** *Government Failure versus Market Failure*. Washington, D.C.: AEI-Brookings Joint Center for Regulatory Studies, 2006. at 2-3 Note that in both cases the definition of *failure* is positive (i.e., descriptive), not normative (i.e., judgmental).

[158] The last significant *federal* regulatory agency to go out of business is the Interstate Commerce Commission. It was abolished in 1995.

[159] Wilson II proves to be an excellent example. According to its authors, TSCA and its implementing regulations have failed to accomplish what they were supposed to accomplish. Their recommended remedy for the problem of ineffective law and regulation is to enact more law and regulation.

[160] *Rentseeking* is defined in economics as the capture of something of value through the operation of legal or regulatory means rather than by voluntary trade or the production of wealth. Rentseeking thus involves

legislation, crafting its many provisions, and designing and implementing regulations. Regulatory agencies must follow elaborate procedures to issue and enforce regulations, and they have great difficulty adjusting over time as more information becomes available or circumstances change. Regulations tend to be extraordinarily static, and this attribute is particularly undesirable in areas where innovation is either expected or desired.

When inefficiencies are found in markets, it is simply inappropriate to assume that regulation will provide superior outcomes. Market failures often correct themselves, but government failures tend to be persistent.[161] The panoply of potential government failures must be carefully examined before there can be any reasoned basis for concluding that regulation is superior. Wilson II says that toxic use reduction offers a wealth of innovative opportunities, and a careful policy analysis might reveal that these social benefits would in fact arise. One reason to doubt this argument is that it relies so heavily on coercion to accomplish its goals and objectives. Coercion is not necessary to motivate innovators to seek out profitable opportunities. It *is* necessary, however, to motivate them to bear uncompensated losses.

Another reason for skepticism is that regulatory systems are generally very poor at managing changing circumstances. Regulation is difficult to enact, hard to design and implement, and often impossible to change. It is entirely plausible that an effort to encourage green chemistry through the odd vehicle of toxic use reduction regulation will instead stifle it under the weight of rules, procedures, and multi-step approval or permitting processes, thereby delaying rather than expediting its adoption.

VII. Conclusions

Wilson II is an advocacy report, not a scientific document. As such, it is unreasonable to expect that the argument presented therein is scientifically and logically sound, carefully researched, and resistant to simple robustness checks such as factual verification. And indeed it does not met these standards, though of course it would have been much more persuasive if it did.

The authors have an agenda – a large and burdensome toxic use reduction program that might (but also might not) replace conventional chemistry with green chemistry. While their ultimate goal might seem imaginative, laudable and attractive, the way they get there is deeply disturbing from a rational, science-based perspective in which assumptions do not substitute for facts, opinions are not the same as facts, and facts must be empirically grounded. Wilson II begins by making certain assumptions that turn out to be irrelevant in some cases, arguable in others, and in many cases simply false. The report is premised on the assumption that the Toxic Substances Control Act is

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the involuntary reallocation of existing wealth rather than the creation of new wealth. It does not improve social welfare, and because it has real economic costs associated with it, it always results in reduced social welfare. For more, see **Tullock, Gordon; Seldon, Arthur and Brady, Gordon L.** *Government Failure.* Washington, D.C.: Cato Institute, 2002.

[161] **Winston, Clifford.** *Government Failure versus Market Failure.* Washington, D.C.: AEI-Brookings Joint Center for Regulatory Studies, 2006. at 76-79. Market failure creates opportunities for market participants, most notably new entrants, to capture its deadweight losses. Government failure is usually permanent.

a failure because it does not compel innovators in chemistry to prove safety before they manufacture, use, or market various products. Then it purports to document this case by reference to pesticides, for which innovators are required by law to meet exactly this burden of proof.

The report displays a deep misunderstanding of how markets and governments work, and little familiarity with either risk analysis or the rudiments of decision-making under uncertainty. The authors' understanding of basic economic principles appears to be seriously limited, and there is no evidence of familiarity with an extensive scholarly literature that speaks directly to the problems they seek to solve. They postulate the axiom that imperfect information about chemicals results in overproduction, overuse, overexposure, and excess risk. But the practical effect of uncertainty about risk on risk averse firms and individuals is they precautionarily act to reduce production, use, exposure, and risk. In such a milieu, the effect of new, scientifically objective information that can be intelligently interpreted will be to reduce the gap between risk perceptions and reality. People will become more confident that chemicals are safe, not less. But there is no evidence that better-informed rational decision-making is the authors' objective, for they are content to impose extraordinarily expensive requirements for the production of new information that has little or no demonstrated value for this purpose.

The heart of the case in Wilson II is that conventional chemistry is fraught with massive human health perils. These are purported to be documented by very specific quantitative estimates of illness, injury and death – none of which are properly documented so that a competent peer reviewer could test their validity. The authors of the report, who also are the authors of these quantitative estimates of illness, injury, and death, have set aside until another day the task of scientifically documenting their claims.

Still, some of these claims can be examined for plausibility, and it does not take much effort to show that they are so implausible as to be summarily discarded. Whereas the report claims than cancer incidence in California is rising, presumably because of chemical exposure, the data show that cancer incidence in California is falling, and at a statistically significant rate. In the face of actual data, would the authors, who are convinced that conventional chemical production and use is directly proportional to cancer incidence, now say that the production and use of conventional chemicals *reduces* cancer incidence? However necessary this might be to sustain intellectual consistency, it seems unlikely to happen.

The report recommends a massive and highly coercive program of state-mandated toxic use reduction, yet carefully avoids being transparent about it. The authors recommend that conventional chemicals be banned from the market unless they can be proved to be "safe." Inexplicably, the report implicitly proposes to exempt favored substances, technologies, manufacturing processes, and products from these obligations. Yet the informational demands for the their preferred substances and technologies could not be lower than for conventional chemistry, and in fact, must be much greater. Whereas current law allows a conventional chemical to remain on the market unless its social costs exceed its social benefits, under the regime proposed in Wilson II a green-chemistry innovator has an ethical duty to satisfy a bevy of highly demanding technical requirements tantamount to proving the absence of risk. An innovator would have to prove each and every "green" claim or federal law would prohibit him from legally marketing the substance, technology, process or product. A policy decision to exempt green chemistry from proving its safety and documenting its varied claims would be tantamount to performing perhaps the world's largest ever uncontrolled human experiment. All that would be required to poison public support for green chemistry is a single dramatic example from this experiment in which the new alternative backfired.

A rigorous, scientifically sound examination of chemicals policy seems like a good idea. Such a study would objectively estimate the social costs and social benefits from all forms of chemistry – conventional, green, or otherwise – and do so without preconditions about how the analysis must turn out or predetermined conclusions about what ought to be done. Wilson II fares poorly against every one of these criteria. At best, it provides a useful handbook of how not to proceed.

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