PROCEEDINGS

OF

CALIFORNIA'S EMERGING ENVIRONMENTAL CHALLENGES:

A WORKSHOP TO IDENTIFY FUTURE ISSUES FOR CAL/EPA
Held June 25-26, 1998 in Sacramento, California

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NOTE TO READER

These workshop proceedings serve as a record of the ideas presented during *California's Emerging Environmental Challenges: A Workshop to Identify Future Issues for Cal/EPA*. A conscious effort was made by staff to capture all the views and opinions expressed at the workshop. The ideas presented in this document are those of the individual speakers and participants. This document does not necessarily reflect the policies or perspectives of Cal/EPA or any of its boards, departments, and office.

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PREFACE

The capability to anticipate problems that may emerge in the future represents a potentially powerful planning tool for California's environmental protection programs. The Emerging Environmental Challenges Program arose out of a recognition within the California Environmental Protection Agency (Cal/EPA) of the significant benefits that may be derived from early efforts to prevent the occurrence or minimize the adverse impacts of future problems, and to take advantage of future opportunities. (Appendix A is a fact sheet on the Emerging Environmental Challenges Program.)

On June 25 and 26, 1998, OEHHA convened ***California's Emerging Environmental Challenges: A Workshop to Identify Future Issues for Cal/EPA*** as an important first step in Cal/EPA's Emerging Environmental Challenges Program. This workshop was set up to provide a forum for scientists and other environmental professionals to discuss future challenges for California's environmental protection programs. This enabled OEHHA to draw from the wealth of knowledge, insights and perspectives of a diverse audience of representatives of government, academia, industry, environmental interest groups and research organizations.

The goal of the workshop was to generate a well-balanced compilation of ideas about possible future issues for the consideration of policy-makers in Cal/EPA as they develop plans for their programs. Its focus was on identifying emerging environmental challenges driven by scientific and technical factors, that are supported by scientific data and analyses, and that can be addressed by Cal/EPA.

The workshop consisted of presentations from a number of distinguished speakers, exploring future challenges for Cal/EPA in four major subject areas (see Appendix B for a summary of the emerging environmental challenges raised by the speakers):

Session I: Environmental Impacts of New Technologies;
Session II: Sources, Releases and Transformations of Chemicals;
Session III: Multimedia, Multi-chemical Exposures and Risks; and,
Session IV: Resource Management and Resources Sustainability

Workshop participants contributed their own ideas about future challenges during break-out group sessions. (See Appendices C, D and E for information relating to the break-out sessions. Appendix F is a list of workshop participants.)

These workshop proceedings are published as a record of the presentations and discussions that transpired at the workshop. The ideas collected at the workshop are being organized, and those which appear to warrant further attention will be identified. The results of these efforts will be issued as a separate document.

WELCOME/OVERVIEW OF CAL/EPA

KEN SELOVER, Special Assistant to the Secretary
California Environmental Protection Agency

Welcome to the Emerging Environmental Challenges Workshop, and welcome to Sacramento. Secretary Rooney was unable to be here because of a prior commitment, but he would like to share his thoughts with you through a video.

Message of Peter Rooney, Secretary for Environmental Protection:

Good morning and welcome to our Emerging Environmental Challenges Workshop. This workshop is very important for the work of the California Environmental Protection Agency. As we look to the future about the issues that we will be facing, we have to plan, and we have to have lead time. It is with your input, gathered over the next two days, that we will be able to meet the challenge of designing a program that delivers environmental protection to all Californians.

Just yesterday, we had the ground-breaking ceremony for the Cal/EPA building. In the near future, this building will bring together the 2,800 employees of Cal/EPA in the Sacramento area. To help us prepare for the future, we also need your ideas, so I would hope that over the course of the next two days, you will be candid with us and will explain in your words what you see as the issues that will be facing the California Environmental Protection Agency for the next decade.

Thank you, in anticipation of those ideas. I am sorry that I am not able to be with you as I am traveling out of state today and tomorrow for the Governor, but I do look forward to reading the materials that you develop. I know they will be helpful.

OEHHA has embarked on a major program of investigating, inquiring and deciding what issues will be of paramount importance to our state in the next few years. This workshop is the opening step. It won't be the last, but it's certainly one of the most important because it marks a milestone in which we are able to bring together all of you, and to hear your ideas. So again, thank you, good luck and I look forward to the work you will produce.

As many of you know, the California Environmental Protection Agency was created in July of 1991 by Governor Wilson to unify the State's environmental authority under a single, cabinet-level agency. The agency's mission is to improve environmental quality, to protect human health, the welfare of our citizens, and California's natural resources. Our latest strategic plan sets forth three key goals for our agency: preventing pollution and stopping polluters; making environmental protection more understandable and attainable; and improving the environment using science and technology.

Cal/EPA consists of six boards, departments and office:

- the Air Resources Board, which conducts research, monitors California air quality; sets policy for controlling emissions from mobile and stationary sources, and studies topics as diverse as health and crop damage, atmospheric pollution and new technology;

- the Department of Pesticide Regulation, which has the primary responsibility for regulating all aspects of pesticide sale and use to protect public health and the environment;

- the Department of Toxic Substances Control, which is responsible for overseeing the cleanup of hazardous waste sites, and monitoring and regulating hazardous waste transportation, treatment, storage and disposal;
- the Integrated Waste Management Board, which conducts monitoring, research, planning and education programs to address the State's solid waste management needs;
- the Office of Environmental Health Hazard Assessment, which provides State and local government agencies with scientific tools, information and advice upon which to base risk management decisions; and,
- the State Water Resources Control Board, which has primary responsibility for maintaining water quality in the state, and the nine Regional Water Quality Control Boards, which have principal authority for permitting and enforcing pollution control requirements for any discharge to surface water, ground water, or wetlands.

The following quote appears in the *Introduction* to the *1998 Strategic Plan* for Cal/EPA:

"We must handle the water, the wood, the grasses,
so that we will hand them on to our children
and our children's children in better
and not in worse shape
than we got them."

-Theodore Roosevelt

The future is the reason for any environmental agency's existence, and is an underlying consideration in any environmental agency's programs. While we must resolve environmental challenges that we are faced with now, we must also pay attention to signals of challenges that may arise in the future.

It is wise to learn from our past. We can also learn from our future. By reflecting upon how trends will progress, what new developments might occur, what their potential consequences might be, and what forces drive change and how, we will equip ourselves with valuable insight and wisdom that will help us be better prepared to confront challenges which may be ahead of us.

Back in 1911, John Muir said, "When we try to pick anything out by itself, we find that it is hitched to everything in the universe." That is clearly true today.

Recognizing the value of foresight, our Agency has established a program to generate information about possible environmental challenges five to ten years from now -- information for policy-makers in Cal/EPA to consider as they develop plans for their programs. This workshop is the first step in our Emerging Environmental Challenges Program, and represents the beginning of the idea-gathering activity for the program. Our goal for this workshop is to draw upon your knowledge and insights to come up with a well-balanced, science-based compilation of ideas about future challenges which may confront the agency.

We are confident that this workshop will provide us with a rich pool of ideas about what may be ahead for our agency. While the output of this workshop is intended as an input into a more comprehensive process for looking at future environmental issues, we view the ideas that will come out of this workshop as being valuable in themselves, and we plan to consider these in formulating plans to help us be better prepared for the future. Our agency will continue to explore other mechanisms for soliciting ideas about future environmental challenges, and hope we can count on you and on other interested parties to continue to provide input into the program.

Thank you again for coming. We look forward to a productive workshop, and hope that -- at the end of these two days -- we can all come away with new perspectives on California's future environmental issues.

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OEHHA'S EMERGING ENVIRONMENTAL CHALLENGES PROGRAM

JOAN DENTON, Ph.D., Director
Office of Environmental Health Hazard Assessment

On behalf of the Office of Environmental Health Hazard Assessment, I would like to warmly welcome all of you this morning to this workshop. As Ken and Peter Rooney mentioned, my office is responsible for providing information to Cal/EPA and analyzing future environmental challenges which may confront the programs within Cal/EPA over the next five or ten years.

And as we all know, it is not easy to predict the future. Fifteen years ago, someone said to me, "you know Joan, I've been watching this stock and you ought to think about investing in it." I didn't. It happened to go by the name of Microsoft. Of course if I had invested, I probably wouldn't be standing here today. Many of us have had similar experiences in having missed opportunities.

I have been anticipating this workshop for the kernels of ideas which may indicate what the future for Cal/EPA programs and for environmental protection in California in the next five or ten years may be. I would like to take the next few minutes to remind you of the wealth of natural and economic resources we have here in California, and to have you think about what we will be passing along to our children, and to our children's children. The choices that we make in the next few years will determine what we pass on. We are faced with incredible pressures in California -- whether they be population growth, or the need to create an economic climate where people can continue to prosper. These pressures have a tremendous influence on California's resources. After taking you through a California travelogue, I would like to then talk about the implementation of our Emerging Environmental Challenges Program.

California is an incredibly diverse state of mountains, valleys, and oceans. We are blessed with enormous diversity in our great mountain ranges, desert, pristine rivers, and over 1,000 miles of coastline. We have incredible ethnic and cultural diversity -- different languages and races. We have biological diversity: a variety of ecosystems, over 6,800 plant species, over 1,000 species and subspecies of birds and mammals, about 175 species and subspecies of native fish, amphibians and reptiles, and over 25,000 insect species.

California is the nation's most populous state, currently with 32 million people distributed at a density ranging from over 16,000 people per square mile in the City and County of San Francisco, to less than two people per square mile in Alpine County.

We have incredible economic diversity. Our broad economic base includes resource industries such as agriculture, forestry, mining; manufacturing; the film and entertainment industry; and travel and tourism (which generated over $61B in 1997, about 6% of the Gross State Product).

For fifty years, California has been the number one agricultural state in the United States, and 65% of the United States' wine production employment is located in four California counties. We are the seventh largest economy in the world, and home to 27 of Fortune Magazine's 100 fastest growing companies. We are also the nation's number one dairy state, and a leader in environmental technologies that improve air quality, water quality and pesticide management, and that provide energy from sources other than fossil fuel.

The question is, with all of these resources, what kind of legacies are we going to be passing along to future generations? We face a number of challenges, problems, and issues in environmental protection in the future.

To set the stage for the next couple of days, there are several givens that I see for California. First is that we are faced with a growing population, from the current 32 million people to a projected 41 million by the year 2010. If the predictions hold true, this population will continue to increase. Second is continued economic growth. Allan Greenspan made the headlines a week or so ago when he said that the nation's economy is the best that it has been in fifty years, and there is no slowdown in sight. Indeed in California, we are seeing the same kind of economic boom; this economic growth has to keep pace with our future population. And finally, there will be increasing urbanization to accommodate the population growth; the urbanization of rural communities is an issue that California will be confronted with.

The goal of this workshop is to anticipate future environmental challenges, and to provide policy-makers at Cal/EPA with valuable information to consider when formulating their future plans for environmental protection. The focus of the workshop is on environmental issues which may emerge in the next five to ten years and that are important to California, that we can quantify by using scientific data and analyses, and finally that are within the responsibility of Cal/EPA.

This workshop is the initial step in identifying possible emerging challenges. In addition, emerging challenges will be identified using external and internal input through various means such as meetings and workshops. Literature scanning will also allow us to keep up with information about future environmental issues. We are exploring other mechanisms for identifying future environmental issues. Challenges identified will then be organized in a systematic fashion, and then screened – using such parameters as urgency, probability, potential severity, scope, imminence, and others -- to distinguish issues which warrant further attention, at least at this time. Selected issues will then be analyzed in more detail, and reports prepared characterizing the issues in terms of current knowledge, indicators available to track the issue in question, its significance for California, consequences, additional data needed, and potential drivers. Findings will be communicated to Cal/EPA and to the public through these written reports, as well as through the publication of periodic updates. As part of this communication function, each participant at this workshop will get a copy of the proceedings of this workshop.

Kevin Starr, the State Librarian for California, said:

"The American people have assigned for California a special role,
and that is to seek out the American future,
to test it, to try its options, rejecting what doesn't work
and building upon what does."

This is particularly relevant for California's environment and our Emerging Environmental Challenges Program. We intend to seek out California's environmental future -- its plausible possible futures -- to test our assumptions about these futures, to identify the options which we have ahead of us, and to use insights gained from this exercise to guide our environmental protection programs.

AN INTRODUCTION TO FUTURES STUDIES

PETER BISHOP, Ph.D.
Studies of the Future, University of Houston at Clear Lake

An environmental workshop which brings together people to discuss and examine the future is a novel idea. My role is to provide a few tips from the futures studies community that might be useful when thinking about the future.

It is an irony that we spend most of our lives trying to understand and influence the future, yet we spend very little time considering how to go about doing so. Cal/EPA, other government entities, industry, academia, and the non-profit, voluntary sector –- we all constantly try to figure out what is going to happen, and we try to influence the future to benefit us, our family, our community, our organization, the nation, and the world as a whole. We spend a lot of time considering what has happened in the past, having been treated to many classes, and many hours of history, some of which were pleasant, many of which were not. But very few of us have actually spent time considering how to think about the future. As a result, we carry around a few misconceptions. My job is to raise some of those misconceptions and to discuss how we might approach the future in a systematic and productive fashion.

First of all, can we study something that has never existed? Can we systematically encourage discussion, learn from, and understand something which has not yet happened? It is possible to do so, but in order to do so well, we have to employ a few tricks.

These are the four key questions: Can we predict the future? Can we know the future? Can we control the future? Can we influence the future?

There are basically two different approaches to looking into the future: traditional forecasting, and futures studies, also known as alternative futures forecasting. Among other things, there is a big difference between these two in terms of their time horizon. Traditional forecasting is concerned with the short-term horizon. Futures studies focuses on the long term – at least 5 years, frequently 10 to 20 years, and even out 50 to 100 years ahead. Because of the long-term horizon, and because everything is connected to everything in the long run, everything has the opportunity to affect everything. Futurists cannot remain specialists, as traditional forecasters are. Futurists cannot narrowly focus on just the environment, or just the economy, or just technology; they are concerned with multiple domains.

Many factors influence the future; as a result, futures studies focuses on a concept which traditional forecasters generally ignore: the possibility of discontinuity. In mathematics, discontinuity is a point where the smooth curve jumps to another place that could not be predicted. Discontinuities are rare, but when they happen, they are extremely important because they change the whole game. They change the model, the framework, and the relationships of things. Traditional forecasting assumes that discontinuities will only occur after the forecast is over. Futures studies recognizes that a discontinuity may occur at any time, and it attempts to examine what would happen if a discontinuity were to occur and how it might happen.

Because of our focus on discontinuity, futurists are interested in uncertainty. Uncertainty is the reason prediction is impossible. Traditional forecasters hide uncertainty, while futurists aim to reveal it. In physics, revealing uncertainty is not the way to get the answer to the problem. Every physics experiment -- when an ice cube is melted in a calorimeter, for example -- assumes that the event is isolated from the rest of the universe. And it is pretty much so, and the calculations work out pretty well. It is simply assumed that there is no uncertainty involved. While that assumption works well in physics and in chemistry, it does not work as well in economics, social policy, or indeed, the environment. In these fields, we cannot employ the rationale that everything else is equal, and there are no big uncertainties involved. As a result of our focus on uncertainty, futurists are much more involved with ideas rather than quantitative techniques. Ideas will describe the discontinuities and the possible worlds that could exist in the future.

Finally, traditional forecasting tries to get the future down to one point, or a single prediction: "Here is what the future will be." Futures studies, on the other hand, aims to develop a range of alternative futures.

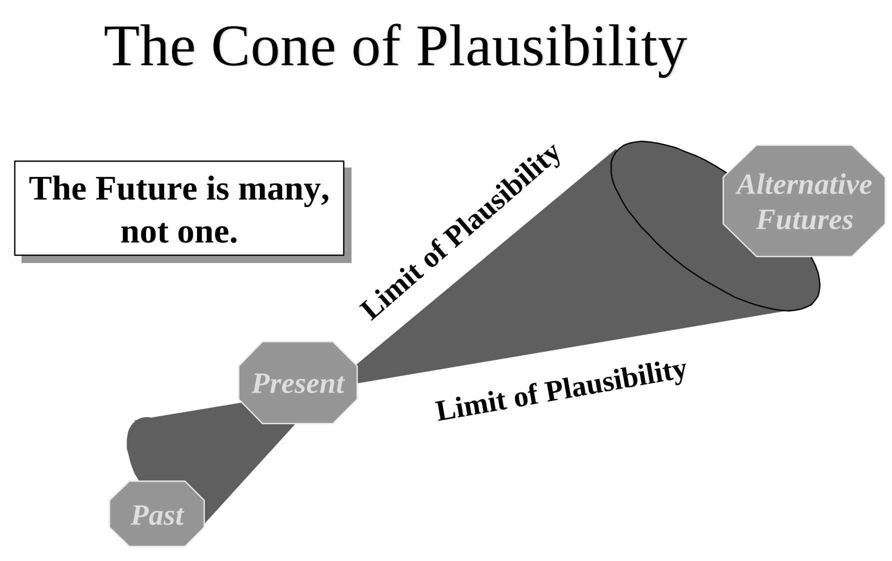
In attempting to reveal uncertainty, it is important to understand that uncertainty comes from a number of sources. The two best known sources are insufficient or incorrect information and understanding. We can reduce both of these, given enough time and resources.

There are other sources of uncertainty, however, that no amount of time and resources are going to solve. Some systems are inherently chaotic. Chaos does not mean that they are disordered. It means that, in the medium- and the long term, even simple systems are unpredictable, because they are subject to a sensitivity to initial conditions. No amount of study will solve that problem.

Secondly, systems are complex; they do things that surprise us. They create things that we have never seen before. There is no traditional forecasting technique that will predict these. Finally, not the least important source of uncertainty is human choice. People are unpredictable to some extent, because they are free, and when they choose, they will choose in ways that will also surprise us.

Inherently unpredictable systems (chaos), inherently novel, self-organizing systems, and human choice are sources of uncertainty that are irreducible. There are no studies, theories, or models that can reduce their uncertainty. The chaos, the catastrophe, the complexity of the world and the environment, and the social and human systems therein require that we deal with uncertainty head-on. We cannot simply assume that uncertainty is not there.

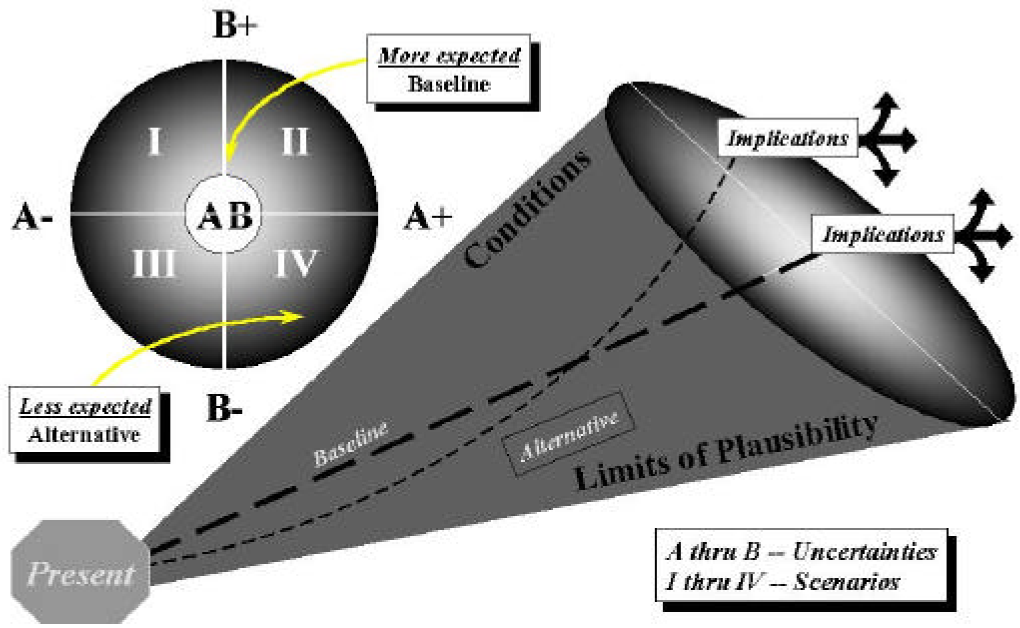
Figure 1



Source: Charles Taylor, Army War College

As a result, the future is a cone of plausibility (Figure 1) -- a cone of increasing alternatives, increasing possibilities. The future is not one thing to be predicted; it is not a central point. Instead, the future is a range, an area. There are a set of possible futures rather than just one. If we can prepare for those possible futures, we will, by definition, be prepared for the future, despite the fact that we do not know which one of those possible futures will actually happen. We do this all the time as individuals. We buy homeowner's insurance, for example. If the house does not burn down one year, we still buy insurance the next and hope the house does not burn down that year either! We prepare for a range of possible futures in our personal lives; why not in our strategic lives?

Figure 2. Alternative Futures Forecasting



Within the cone of plausibility is a baseline future (Figure 2) -- the future that we expect to happen. The baseline is based on trends which traditional forecasters attempt to predict. Is the baseline the most probable future? No, because even the most probable event is not what usually occurs. For example, although seven is the most probable combination of numbers when rolling two dice, it only comes up one out of six times. That means it does NOT come up five out of six times! By focusing on the probable future, therefore, we will probably be wrong most of the time.

Rather than focus on just the probable, we should think about the alternatives -- other futures that could occur because of the uncertainty, the possible discontinuities, and our lack of understanding of or information on the systems that affect us. The alternatives map the range of possible futures. The center of that range is the most probable -- the baseline future -- but there are also dimensions of uncertainty. One dimension, for example, might be state policy (A in Figure 2), and another, the reaction of the environment (B in Figure 2). In the simplest case, out of those two dimensions, we can develop four scenarios: four quadrants of possibility (I, II, III, IV in Figure 2). These are not all the possibilities in the future, but considering and being prepared for all four is a better step than just preparing for the center (AB in Figure 2). Preparing for the complexity and the possibility of discontinuity is what futures studies is all about.

When they talk about the future, most people say, “This is what will happen.” Or, “This is what must happen.” Or, “This is what should happen.” The words ”will,” must,” and “should” are fine words, but they are not very helpful in dealing with the future. More appropriate alternatives are “may,” “might,” and “could.” These words seem to suggest that we are not being clear, that we are not thinking hard enough, or that we have not gathered enough data. However, thinking hard and having data will not solve the problems of chaos, complexity, and human choice. These words reflect the way the future actually is -- the possibility of multiple futures, both good and bad. Using these words enables a more creative way of talking about the future, allowing us all to share in a more or less safe and supportive environment. We need to listen to other people’s futures, without having to decide at this workshop, which of those are true, which are right, or which are probable.

Futurists tell a lot of stories. The story, an ancient means of communication, is still alive and well in our culture today. It is a way of capturing the essence of a message, without worrying about the details. Good speakers, politicians and advertisers use stories to convey their message. Stories about the future talk about possibilities. The details are not at issue; they may happen a different way. In case the story materializes, however, should we not, as prudent people, consider what we would do? For this workshop, I urge us to tell stories about the future.

What are these stories about? The future occurs in many domains: people, the natural environment, technology, economy, government, and culture. All of these are sources of change. Everything interacts with everything else, simultaneously. Change occurs as a result of trends, discontinuities and choices. These affect how the future actually emerges.

Our stories of the future are limited only by our lack of information and understanding – what we do not know – and by our unexamined assumptions – what we think we know but do not. A workshop like this can help to uncover the more important problem — erroneous assumptions. It is only in the face of challenge that our assumptions are revealed. We need to listen carefully, therefore, in order to hear and accept the challenge and uncover in what another person is saying what we have not yet considered. The more we know our assumptions, the more varied and plausible our imagined futures will be.

Our assumptions affect our stories in deep ways. There are optimists who believe that, with good hard work and with ingenious strategies, the future will be better than the past. The optimists are counterbalanced by the pessimists, who tend to focus on short-term negative trends, technological problems, and human errors. There are also transformationalists, who believe that the future will be so different that optimism and pessimism do not really apply. They believe in a break with history, in less technology, and in universal human potential. They also tend to focus on spiritual, societal and environmental concerns. Then there are the fatalists, who believe and assume that there is nothing that can be done about the future – that events are so unpredictable, and forces so overwhelming, that there is little conscious human control over them.

The future is a big place, and learning to think about the future is a life-long quest. Let me just conclude then with three words to remember throughout the speeches, discussions, and break-out sessions at this workshop. The first word is to **listen**. Listening is the beginning of communication, and listening to ideas -- particularly ideas that seem strange, wrong, or threatening -- is the beginning of learning. The second word is to **speak**: tell your story, your assumptions, and your image of the future, in a spirit of cooperation and mutual search for assumptions that need to be uncovered. And finally, to **enjoy** -- enjoy the opportunity to explore foreign territory that is not a physical space, but a new and unexplored time.

The outcome of futures studies is not to correctly predict the future, but rather simply not to be surprised. The only way to avoid big surprises in the future is to allow ourselves to be a little bit surprised everyday, while accumulating ideas about a range of alternative futures. Allow yourself to be surprised today and tomorrow. The result will be less surprise and more security and success in the future.

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THE USE OF FORESIGHT IN ENVIRONMENTAL PROGRAMS

GENEVIEVE MATANOSKI, M.D., Dr.P.H.
Johns Hopkins University

Introduction: Current Approaches

Protection of the environment requires that we begin to think about the future and what we would like to see in our world. Only recently have some organizations such as the Science Advisory Board (SAB) of the U.S. Environmental Protection Agency (U.S. EPA) and the G7 International Organization begun to utilize futures thinking in their efforts to plan their environmental agendas. Based on my involvement in these endeavors, I would like to share with you some of the results of these activities and my thoughts regarding the importance of futures approaches to environmental problem-solving.

Environmental planning generally has focused on mistakes of the past and regulation to remedy those mistakes. Legislation to try to keep the air safe for humans and ecologic systems has certainly improved air quality. However, as we become more sophisticated in evaluating the success of our regulations, we find we still have many environmental problems. We have discovered that the mortality of humans is increased even at low exposure levels to particulate air contaminants. We recognize that there are large numbers of Superfund sites which must be remediated, but the actual clean-up of those sites is difficult to implement and the completion of the work will take many years.

The approach which we take to the environment today focuses on improving the recognized detriments in human and ecologic health caused by past environmental insults. This approach to maintaining a healthy environment is a rather frustrating business. It leads us to wonder where we are going over the long-term. We attempt to solve many environmental problems only to have new questions arise: What about our indoor air? What risks are associated with our use of electricity and cellular phones? Are the foods being consumed by our children safe, given current pesticide controls? Can estrogen-mimicking compounds cause human disease or damage ecosystems? Does the public enjoy the quality of life it desires in relation to its environment?

The environmental community must look at its current approaches, and ask if these are accomplishing the intended end result. Fixing the environment after problems have been identified leads to many difficulties. The costs of fixing problems are enormous, in terms of both time and money. In addition, the success of such endeavors in producing an environment which at least resembles the original conditions to an extent which will support the natural habitat is still in question. Perhaps more importantly, the question remains as to how sustainable the fixes proposed will be – i.e., will these maintain the restored habitat over time? These are three issues that are common to many efforts at remediation: the success of restoring original conditions, the sustainability of the "fix," and the cost of the project in time and money.

The emphasis in environmental control is shifting to prevention to avoid new long-term damage. Of course, we still will have the problems of remediation of past mistakes for many years to come. Admittedly, prevention which really anticipates eliminating distant future problems has difficulty. How do we anticipate a problem if it has not been realized? Most of prevention today focuses on problems which we expect might occur secondary to some action because we have seen the problem before in a similar situation. Sometimes we can anticipate a problem because we know that a potentially hazardous exposure will take place if nothing is done in advance to eliminate an agent. This preventive approach often is not very anticipatory of long-term problems. Evaluation of the effectiveness of any preventive program is difficult if there are no recognized events in the past which the program aims to prevent. However, the control of environmental problems must move beyond addressing those which are currently anticipated and are on the radar screen, and begin to consider those problems which we have not yet seen.

Is such futures thinking necessary? The Science Advisory Board (SAB) of the U. S. EPA emphasized the importance of this activity in its document, *Beyond the Horizon: Protecting the Future with Foresight* (1995). This parent document is accompanied by supporting documents produced by the various subcommittees of the SAB. The committees developed several recommendations. While the general recommendations are very important, the value of the exercise is not related as much to the specific areas pinpointed as possible future problems, but more on the emphasis on a new direction in environmental planning which must be incorporated into current environmental mandates. The importance of futures thinking is to get the individuals who have responsibility for the viability of the environment to begin to view their mandate with a long-term approach to problems and solutions.

How important is this new role for environmental agencies, both national and state? Abraham Lincoln expressed the reasons why we must focus on the future in the following words: "If we could first know where we are and whither we are tending, we could better judge what to do, and how to do it." In its 1995 report, the SAB reiterated this thinking, specifically with regard to the future and the environment when it recommended that "....looking beyond the horizon is essential to the nation's future success in protecting the environment." The SAB went one step further and warned about the results of not paying attention today to potential future problems: "When one generation's behavior necessitates environmental remediation in the future, a burden of environmental debt is bequeathed to its children just as surely as unbalanced government budgets bequeath a burden of future financial debt." That debt may also include permanent losses of our environmental resources of today. Therefore, it is clear that we can no longer ignore our future responsibility to the environment and focus solely on the repair of our past mistakes. The SAB firmly stressed this conclusion: "EPA, and other agencies and organizations whose activities affect the environment, should give as much attention to avoiding future environmental problems as to controlling current ones. In particular, EPA should establish a strong environmental futures capability that serves as an early-warning system for emerging environmental problems." These precepts are the first two recommendations of the SAB to U.S. EPA (Table 1).

Table 1
Recommendations from
"Beyond the Horizon: Using Foresight to Protect the Environmental Future," 1995

1. As much attention should be given to avoiding future environmental problems as to controlling current ones.
2. As an essential part of its futures capabilities, EPA should establish an early-warning system to identify potential future environmental risks.
3. In a longer-term, more comprehensive effort, EPA should evaluate five overarching problem areas related to a number of potential future environmental issues.
   - Sustainability of terrestrial ecosystems
   - Non-cancer human health effects
   - Total air pollutant loadings
   - Non-traditional environmental stressors
   - Health of the oceans
4. EPA should stimulate coordinated national efforts to anticipate and respond to environmental change.
5. EPA, as well as other agencies and organizations, should recognize that global environmental quality is a matter of strategic national interest.

The first two recommendations reiterate the conclusions which were the main focus of the SAB document, that U.S. EPA must pay attention to the future even while controlling current problems. This statement is in effect quite revolutionary as it suggests that U.S. EPA should devote attention and control efforts to possible future problems which may arise with equal importance and vigor as it does the regulatory activities directed at control of existing problems. To do that effectively, U.S. EPA will need to plan for an early warning system to identify potential future environmental risks.

The fourth recommendation warns that control over the environment is fractionated in the government. The actions of another agency can have serious consequences on the environment and yet, until recently, very little attention was paid to the long-term consequences of other agencies' decisions. Yet many of these agencies (e.g., the Department of Energy, the Department of Defense, and the National Aeronautic and Space Administration) are charged with managing long-term programs. Environmental considerations must therefore be included in all futures planning of other agencies.

SAB also recognized that global environmental quality could become a strategic national issue. It certainly is a crucial part of treaty considerations regarding use of the Great Lakes.

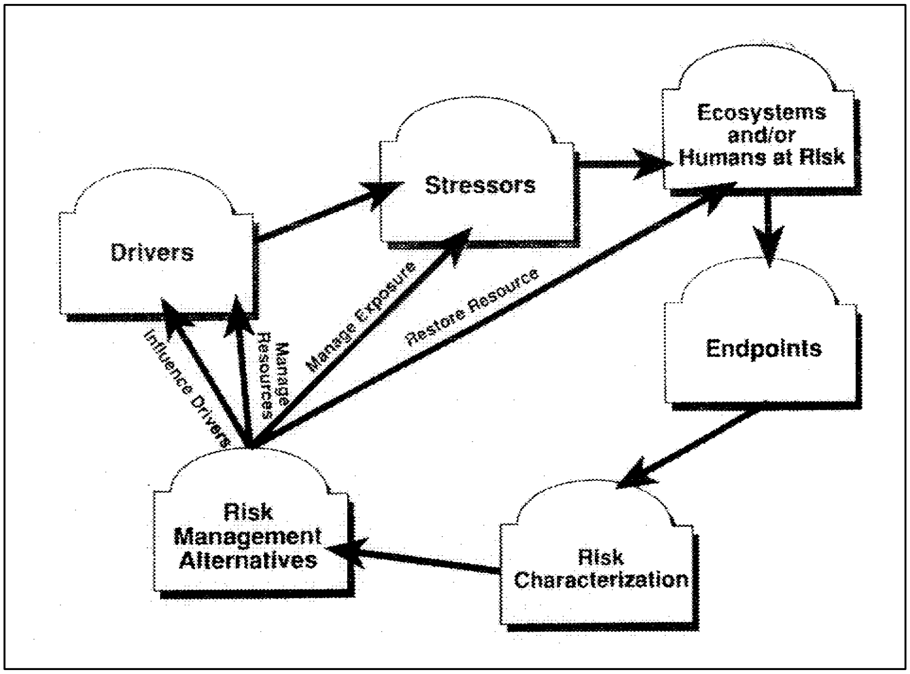
Futures Thinking

Foresight or futures thinking is not an exercise of fortune-telling or crystal-ball gazing. It is not an exercise to predict gloom and doom, as is often done at environmental futures meetings. As SAB found, it is an exercise demanding a search for new observations, new thoughts, and new technologies, and expanding upon this information to project possible resulting future impacts. It involves a process of investigating the ideas that are not accepted fact today, but which might be important for the future -- those that are "beyond the horizon." As stated by SAB, "The value of futures research and analysis lies not in making predictions, but in analyzing and organizing information that can help shape decisions and actions." Futures thinking can use current trends, current technology, and current facts, but it must take these observations out of their context in the present, and out of the beliefs of the majority about where we are headed. Futures thinking requires speculating on what might happen if some event should interfere with our current beliefs. Only then can we begin to plan in a way that will enable us to be in position to act appropriately, no matter what direction the forces on the environment may take.

SAB examined a comprehensive list of future problems suggested by various subcommittees with different areas of focus such as ecology, radiation, and engineering, as well as the suggestions of the parent committee. From that problem list, SAB suggested five overarching problem areas for U.S. EPA to evaluate: sustainability of terrestrial ecosystems, non-cancer human health effects, total air pollutant loadings, non-traditional environmental stressors, and health of the oceans.

These five areas represent a widely different array in terms of impact characteristics and time horizon. The first three listed are already recognized as environmental issues but for which either the solution is not apparent or the focus has been minimal. For these areas, the full extent of the problem has not been documented, and there is often no accepted way of addressing the issue. The fourth area, non-traditional environmental stressors, include the group of hormone-mimicking agents which are known to be present in the environment, but for which there is no accepted association with known human disease. The final area, the health of the oceans, may be an emerging problem based on clues reported from various sources but, at present, there is no recognized risk. Many still feel the oceans can cleanse themselves; yet recognized problems at the shoreline and contamination farther out to sea suggest that this system may not be as immune to environmental insults as had been thought.

Figure 1. Conceptual Model of Drivers, Stressors, and Endpoints



What are the components of systems which can result in environmental change? SAB developed a conceptual model of the components which influence an environmental risk. As illustrated in Figure 1, the drivers are critical initiating factors which produce or change environmental risk. However, these are usually not factors which are likely to be directly under the control of a single governmental agency or even any branch of government. Examples of drivers which are most crucial to the development of environmental problems are population growth and urbanization, economic expansion and resource consumption, technological development, and environmental attitudes and institutions. These were the major factors used in developing scenarios in the SAB futures project, although many other drivers can be possible influences. Examples of stressors which are the target of environmental interventions include airborne agents, pesticides, ground water contamination and habitat alteration. The important factor to recognize in the model is that if one approaches the environment from a futures perspective, it is possible to manage risks at the stage of the drivers and stressors by managing resources, thereby avoiding the need for steps requiring control of exposures or remediation of a problem.

Obviously, when environmental problems have already been recognized, the point of intervention is close to the identified endpoint. This is especially true in the management of human health effects. The approach in humans is to identify the agent suspected of causing disease, be it lead, mercury, or particulates, and then to eliminate that exposure for humans to the extent possible. Control of ecological problems tends to focus closer to the point of the driver-stressor interaction, regardless of whether current or future effects are being examined. The ecologists look for remediation of the problem by controlling the development of agriculture or by relocating transportation routes to areas where there will be no disruption of habitat patterns or destruction of water resource availability. Human health risks are focused on specific substances which may cause specific endpoints, such as particulate air pollution and mortality, rather than urbanization. However, in either situation, futures thinking, which places the focus of management on the drivers, poses a challenge since control of these drivers is not considered a part of the role of U.S. EPA. Therefore, new methods of management may be needed.

Issues to Consider

Let me share with you a few of my ideas about future issues we should be thinking about. In California, for example, with farming as a major industry, the long-term consequences -- good and bad -- of bioengineered plants need to be examined. What might their impacts be on the humans who consume them? The environment in which they are grown? The other part of farming that becomes extremely important is water: water use and water loss. Water is our biggest commodity and necessity. Yet we are using it very poorly, and are experiencing a lot of the consequences of our practices. We need to begin to think about water management much more systematically.

Demographic trends indicate the population is aging. This raises a number of issues. For example, where will the elderly be housed? They tend to not want to be in a house all by themselves. What are you going to do with them? What kinds of drugs will they be taking, and will these go into the water system? In the next 15 years, what kinds of drugs might there be that are going in water supplies, into the ground? Very little thought is given to these kinds of issues. It's not just population growth; it's a population growth that is disparate in terms of its characteristics, which lead to very important issues to consider.

FUTURES AND TODAY: HOW CLOSE?

SAB suggested a future issue in 1994: "Emphasis is placed on multiple end-points and multiple exposures requiring new risk management criteria."

Current issue:

- Food Quality Protection Act of 1996
- Recommendations of multiple committees for integration of risks (1997 and 1998)

Most of the futures thinking of scientists is not really very long-term. So, if an item appears on the future radar scope, we probably should begin to do something about it now. As an example, in the SAB list of items from several committees was a statement that in the future, "Emphasis is placed on multiple end-points and multiple exposures requiring new risk management criteria." SAB suggested this in 1994 as part of a futures project. The pesticide program in U.S. EPA was already considering methods by which to scientifically combine exposures from various sources into a single risk assessment. Congress moved science even faster by enacting the Food Quality Protection Act of 1996, which requires that U.S. EPA combine exposures and risks from all pesticides and all sources when considering risks to children. Various SAB committees in the last two years have again recommended that U.S. EPA combine or integrate risks before deciding on regulatory options. The implications of this recommendation has been examined by SAB in their soon to be completed "Integrated Risk Project." Their deliberations suggested that integrating risks to try to decide on a course of action may lead to new and perhaps revolutionary changes in the way the agency considers risks. The point to be learned here is that, for the most part, the items included in many of these futures exercises are not really far away. Our five-year horizon may be closer than we imagine.

IMPEDIMENTS TO FUTURES THINKING

- Governmental management
- Governmental laws and regulations
- Scientific thinking

To engage in futures thinking and then to be prepared to act on potential problems identified from that activity is a very difficult process. As shown above, at least three factors are impediments to these endeavors. Governmental officials have very short time frames and usually focus most of their attention on the crying needs of today. Although they may enjoy a period of speculation as a respite from the "real" world problems through engagement in futures exercises, they seem to find it difficult to truly look long-term, since the political calendar is usually divided into four-year blocks in many cases.

Governmental laws and regulations sometimes impede us from doing long-term thinking because of their focus on taking care of the past mistakes. There is nothing wrong with this, but we have to somehow jump over that boundary and add a component of futures thinking.

Finally, as a scientist, this is the hardest thing that I do. If I sit down at a meeting, I need a non-scientist to poke me in the ribs and say, “yeah, but did you think about this, and did you think about that?” As a scientist, I want facts, and I want everything I do to be based on those facts; I may speculate a little bit, and interpret a little bit, but I still need to be grounded in facts. What we need is a group of scientists interacting with a group of people who are unbound by the need for facts, individuals who can think way beyond today and into the future.

So I really petition you, while you are at this workshop, to open up every single idea -- however wild it is -- and let your colleagues scoff at you for a while; that’s fine. But make them put your idea down on a list. And they will scoff. While serving on the SAB Executive Board, I laughed when I heard it said that, in the future, there may be four farms feeding the entire United States. It has also been said that technology may come to the point where we could move under different mechanisms than our currently accepted automobile engines -- sure, that is science fiction and will never happen; but maybe it will. You need to think about ways that are totally different, and don’t be upset if your colleague calls your idea wild. It’s the wild idea that really reflects futures thinking, not just forecasting from current activities.

Good luck to you all. You have a hard job ahead of you, but it’s a fun job. Practice will improve our skills. We can't afford to wait. So don’t let these futures planning activities stop here.

OVERVIEW OF FUTURE TECHNOLOGIES

WENDY SCHULTZ, Ph.D.
University of Houston at Clear Lake

My role is to establish a context for the more specific presentations of my fellow panelists by providing an overview of technologies in the future. I will attempt to set the tone for exploring and provoking imagination. One of the basic ground rules of futures studies is that you cannot predict the future -- there is not a single “The future,” but rather there are alternative futures.

In terms of the emerging issues that futurists track, technology is often the fastest moving domain, progressing very rapidly from the gleam in the inventor’s eye to instant ordering on the Home Shopping Network. This can take place in a matter of months. Or a new technology can go from a garage workbench to global distribution in a year or two. We have become very good at innovating, mass producing, marketing and distributing new technologies.

Some of the hotly anticipated new technologies include: bioengineering, nanotechnology, ubiquitous microprocessors, intelligent agents, smart inks and smart textiles, and zero-point energy. Let’s examine some of these.

Bioengineering can mean anything from cloning to transgenic plants and animals to computer designed creatures.

Nanotechnology is the emerging group of potential applications that occur where shrinking microprocessors and the growing applications of new materials (such as buckminsterfullerene, buckyballs, or buckytubes) meet microengineering with scanning tunneling microscopes. This includes the creation of extremely small, potentially programmed, self-directed machines that perform small services in extremely efficient and hopefully resource-conserving ways.

Ubiquitous microprocessing is a phrase that was developed in California at the Xerox Palo Alto Research Center. Ubiquitous microprocessing will move us from a present where you have multiple computers, to a future where multiple computers have you! As microprocessors become increasingly small, cheap and powerful, they will become embedded in everything. Computers will be tracking what your needs are through intelligent expert systems; they will also track where you are, and how information needs to follow you through your day. A possible scenario illustrating the use of ubiquitous microprocessing could be: It’s six-thirty in the morning, and the bed sends a message to the shower, “She’s a little slow in getting up today. Drop the temperature by five degrees, maybe it’ll get her moving. And notify the coffee pot that it’s time to start percolating.”

Intelligent agents are variations of some of the software technologies, designed to work hand-in-hand with ubiquitous microprocessing. Programmers are developing a myriad of expert systems that are designed to learn about your individual needs, and adapt to those needs and offer you services. Imagine having a very smart desktop that watches what you do for a week, and then informs you, “I’ve noticed that you’re writing the same memo to your staff every Monday morning. Surely I could do that for you?”

Smart inks and smart textiles are both examples from prototype projects being explored at the Massachusetts Institute of Technology. These combine new materials advancements with some of the nanotechnology initiatives and the idea of ubiquitous microprocessing to create chemicals with small decision systems triggered by very minute electrical fields. These chemicals can be embedded in paper, so that 10 or 15 years from now, you may only buy a single book with what seem to be blank pages. When hooked up to an electronically transferable media, the embedded ink molecules are triggered to switch to black and white in certain patterns, producing a copy of

War and Peace, or of John Grisham's latest bestseller! The book can then be converted back to its original blank form, ready for reuse: the joy of turning pages that are infinitely renewable -- the last book you'll ever buy, the infinite book. Smart textiles will be embedded with controlling microprocessors that could change the texture of the fabric -- loosen the weave, change the color, and so on. What would these technologies do to the amounts of ink and dye processing that we currently use? How would these impact the inputs and outputs to the environment? How would a smart book affect trees, paper, water, and other resources being invested in publishing paperbacks or newspapers that we throw away on a daily basis?

Zero-point energy is one of the technologies that lies further out on the timeline. It is based on the idea that there are very, very low levels of background energy throughout the universe that we might be able to tap -- again using very small scale technologies -- to provide us with ubiquitous energy production, as an analogy to ubiquitous microprocessing.

The preceding examples were chosen because they are all "colliding," mixing with each other in ways that will magnify the probability of their occurrence, and that will create entirely new devices and new opportunities for yet other emerging technologies. New technologies are frequently designed for a serious purpose, but humans are not essentially very serious as a species. Hence, a technology that is developed as a tool is often transformed into a game -- often before most of us even figure out how to use it as a tool.

We are living in an age of new developments in how the new develops. There are a number of aspects to this. First, we have moved away from a mono-disciplinary scientific paradigm to a multi-disciplinary, inter-disciplinary, or in some cases trans-disciplinary one. In the last 50 or so years of scientific research, we have gone from physics, biology, and chemistry – very tidy scientific thinking, looking at particularly well delineated fields of study, very reductionist, that is, taking one particular topic, taking a tree, a mammal or a piece of engineering, and just considering it of itself -- to looking much more at the interactions of things, so that we now have physical chemistry, biophysics, and organic chemistry. Some of the most important scientific thinking is happening where different sciences merge. In the environmental area, we have moved away from simply considering one aspect of the environment, to more integrated approaches with the advent of systems science and systems approaches, an example being current watershed management approaches. You can't consider just the plant. You can't consider just the housing. You can't consider just the medical effect of the drug that you were giving the patient while the drug is in the body. You have to consider the system that is the source of the input, and the system that it will be going to. In essence, we have to learn to live with less defined boundaries.

Global communications and computer networks are also accelerating the dissemination of data and information globally. Ideas are in motion, new data are colliding with old data, data from different cultures are mixing around with each other more than they ever have before. We have opportunities to share our interests with people all over the globe in ways that we previously did not. As futures researchers, Peter Bishop and I especially appreciate the opportunities to communicate with the large global community of futures researchers and maintain our sense of intellectual liveliness through the Internet, given that there are very few of us in this field in universities around the United States.

The ability to trade ideas is very important; creativity is often defined as the synthesis of two concepts that previously existed separately from each other. Overlaying different world views, overlaying different ideas, overlaying different concepts generally generates yet more ideas, new perspectives, and deeper perspectives. Not only are new data accessible globally in databases, but so are old texts: primary historical documents have been digitized -- not merely scanned in and recorded as a graphic – to enable, for example, keyword searches of ancient Korean court records for every instance where the court used "elephants for transportation"; within a day, you can complete almost all your research for a great new article on Korean history. The digitization of information is making connections and data synthesis much easier, all around the world, across multiple disciplines. It will change and speed up how we do research.

We are extending our reach. With the Hubbell space telescope we can look out to the far reaches of our universe and back to the beginning of time. With electron microscopes we can zoom in, looking down to the level of atoms, and we can even manipulate single atoms to spell out organizational logos, as researchers at IBM did a few years ago. The problem, of course, with extending your reach is that it becomes increasingly difficult to keep your aim steady and precise. With a greater extension of reach, we have a greater possibility for fumbling. In this workshop, we should be thinking about all the ways we could possibly fumble as we extend our reach.

If three of us went off to the edge of a pond and threw in three stones, each one of those stones would, of course, generate a set of waves in the water. If we threw our three stones into the water very close to each other, those waves would start intersecting. Similarly, there are very interesting and powerful ideas, and potentially powerful applications in technologies, that are being created from the interference patterns among new technologies and new thoughts that are proliferating through our very rich information systems.

Let's look at some examples of technologies emerging from the interference patterns involving multiple disciplines and new data. Nanotechnology and biotechnology could give rise to microscale artery scrubbers and landfill miners. In the future, there may be little machines that we can inject into our arteries to scrub them out, making it possible for us to eat all the coconut cream pie we want without a problem. The International Mining Association has been exploring the possibility of using a nanotechnology application combined with buckytubes to do very precise mining, making it possible to mine and recycle minerals and metals from landfills. Will these microscale artery scrubbers and landfill miners be very small machines, or machine-designed living organisms? At what point will nanotechnology and bioengineering meet, and perhaps blend together?

Eco-friendly chemical production may emerge from new materials and genetic engineering, leading to the cultivation of transgenic plants and new agricultural crops not requiring fertilizers. Plants can be designed to excrete oils on their leaves as plaques of plastic (there are, in fact, some prototype examples of these at Monsanto). What would the future look like when plastic production facilities look like farms, rather than the refinery centers of Pasadena, Texas?

Practical telepathy is an interesting idea involving human-machine interfaces. Growing neurons on microprocessors will enable microchips to be hooked into your brain, so that your cellular phone is in your head -- you can access the Internet directly.

Personal pharmaceuticals, or drugs designed specifically for your DNA pattern, could have interesting environmental implications. With these drugs, pharmaceuticals excreted into the water may not be a concern; or perhaps, they may become an even greater concern.

One of the emerging sets of issues and patterns that we might want to think about at this workshop is the increase in the ambiguity of impacts – instead of identifying "either/or" impacts, there is a need to identify both positive and negative impacts. What if all these little nanomachines that are out there mining landfills, fixing things, or cleaning out our arteries, or the tailored bacteria that were designed for oil spills get loose in the environment? Will this have beneficial, or adverse consequences? Will this mean that environmental cleanup will involve hunting after machines or organisms that "know" they are being hunted, and attempt to "run away"? Or will these smart machines and organisms be smart enough to "return home"?

There will appear to be a blurring of borders between the natural and the artificial, the evolved and the constructed. When bioengineered new plants start growing in areas they should not, what is the difference between invasion by this terrific new agricultural product and an infestation of an alien species? We could be creating an alien species infestation ourselves. There is a possibility that we will be able to conserve our resources more, and be much more efficient when we are operating on microscales; at the same time, we are also likely to experience much more concentrated and focused impacts that might be even more transformational than those of the past.

FUTURE ENERGY TECHNOLOGIES

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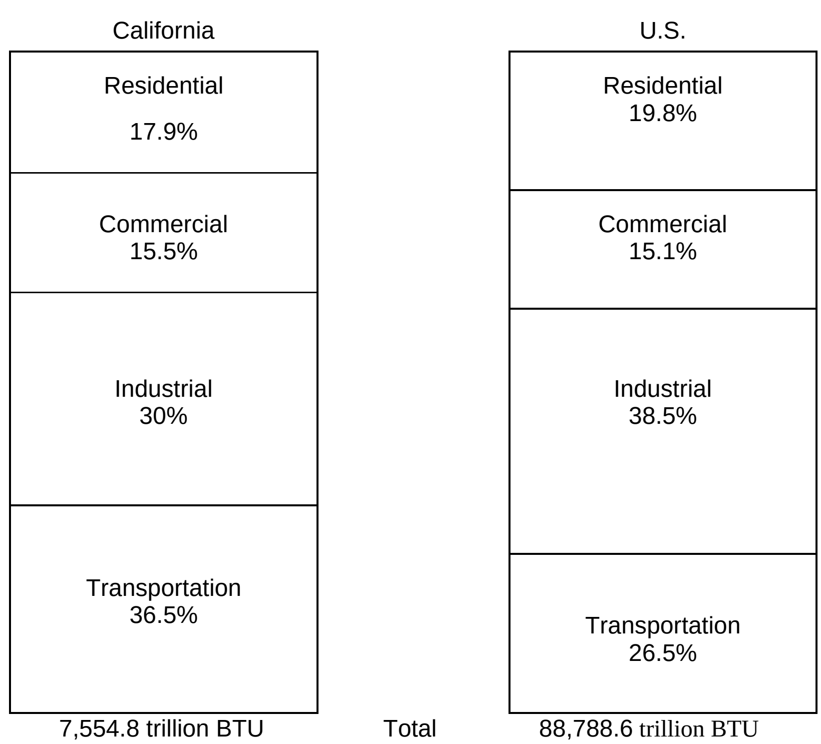
From an energy standpoint, all of us view sustainability as a goal; my view is that it needs to be achieved by increments. Since we live in a time of chaotic change, straight lines cannot be drawn to project energy use, energy prices, and environmental impacts; since there are certain forces that effectively impact us exogenously. For example, the next geopolitical crisis over oil will increase oil prices. Events like this that have the potential to cause drastic changes are certain to happen; it's just a matter of when.

We are dealing with a complex world where there are interrelationships among everything. The demographics of California drive change. The level and the quality of education drive technology and technology choices. Demographics, economy, education, and technology are all components of nature and the environment. As part of this, regulatory changes, as well as deregulation, will provide opportunities and uncertainties.

Current Situation

Although California mirrors the nation in terms of total energy consumption, there are some notable differences in consumption patterns (Figure 1). California's industrial sector accounts for 30 percent of the total energy consumption for the State; nationally, the industrial sector consumes 38.5 percent of the total energy. California's transportation sector, however, consumes 36.5 percent of the total energy, while nationally this sector consumes 26.5 percent. This is why it is rational to discuss energy in two contexts: the fixed and the mobile sources. California also uses significantly less energy on a per-capita consumption basis, about two-thirds of the national per-capita average.

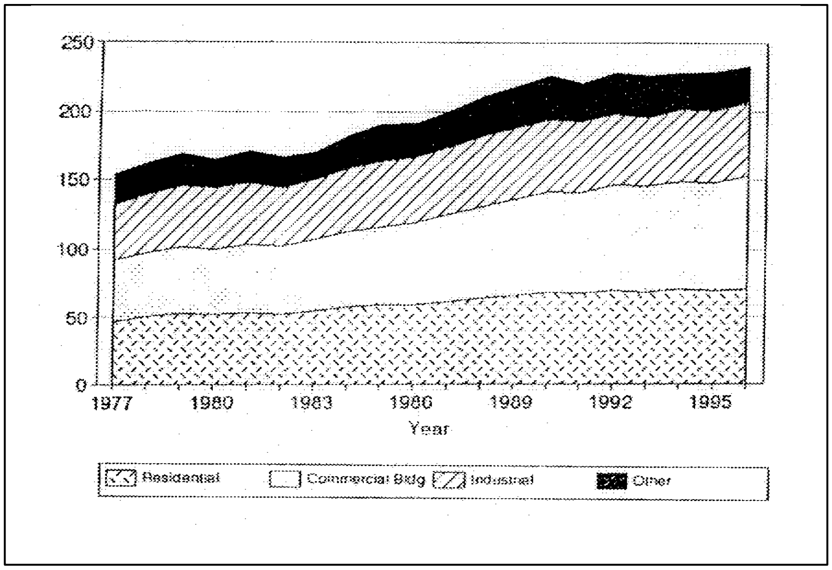
Figure 1. Total Energy Consumption By Sector, 1994*



*Source: States Energy Data Report, 1994

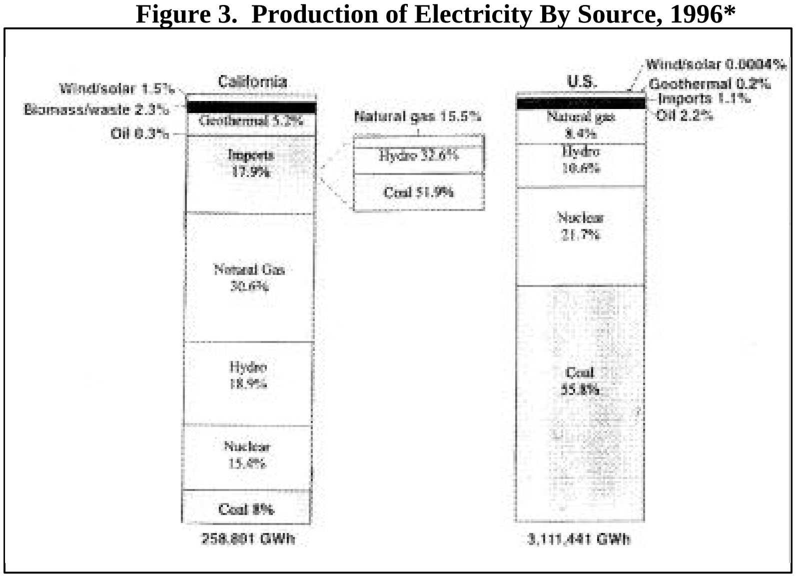
Electricity consumption has been steadily increasing over the years (Figure 2). Increased growth is expected in the commercial sector, but growth in consumption by the residential, industrial and other sectors is expected to remain essentially at the same level.

Figure 2. California Electricity Consumption*
(Billion Kilowatt-hours)



California is significantly different from the rest of the United States (U.S.) in terms of sources of electricity (Figure 3). Electricity in the U.S. is produced predominantly (55.8 percent) from coal, with an additional 21.7percent produced from nuclear sources. California, on the other hand, is much "greener," with 30.6 percent of its electricity generated from natural gas, and only 8 percent from coal; other significant sources are hydroelectricity (18.9 percent) and nuclear energy (15.4 percent). Much of this is due to technology innovation, the availability of resources, and the culture associated with people willing to look at new technologies. However, California imports 17.9 percent of its electricity, with more than half of the imports generated from coal.

Figure 3. Production of Electricity By Source, 1996*



There has been a growth in a number of technologies associated with smaller plants, e.g., cogeneration, geothermal energy, wind energy, solar energy, waste-to-energy, and small hydroelectric plants. There is a lot of interest in cogeneration, nationally as well, because of increases in efficiencies. A number of new plants being constructed for the production and sale of electricity in California will be cogeneration units.

Relatively, California does not pay a lot of money for energy. Although electricity costs in California are relatively higher than in the rest of the country, these costs are generally not an issue. The production costs associated with deregulation are only a fraction of the total service provided to consumers. Whether this will become an issue important to consumers remains to be seen.

Energy Use Projections

There has been, and will continue to be, an overall increase in electricity consumption in California, and electricity will continue to come from a variety of sources. For fixed sites, it is likely that natural gas or natural gas combined cycle will continue to be the near-term technology choice, because the efficiencies are greater, and the capital costs associated with building those facilities –as well as the delivery costs of

The California Energy Commission projects a growth in both peak demand and in total consumption of energy in California over the next several years. Current projections indicate that certain energy-efficient advances in end-use technology will reduce some of this demand. This may not be correct because there are other drivers for electricity use under deregulation, and the question is whether to go with fixed resources (importing fossil-fired electricity, including electricity generated by coal-fired plants), or to start looking at distributed systems. The choices will be made as a function of costs and consumer needs and interests.

Some of the changes in energy mix will be driven by external factors:

Demographics. California's population is growing. The population is aging and becoming much more diverse. One reason for the State's low per-capita usage is its very benign climate. As more people move to California, there will be less available housing in benign climates, and more homes will be built inland, where more energy will be required for transportation and for comfort.

Economics. As competition increases under deregulation costs will be driven down for available technologies, while efforts to improve reliability and environmental performance may languish.

Technological change. This is driven by such factors as pure research and development efforts funded in part by Public Interest Energy Research (PIER) and the technology certification efforts within Cal/EPA; which will have a greater impact on distributed systems for power generation and mobile sources.

Natural systems. Resource availability, geography, weather, and natural disaster will have an impact on energy supply and demand. Specific factors include California's agricultural base, seismic events that may occur in the future, and storms and their impact on water availability.

Government. Government as a driver of change may act in two ways: promulgating technology-forcing regulations to attain a specific objective (such as the Air Resources Board's regulations for controlling evaporative emissions); and promulgating regulations in response to technology (e.g., deregulation of the energy industry as a result of technology-driven forces).

The energy mix is going to change. Since California itself is a powerful driver of the economy, the advantage to deregulation in this State, in terms of electricity generation and energy use, is that it is feasible to develop technology for the California market because the base for use is so large. Technology developed and tested in California can then be exported to other markets.

There are certainly other groups that will drive change. California has an economic engine called Silicon Valley, both as technology development and use. For example, improved information technologies can provide better real time data for the distribution and demand of electricity. The insurance industry is concerned about risk management for effects associated with climate change, in terms of damages from more frequent "100-year" storms and electricity outages, which can lead to destroyed production runs. Non-governmental organizations, or NGOs, play a role in information dissemination, in mobilizing individuals to act, and in initiating lawsuits where, in their view, things are not being done right. Effectively communicating and describing information in terms understandable to the public will be critical.

There are other external factors to consider: implementation of international carbon dioxide reduction treaties, for instance; natural phenomena that can affect energy choices; security issues, such as liquid fuels costs (which are associated with geopolitical events); nuclear materials (and public perception of their associated risks); new environmental and public health findings; and public sector initiatives which may have unintended consequences on energy use.

There are available (or soon will be available) advanced technologies aimed at increasing efficiency and minimizing environmental impacts and costs across the generation, transmission/distribution, and end-use sectors. Examples are advanced energy storage technologies (e.g., flywheels, batteries, superconducting magnetic energy storage, capacitors and fuel cells) not only in fixed systems, but also in mobile sources; information technologies, such as advances in supervisory control and data acquisition that can assist in securing the transmission and distribution system and improving reliability; high-voltage direct-current transmission and power transformers and underground high-temperature superconducting cable that can improve transmission and reduce distribution losses; coupling utilities and transportation with advanced electrolysis and hydrogen technologies to increase baseload capacity and enable intermittent renewables such as photovoltaics and wind; and advances in the efficiency of lighting, window glazing and building design, materials and HVAC systems (e.g., smart building systems) that decrease energy demand. It is critical to be cognizant of the potential impacts that may be associated with these new technologies that will penetrate the market in five- to ten- years. Many of these technologies are associated with information and its distribution, and with decision-making made possible by access to better information.

End-use technologies now being developed will have an impact on lifestyle and energy demand. It is projected that three-quarters of the energy demand in the future will be met as a result of energy efficiency improvements. It is uncertain whether increased efficiency actually will result in less energy use. Use may increase because consumers enjoy toys and games, and other gadgets which will require more energy.

Unintended Consequences Associated with Advanced Technologies

It is necessary to constantly examine consequences from a multidisciplinary perspective. Often decisions are made based on a sense of urgency about the need to act, but without the benefit of having all the necessary information. New technologies designed to improve the environment in one area may actually result in adverse effects (unintended consequences or "dangling impacts") in another area. For example, the increased use of biomass for electricity generation may lead to air quality and water resources impacts. With new technologies for energy storage, increased use of batteries may lead to disposal problems; in addition, nonoptimized storage systems may actually increase emissions because round-trip efficiencies are less than 100 percent.

An integrated view of how energy systems work must be developed, striving towards a carbon-free system and eventually – as we move toward a better hydrogen-to-carbon ratio of energy use – leading to a hydrogen energy economy. However, since we are entering another "fossil fuel century," the achievement of these goals will be well into the 21st century at best.

Conclusion

There are several "Es" that are keys for developing new approaches involving energy use, environmental protection and technology commercialization:

Environmental quality and the desire to improve it often drives technology development, and overall energy use and energy technologies have a significant impact on environmental quality. **Energy technology development** is possible only when permitted by **economics**, i.e. when new systems are cost-competitive with existing, less environmentally benign systems. **Education** plays a critical role in getting consumers to "buy into" a new technology; people must be comfortable with these systems, or they will not use them, even if they are economically reasonable. Education is also necessary to ensure that the operations and maintenance for fixed systems will be understandable to those who need to know how these systems work. Finally, in a diverse state such as California, we have to understand **equity considerations** in a sensible way. We also have to look from an economic perspective at how these energy technologies can be exported to other countries to help justify development costs.

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FUTURE TRANSPORTATION TECHNOLOGIES

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Motor vehicles have influenced virtually every aspect of our society. In many ways, they represent a huge success story. Today's vehicles are reliable, durable, and (for such complex machines) inexpensive. They provide us unprecedented mobility, freedom, personal security, comfort, and convenience. Our appreciation for these benefits and our attraction to motor vehicles are evidenced by a few simple statistics (Table 1).

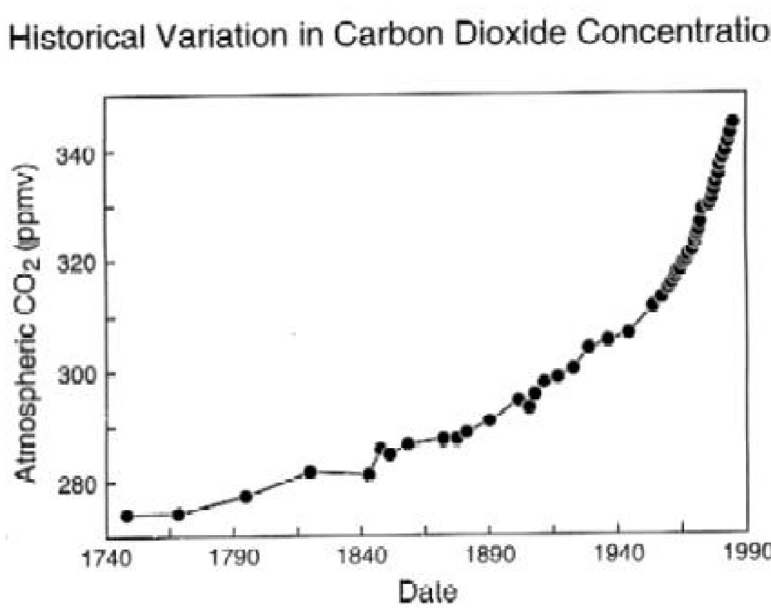
Table 1. More Vehicles and More Travel, USA*

	No. of Vehicles (millions)	Vehicles/ Capita	Vehicles/ Driver	VMT/Driver (Thousands)
1950	43.5	0.29	0.70	---
1960	66.6	0.36	0.78	---
1970	98.1	0.48	0.88	8.4
1980	139.8	0.62	0.96	9.9
1990	179.3	0.72	1.07	13.0

Source: Nationwide Personal Travel Survey, Oak Ridge National Laboratory (1995)

There are over 180 million vehicles in the United States (U.S.), more than one per licensed driver. There are more vehicles and more vehicle-miles driven than ever before. Clearly people find motor vehicles to be a very attractive, important, and beneficial technology.

But along with the benefits come many large costs. One of them is large quantities of carbon dioxide emissions. Figure 2 shows rapid increases in carbon dioxide (CO_2) concentrations in the atmosphere, about ¼ of which worldwide comes from transportation. This percentage is slightly higher in the U.S., with about 30 percent coming from transportation.



Another large cost is energy use. Conventional wisdom says oil production will peak around 2010 to 2015, and start declining (Figure 3). Most analysts in the oil industry believe, however, world petroleum production will continue to expand well beyond 2015, due primarily to technological innovations in finding and extracting oil -- the yield rates from oil fields are increasing, and “dry holes” are becoming increasingly rare. Because of these successes, the price of oil is not rising, despite the depletion of finite oil reserves. Indeed, the price of oil has not changed in over 100 years. While there have been spikes, up and down, the rolling average has not changed. Will there be disruptions in the near future? Will the industry continue to meet expanding demand?

Clearly, the oil supply is finite; we cannot keep producing oil forever. At some point not so far off, we will need to convert our cherished motor vehicles to other energy sources (Figure 3). Many alternatives exist in abundance, including vast quantities of remote and “unconventional” natural gas. Most of these alternative sources have higher costs and/or higher environmental impacts than today’s petroleum. Our embrace of petroleum fuels will soon loosen. But how soon and how fast? As a society, we have much to say about what energy sources we use in the future.

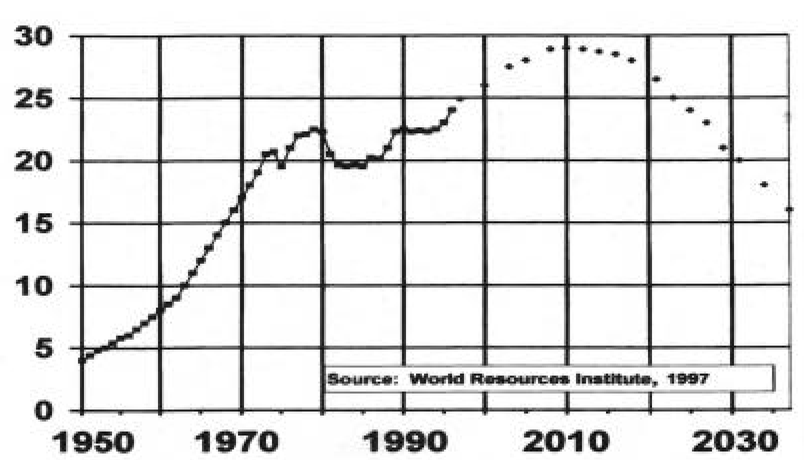


Figure 3. World Oil Production Forecasts, Billions of Barrels Per Year

One of the implications of having relatively inexpensive and, at least as perceived in the petroleum industry, relatively abundant oil supplies, is diminishing concern for fuel economy. While today’s vehicles consume about the same amount of fuel per mile as they did 15 years ago, they are in reality about 40 percent more energy-efficient. But energy efficiency improvements – resulting from use of lighter materials and more efficient combustion -- have been diverted to make larger, more powerful, and more accessory-laden vehicles.

Another major cost associated with vehicle proliferation is air pollution. Oil and automotive industry advertisements boast that not only has air quality improved virtually everywhere, but that a large part of this has been due to dramatic reductions in vehicle emissions. While they are correct, actual emission reductions are not as dramatic as claimed. Data indicating a 98 to 99 percent reduction in emissions from vehicles do not fully account for the deterioration and malfunctions that occur over the life of a vehicle and are based on artificial driving cycles that do not reflect actual driving conditions. The actual improvements are impressive, but not nearly that large. A more accurate estimate is about a 90 percent reduction in carbon monoxide and hydrocarbon emissions, and about a 70 percent reduction in nitrogen oxides emission per vehicle mile since emission controls were first imposed in the 1960s.

These impressive improvements are expected to continue. Emission standards continue to ratchet down. Standards are in place for substantial reductions between now and 2003, and new standards are scheduled for adoption in November 1998 that will force another major round of emission reductions. The outlook for continuing reductions in motor vehicle emissions is positive, though not assured, especially given continued increases in travel.

As we face the future, it is clear that the options for addressing many of the adverse impacts of motor vehicles involve either inducing people to drive less, or fixing the technology. Changing behavior – through ridesharing, transit use, bicycles and walking, through shortening and eliminating trips, and through changes in land use -- is attractive for many reasons. It reduces environmental impacts and congestion problems without having to build expensive infrastructure, and it facilitates the creation of more livable communities.

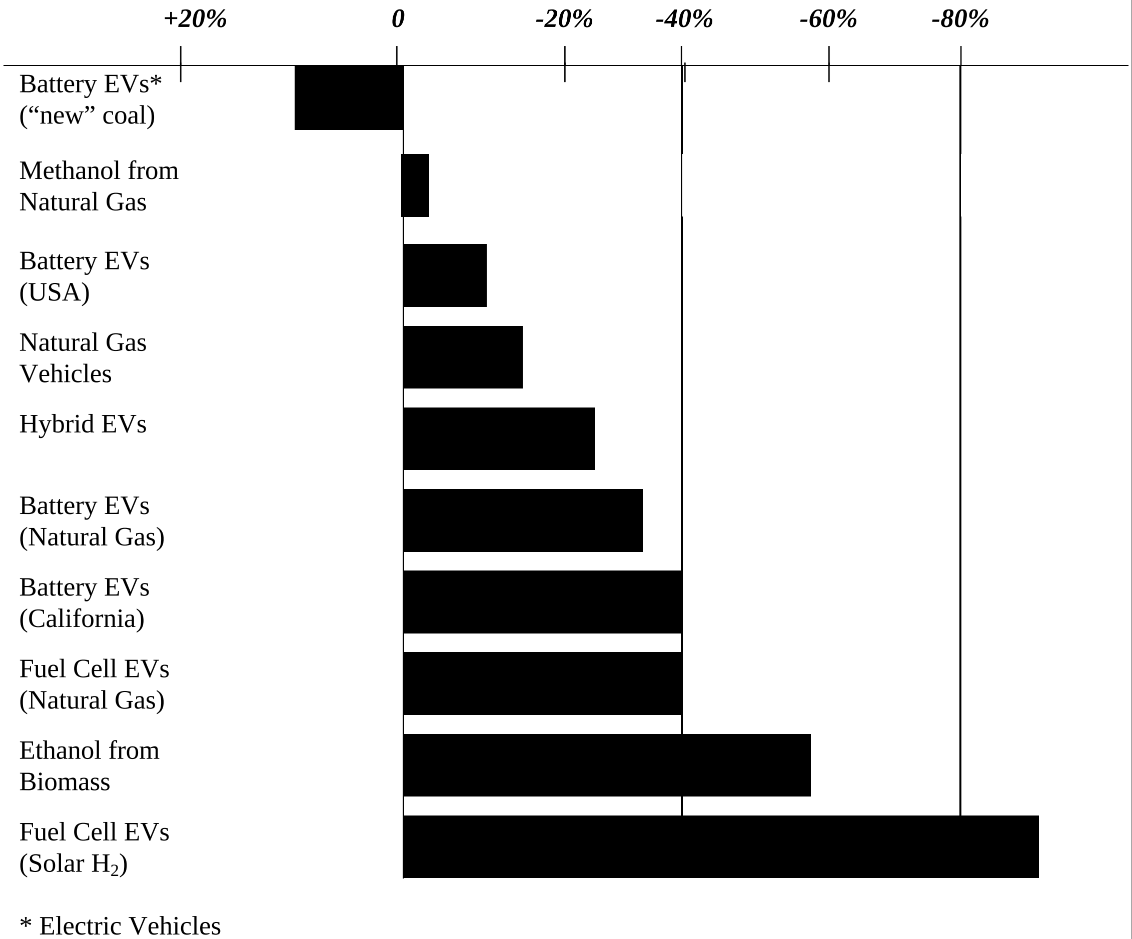
The technology fix strategy targets the vehicle instead of the user. It involves lower emission rates, alternative fuels, and more energy-efficient vehicles. Technologies already exist that could dramatically lower emissions, greenhouse gases and energy use from vehicles. These changes, however, will take some time. Vehicle turnover is slow, and consumer acceptance of new technology is often slow – especially when the principal attractions of these technologies are largely outside the marketplace. Public policy plays an especially large role in bringing these technologies to market, in assuring that environmental and energy benefits are fully accounted for in the decision by companies to produce them and by individuals to buy them. It may take 30 years before we benefit from technology that is today characterized as already here or "very close." The lesson is, we better get started soon, or we will push that horizon year even further into the future.

What we need are more environmentally benign vehicles. Already, a tremendous amount of innovation is occurring in some critical technology areas -- in lightweight materials, energy storage (batteries, ultra-capacitors, flywheels), fuel conversion devices (fuel cells which convert a chemical energy into electrical energy), renewable fuels, and electronics. An opportunity exists to direct technologies in ways that have major social benefits.

A wide variety of new vehicle fuels and technologies provide the potential for major reductions in greenhouse gases (Figure 4). But we must be selective. For instance, methanol made from natural gas and used in a conventional spark ignition "gasoline" vehicle produces about the same greenhouse gas emissions as gasoline. Likewise, battery electric vehicles are not a panacea. Reductions in greenhouse gas emissions resulting from a battery electric vehicle will depend upon the source of the electricity. When the electricity comes from coal, battery electric vehicles will actually produce more emissions than a gasoline vehicle. In California, very little electricity comes from coal, making this state one of the best places in the world, environmentally speaking, for battery electric vehicles. Battery electric vehicles using energy from a typical mix of electricity sources in the U.S. yield about a 20 percent improvement; in California, where little coal is used, about a 50 percent improvement. Hybrid electric vehicles have the potential for very large reductions, depending on their design. Fuel cells running on natural gas yield a 50 to 60 percent reduction. Biomass fuels yield as high as an 80 percent reduction. With solar hydrogen[*] used in a fuel cell, about an 80 to 90 percent reduction in greenhouse gases can be achieved. Most of these technologies are commercially available now, or will be shortly.

[*] Hydrogen produced from water using solar power.

Figure 4. Effects of Alternative Fuel Vehicles on Greenhouse Gas Emissions



The air pollution benefits can likewise be significant from most of these technologies. Fuel cells running on solar hydrogen have essentially zero emissions. Battery electric vehicles running on some of the cleaner sources, can also result in a huge improvement. In California, with the very clean electricity-generating powerplants, these vehicles can cause reductions of 80 to 95 percent in most pollutant emissions (Table 2). Particulate matter is the only air pollutant for which reductions may not be significant, but this is mostly because gasoline combustion is a very minor source of particulates.

Table 2. Electric Vehicle Emission Impacts, %
California, Year 2010*

	Minimum Impact Scenario	Maximum Impact Scenario
HC	-95	-96
CO	-95	-99
NOx	-65	-84
SOx	+ 5	-52
PM	+30	- 1

Source: Institute of Transportation Studies, University of California, Davis

General Motors, Honda, and Toyota all manufacture and sell advanced electric vehicles. Battery electric vehicles have been controversial and not commercial successes. One reason is that, in order for an electric battery vehicle to be of comparable performance to a gasoline vehicle, it requires a large battery, which is heavy and expensive. From a technical, environmental, and economic perspective, smaller electric vehicles represent a much preferred alternative. They have much smaller energy requirements than regular sized vehicles, and thus need much smaller and less expensive batteries. With the proliferation of vehicles, it would not be difficult for households to replace one of their vehicles with a small electric car for commuting and local use.

Various other options are being pursued to create environmental vehicles that are not so dependent on batteries. One such strategy is the hybridization of a small combustion engine with an electric driveline and battery. In this way, a small battery and engine can be used, and the engine can be operated at a steady efficient level.

Fuel cells, which convert chemical energy into electricity, are another option. They are highly reliable, and produce no noise and essentially zero emissions. Costs are still high, but dramatic improvements have been made since the early 1990s when fuel cells were first identified as an attractive automotive technology. Much of the automobile industry, and even the energy industry, apparently believe that fuel cell vehicles will dominate in the future.

In general, enormous progress has been made in improving the environmental performance of vehicles, and at relatively little cost. Indeed, emission control costs for gasoline vehicles will probably never exceed costs experienced in the 1970s and 1980s, even though emissions are dropping to a fraction of what they were. Technical innovation has been -- and continues to be -- highly effective in reducing emissions. The challenge is in jumping to the next generation of vehicles – those powered by electric drivetrains, using various combinations of small combustion engines, as well as batteries, fuel cells, and other energy storage devices.

The most effective instrument for encouraging investments in these advanced propulsion technologies has been California's zero emission vehicle (ZEV) mandate. Although not the most economically efficient approach, the ZEV mandate has, nonetheless, had a much larger effect in developing and encouraging innovation than any other government action. It is critical that this blunt instrument be made more flexible and complemented with incentives to industry and consumers. It is also critical that California develop the engineering and science expertise to support industry investments in these new technologies.

The future may not be far off. It is plausible that by 2020, 80 to 90 percent of vehicles sold in this state would be hybrid, fuel cell, and/or battery electric vehicles -- with far lower emissions, greenhouse gases, and energy consumption. There are plenty of opportunities for technological innovation, coming from many industries. The challenge is to imagine a future that is different from the past and to devise means of realizing that future. It means different types of vehicles. It means using vehicles in different ways. It means moving away from today's transportation monoculture – where all vehicles serve all purposes, and bicycles, transit, and walking are dwindling. Government plays a central role in guiding investments toward those technologies that are more environmentally benign. The choice is, in a sense, ours.

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FUTURE AGRICULTURAL TECHNOLOGIES

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When people speak about California from an economic perspective, they think about three things: movies, agriculture, and technology. My talk today will address the latter two.

The two types of technologies that are very hot in California today are computers and biotechnology. Both of these will have an incredible impact on California agriculture, and the resulting environmental implications will largely be influenced by policy.

Agriculture is a big industry. It produced $24 billion worth of output last year, and its related industries generated about 20 percent of the gross state product of California. California is a major producer of fruits and vegetables for the United States (U.S.). Generally, you can speak about California agriculture as three types of activities: (1) low-value crops -- field crops like cotton, alfalfa, wheat; (2) high-value crops -- fruits and vegetables; and (3) livestock.

One trend that is likely to continue is the increased shift in the use of agricultural land for high value crops, instead of low value crops. For example, the west side of the valley that once was an area for cotton and wheat is increasingly becoming an area for lettuce and tomatoes. There is a big difference in productivity and value resulting from this shift -- from $500 per acre to $6,000 per acre.

As the most productive agricultural state in the nation, California has to deal with a variety of environmental problems associated with agriculture: water, pesticides, animal waste, air pollution, and others. Much of the agricultural technologies in the future will be driven by the need to solve environmental problems. It is important to recognize that California agriculture supplies a very important global need. We produce fruits and vegetables that make up about 50 percent of the fruits and vegetables for the U.S.; we are also a significant supplier of produce to the Pacific Rim countries. At least this part of California agriculture will increase in the future, and the resources that it demands will be in conflict with other uses.

Farmers are often perceived as being against the environment. At least in my view, farmers are not against the environment; they know it and live with it as much as -- or more than -- anyone. On the other hand, they are businesspeople who may take advantage of opportunities and gaps in regulation. Technology and policy are often the key to understanding agriculture in California. When policy is lax, and technology is not available, the agricultural industry behaves in one way; when policy is tight, and technology is available, farmers respond. Farmers want to be environmentally sound; they know the environment well, and have a good appreciation for it.

Technology cannot be isolated from regulation. Introduction of technology is often induced by regulation and by economic constraints. A good case study to illustrate this is the drought. The drought showed that when constraints are present, farmers and institutions adjust. The cost of the drought to California was much less than the cost of the freeze to citrus growers during one of the drought years. Farmers adjusted to the drought by adopting drip irrigation, which allowed them to use less water while keeping yields, by adopting sprinkler irrigation, by using groundwater, and by reducing the acreage of low-value crops. Even the institutions adjusted. We established water banks, which saved trees and high value crops throughout the valley. The drought showed that when there are constraints and when people use policies right, then technologies that are available are used to good advantage. Drip and sprinkler irrigation technologies existed, but were not used intensively prior to the drought. Similarly, the idea of water banks existed, but it was not until there were constraints imposed by the drought that the concept was implemented. The elements of constraint and policy are very important in driving the application of technology.

What type of technologies will we see in agriculture? There are two major types: precision technologies, and biotechnology.

Precision technologies have two characteristics: the use of computer electronics and communications equipment to adjust resource use to variability of time and space; and the reduction of residues.

Generally, land is highly variable. There are variations in slope, water-holding capacities, and micro-climates, which necessitate adjustments in water use and application of fertilizers and pesticides at every location, according to specific conditions. Currently, existing equipment is relatively primitive, and the same quantities of resources are applied regardless of location. Precision technologies will use different types of devices to monitor applications to suit exact conditions. Some of the precision technologies that we see now are satellite-driven and are akin to space technology. It is likely that in the future, precision technology will be on board vehicles that monitor conditions and adjust to them. A combination of geographic information systems (GIS) databases and geographic positioning systems (GPS) will provide data to be used in adjusting application to conditions. Precision technology will have a significant effect. It will increase yield, reduce water use, and most importantly, reduce residues. One of the biggest problems with today's pesticide application is that a large percentage of the applied pesticide ends up in the atmosphere instead of on the targeted crops. Chemical are sprayed from an airplane, and about 50 to 70 percent misses the target.

Some precision technologies currently exist. Drip irrigation, for example, produces efficiencies of up to 90 percent, if done right. Some of the computerized irrigation in the valley have a 95 percent input efficiency. Some pesticide application technologies have very high efficiency rates -- up to 90 to 95 percent. The use of precision technology raises another point: it often does not matter what you use, but how you use it. With good application technology, many of the chemicals that cause problems associated with drift, worker safety and others will be reduced; with more precise, proper application, the residues will not be there.

Precision technology has an incredible future. Because it requires coordination and investment, however, it is unlikely that farmers will adopt it unless they have to. This is an area where policy can play a critical role. Approaches such as penalties assessed against input use, taxes imposed on agricultural chemicals, and increased prices of water may be necessary to promote the development of precision technology. Policy approaches may involve direct control, or the introduction of institutions – e.g. certification of applicators to regulate pesticide use; notification mechanisms regarding what is applied and how it is applied to ensure that chemicals are applied properly to reduce residues. With precision technology comes the potential for much more efficient water use, and for some of the environmental side effects of agriculture to disappear, or to be reduced significantly. Regulators have to understand these technologies well in order to encourage their development, to identify ways to use them to achieve environmental protection, and to maximize their beneficial impacts.

Precision technology will provide tools for regulators. The difficulty today in regulating agricultural waste management is largely due to a lack of information about where the waste goes, and how it is handled. Satellite technology and GIS data will enable better monitoring of pollutants and thus, better regulation, particularly of non-source pollutants.

The second type of technology that will complement precision technology well is biotechnology. Biotechnology includes many elements, but its key feature is the manipulation of organisms. In agriculture, biotechnology has been used to produce soy bean and cotton varieties that are manipulated to oppose pests, or to lose resistance to herbicides. Biotechnology has been successfully used in medicine, from which we have learned several very important lessons.

Medical biotechnology has three features. First, this is one technology that is university-derived. Most of the initial innovation occurred in universities and moved to the private sector through a process of technology transfer. Secondly, in the private sector, it was carried out by new companies that were supported by venture capital. And finally, these new companies grew, and exported the technologies across international borders. This pattern is very important in my view as an economist. It demonstrates the potential for venture capital to generate new companies based on university knowledge. It is a secret weapon that the U.S. has, California in particular, and is the key to growth. This pattern has not happened much in agriculture because much less research occurs in animal and plant biology than in medical biology. Further, agricultural biotechnology is, to some extent, more risky to the environment because manipulated organisms are released in the field. Hence, the environmental regulations tend to be relatively severe. Despite these factors, however, we are starting to have some success in agricultural biotechnology. The industry may be about 15 years behind medical biotechnology, but it is moving to the future.

What types of products may we expect to see? We expect to see products that will replace and augment chemicals. We will see pest-resistant and pesticide-resistant plants which will allow for the more effective control of plant diseases and the more effective use of herbicides. The dynamics and the evolution of this type of technology will depend upon chemical regulation. If, for example, chemical pesticides are banned, more biotechnology products will emerge to replace them. If the use of chemical pesticides is not restricted, biotechnology will be retarded. It is not clear, however, that restricting chemical pesticides will be beneficial at this time, because biotechnology products may take several years to develop.

Another application of biotechnology in agriculture will be its use in improving food quality. If a grower can produce a peach that is sweeter and better looking, that grower can suddenly triple the price of that peach. Biotechnology can improve sweetness, smell, manageability, and shelf life. As long as consumers will accept the concept of biotechnology -- and I think that they will -- there will be increased product diversification and production of new types of fruits and vegetables, tailored to different tastes. In the future, cereal companies will start designing fruits and vegetables. It is likely that California will be the state where the designing is done because of its strong universities, with production occurring elsewhere. California is also likely to be the area where seeds are produced for use all over the world. The Central Valley may well become “Biotech Valley,” where technologies and new varieties are developed.

Another area for biotechnology is in the production of fine chemicals. Today there are already companies that use algae and other organisms in producing food coloring and cosmetics using biotechnology. Future products may include eggs that are cholesterol-free and meat with lower fat. Biotechnology will also be used in the production of medical products through agriculture; the boundary between agriculture and pharmaceuticals may be opened up, and the field of agro-pharmaceuticals will arise. This may become the area where most of the evolution will occur. Suddenly the regulators will have to deal with agriculture both from an environmental perspective, as well as a medical perspective – for example, how much of a banana that has a certain antibiotic can people eat? This is a potentially exciting area that will change the ways by which agriculture operates and performs.

Agricultural biotechnology has applications in waste management. Bacteria and other organisms are already used to destroy existing waste products and even convert them to useful chemicals. In the future, there may be farming in an area that is marginal as a result of the use of some of the waste products as food for certain products. Biotechnology will be used to generate different types of energy. Certain bacteria will be applied to a waste land for energy generation. Then there is the area of cloning livestock, not only for food but also for medical purposes. A variety of issues will be involved in cloning -- issues of morality, issues of value, and issues that regulators will have to learn much about.

Biotechnology and precision technology are going hand-in-hand. Biotechnology will provide a lot of variety to precision farming. The two together will enable agriculture to take advantage of diversity.

In the future, there will be much more emphasis on taking advantage of heterogeneity and diversity. Some people think that biotechnology will destroy biodiversity; I disagree. The key in agriculture is to take advantage of heterogeneity. With biotechnology and precision technology, agriculture will have adjustable systems that will allow growers to adapt what they grow and how they grow them to the environment. A key element in precision technology is not what you use, but how you use it.

The development of technology will depend, to a large extent, on policy. The development of biotechnology can be accelerated by stronger regulation of pesticides. The development of biotechnology can be accelerated by spending on research. The biotechnology revolution will not occur unless there is significant continued research in biology and environmental issues in the universities; private companies are very good at taking technologies that are ready and moving them forward, but not at coming up with new concepts.

All in all, we will see a technological revolution in agriculture that will take advantage of diversity, and respond to incentives. The challenge to regulators is to know the technology and to provide the right incentives.

POLLUTANTS DISTRIBUTION IN A DYNAMIC ENVIRONMENT: A MULTIMEDIA PERSPECTIVE

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A product's life cycle starts with raw materials, which go through various processing and manufacturing steps, producing emissions as well as products for use and disposal. As chemicals enter the environment, they may cycle through the environment, causing exposures, which lead to risks requiring risk reduction strategies. By examining this life cycle, one can go back to various steps along the process to determine where risk can be reduced and then ask the question, "Have we used the appropriate risk reduction strategy?"

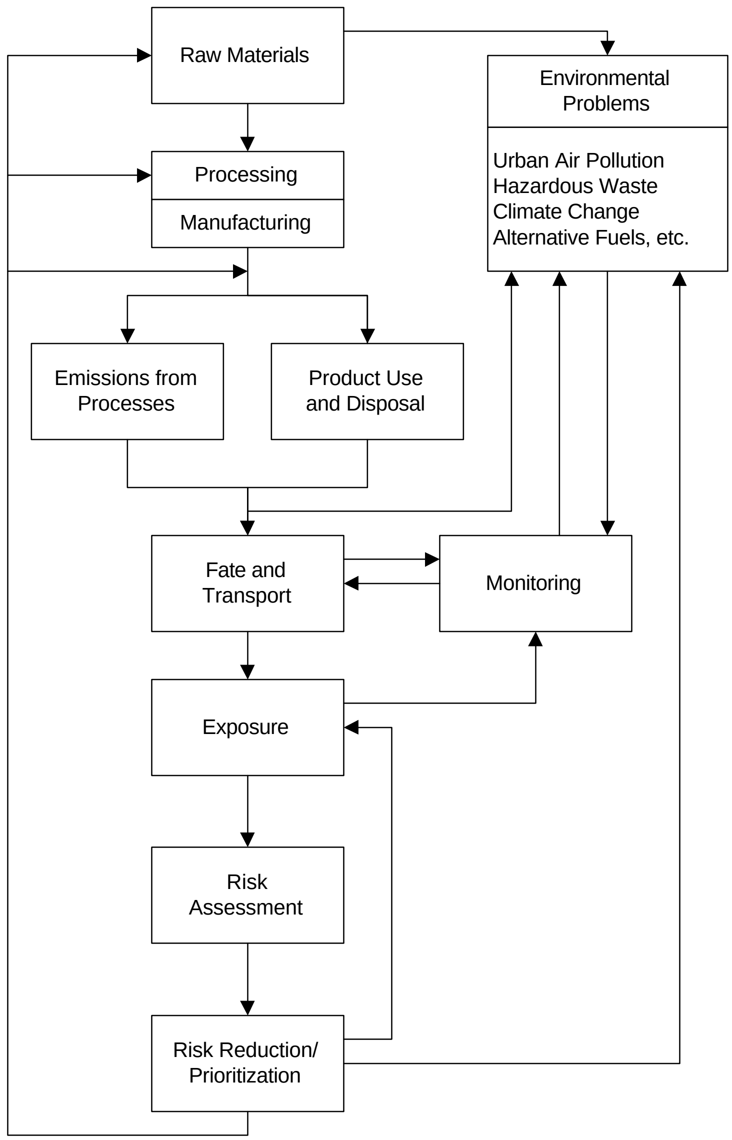


Figure 1. The Challenge: Integrate risk assessment with life cycle analysis

At present, life cycle analyses are conducted for the purpose of saving energy and reducing the mass of emitted pollutants. These actions do not necessarily reduce risk significantly. One of the challenges which confront us is how to integrate risk assessment into life cycle analyses.

No matter what medium it is originally discharged into, a chemical is distributed to other media when it enters the environment. A chemical that is released to the atmosphere, for example, may find its way into the soil and the water, and tend to cycle in the environment. Humans are exposed either directly or indirectly to various media -- not only air, water and soil, but also fish, vegetation, and others – and all these media, in turn, interact directly or indirectly.

The environment is dynamic and spatially variable. When dealing with contaminants that may end up in the vegetation that we eat, or in the fish that we eat, the approaches used typically assume steady-state or equilibrium, not recognizing that things change over time. This may be a very important consideration in addressing susceptible populations. Exposures can involve direct pathways such as inhalation, ingestion, and dermal absorption, or indirect pathways, such as inhalation of chemicals volatilized from water during bathing.

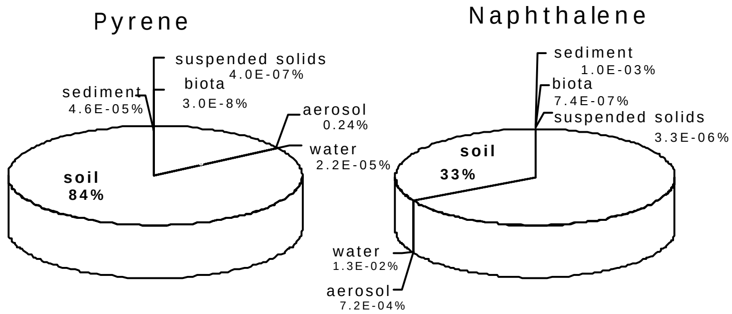
California is a rather complex area. Southern California, for instance, is indeed a multimedia system, with the ocean, the mountains, and the shore area. Both model predictions and actual measurements have shown that ozone concentrations in the area vary with altitude and spatially. Environmental pollution is quite complex in this terrain, and it is essential in assessing exposures and risks to take into account actual details of topography.

In addition, during times when breezes are blowing from the ocean inland, plumes of a surface tracer have shown that pollution from the urban areas is transported inland towards the Mojave Desert, for instance. Clearly, urban areas can also have an impact on outside regions, indicating that urban pollution problems are not simply a local concern given their impact on adjacent areas. The regional nature of air pollution can be dealt with more adequately by using more realistic air pollution models. Current models are inadequate because of their use of oversimplified representations of boundary layer physical processes, their incomplete treatment of particle microphysics and physical chemistry with respect to applications to the evaluation of health effects, and their reliance on chemical mechanisms for smog formation that are not fully validated. There is a need for models that consider the microphysics, detail chemistry and topography. While the incorporation of these factors is not an easy task, it is certainly feasible.

At the same time, it is also important to realize that the air pollution problem – such as Southern California's -- is not simply restricted to air. Let us examine this by looking at two chemicals -- pyrene, a semi-volatile polyaromatic hydrocarbon, and naphthalene, a volatile polyaromatic (Figure 2). The mass distribution of these chemicals in the Los Angeles Basin indicates that much of the pyrene (84 percent) can be found in the soil; this means that whatever is emitted to the air, which is a major pathway for emissions of pyrene, actually ends up in the soil. Because it is semi-volatile, pyrene will adhere to particles, and be removed by rain and by dry deposition very effectively. On the other hand, the more volatile naphthalene is present primarily in the gas phase (67 percent). In conducting an exposure analysis, therefore, it will be necessary to distinguish between the properties of the chemicals involved because these affect how they travel.

Chemicals do not respect environmental phase boundaries; nor do they respect regional boundaries. Chemicals are known to partition to multiple environmental media. Multipathway exposures lead to multimedia risks. Population is dynamic, and it is important to consider time-activity patterns in characterizing exposures. While actual field measurements are useful, these measurements typically are not *a priori* predictive, and we can only measure so many chemicals. All of these components comprise the multimedia problem. What is needed to adequately deal with this problem is an integrated approach that will incorporate considerations relating to the complicated terrain, the multiple environmental media, and population dynamics.

Figure 2. Mass Distribution: Pyrene and Naphthalene in the Los Angeles Basin



One of the important elements of a multimedia analysis is a thorough understanding of transport along various media, including such important pieces of information as both stationary and mobile sources, physico-chemical parameters and reaction kinetics, and geographic and meteorological information. All these considerations need to be incorporated in determining exposures and in retrospectively and prospectively characterizing environmental impacts.

There are several challenges involved in multimedia analyses. The environment is a very complex system. All media interact, either directly or indirectly, and a detailed and exact description of the complete multimedia environment is not currently realizable. It will be necessary to establish what is acceptable in terms of the level of spatial and temporal resolution. In such a systems approach, there needs to be an understanding of the key features and mechanisms that govern system behavior.

Chemicals in the environment may be in the gaseous phase, dissolved phase, or particle-bound phase. This information is critical in characterizing intermedia transport because, for example, the transport of chemicals in the particle-bound phase is not directly affected by equilibrium constraints, and can be moved about in the environment very efficiently by rain, dry deposition, or wind resuspension.

Most chemicals that are non-volatile and semi-volatile will end up primarily in the soil. For example, although emitted in air, polyaromatic hydrocarbons (PAHs) and nitro-PAHs will mostly reside in the soil. As molecular weight decreases, volatility increases; the lower molecular weight chemicals tend to reside in the air. An understanding of how chemicals are partitioned between particle phase and gas phase becomes very important, especially in view of the increasing concern with $PM_{2.5}$ -- we need to know what chemicals are in the size fraction which is believed to be most important as far as health effects are concerned.

The universe of chemicals that we have to deal with is extremely large. There are just about 189 air toxics on the federal list of hazardous air pollutants; there are approximately 240 chemicals on the Cal/EPA air toxics list. Some of these listings are for chemical classes – the listing of PAHs, for example, includes dozens of chemicals; diesel fuel, hundreds of chemicals; if members of these classes were to be counted individually, the total can easily go over a thousand chemicals. The U.S. Environmental Protection Agency (USEPA) lists about 3,000 chemicals targeted for ranking and evaluation for pollution prevention action. There are thousands of chemicals that are produced synthetically in this nation. There may be over 10,000 chemicals that require evaluation from a pollution prevention viewpoint!

In order to understand sources and to be able to anticipate and forecast, it is important to know, for each chemical or chemical class, where it is used and in what context. Benzene, for example, is emitted mostly by mobile sources. Hence, controlling the mobile sources can reduce benzene emissions by about 58 percent, addressing a large part of the problem. Efforts can then be directed toward the rest of the sources of benzene emissions. From a regulatory viewpoint, there is a need for source characterization -- a profile of the emission sources -- for every chemical of concern.

It is not possible to measure the emissions for every chemical and for every potential source; currently, reporting by industry provides part of the information. Estimation methods are needed. Field monitoring that will provide the basis for forecasts is also needed. This source information will need to be accessible to communities. While certain information is available now (such as the Toxic Release Inventory information), it is not accessible in a form that the public can use via an expert system as direct input into a forecasting model. This information will need to be provided on a geographical basis through geographical information systems (GIS). For many of the chemicals of concern, physicochemical and toxicological data are currently not available, and most chemical property prediction methods, including structure-activity relationships, are limited to few specific chemical classes. The challenge is to build reliable and accessible databases for all this information, and to develop robust estimation methods for use in forecasting.

The issue of transformation products (e.g., chromium VI from chromium III; methyl mercury from mercury; and nitro-PAHs from PAHs) that may be more toxic than their parent compounds is also often overlooked. A more complete evaluation of risk will require a focus on both reactants and products. Many of the nitro-PAHs, for example, are more mutagenic than their parent compounds. In most cases, the mutagenic density of the nitro-PAHs has been found to be higher than their parent compound's. Although mutagenic density is not necessarily indicative of carcinogenicity, these data suggest a need to pay more attention to transformation products. However, existing regulations (such as the Clean Air Act) generally do not address daughter toxic products, only the parent products.

There are a variety of models that, over the last 20 years, have been developed to simulate how chemicals move about from one medium to another. The difficulties associated with these models involve the level of accuracy and the level of information required as inputs into the model. Some of the compartmental models, such as the Cal/EPA Cal-TOX require input of about 100 parameters or more. Spatial models, which incorporate considerations of distance and time, require over 1,000 input parameters; at the same time, the level of expertise required to run such model increases. With the exception of the very simplistic ones, these types of models can be run by only a small number of people. These tools need to be made available in a community-based model. There are currently efforts at the U.S. EPA to do this.

Further, current models have certain limitations. One such limitation is the fact that models are not modular, and have to be "reinvented" whenever a different situation arises. Modelers may prefer to use one model over another based on how much they know about that particular model. Technology exists today that makes it possible to build modular, reusable components. In addition, most of the models that exist today lack GIS connection, and more importantly, an expert shell system for the future. There needs to be greater focus on the user. What does that mean?

Approaches for integrated multimedia exposure assessments -- whether they are conceptual or computerized -- should not be designed from the modeler's viewpoint, but from a user's problem-solving perspective. Such approaches need to be designed around the user, with an expert system that will guide the user through answering some of the problems. For example, a user may pose the question: Is chemical X a problem? What will need to be done in order to answer that question? Often, agencies have to reinvent the process every time a different chemical is involved in order to figure out if there is a problem. What is needed is a system that interfaces with a user through an expert system, through graphical user interface, and through geographical information systems for information about chemical sources and population dynamics in the area. The system should draw on emission inventories, databases that contain field monitoring information, and chemical information systems, while allowing the user to actually define the environment in question. All this information will be considered in solving the problem that the user posed. While such a system seems too futuristic and would appear to require an enormous amount of resources, U.S. EPA has been moving in this direction. My own experience has been that each time I had to conduct an analysis involving a new set of problems or chemicals, I have had to spend an enormous amount of time collecting information about sources, about chemicals, and so on.

In summary, an integrated approach to assessing regional contaminant distribution, exposure and health effects is definitely needed. This approach should consider, to the extent possible, the best available science and mechanistic understanding to enable forecasting. There is a need for community-accessible databases and models that will allow interface with forecasting and regulatory models. The models should be accessible to different developers, who should have the capability to improve on various modules, so that the community at large will benefit. There is also a need to consider co-regulating various air pollutants and toxics within a regional framework.

In coastal areas, intermedia transfers can be important, and therefore need to be better quantified. Moreover, the relationship between air pollution and water quality in arid climates also needs to be quantified. As better monitoring is developed, regional monitoring networks should be designed to provide information useful for data assimilation to better forecast pollution episodes, as well as chronic exposure, rather than simply data collection. Finally, there is the issue of how urban pollution can affect regional pollution. For example, the haze problem at the Grand Canyon has been attributed by some to power plants, and by others, to pollution from the Los Angeles Basin. The eventual dispersion of regional urban pollution to larger scales – through air and water – should be considered as criteria for control and regulation.

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THE UNFINISHED AGENDA: NON-POINT SOURCE POLLUTION

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Non-point source problems in the future can be classified into three categories: those that are already well-known; those that are predictable from current trends; and those that would be complete surprises.

In the first category, many are well known issues that have existed for some time, and have been difficult to mitigate. Examples of some of these problems include metals, trace elements, salinity, pesticides, nutrients, and sedimentation, from such sources as abandoned mine drainage, intensive irrigated agriculture, dairies, grazing and forestry. Sedimentation is one issue that has not drawn much attention, but is extremely important. There are over 9,000 miles of streams in California that are adversely impacted by erosion problems causing sedimentation, and well over a fifth of the stream segments are listed as impaired in California due, at least in part, to sedimentation problems. Pesticides represent an old problem that will be confronting us in a new form – i.e., many of the estrogen mimickers and thyroid mimickers are from pesticide sources.

One reason for our slow progress solving non-point source pollution problems in the past has been the inability to establish a system of accountability -- that is, it is very difficult to make individuals responsible for the pollution they create when it falls into the non-point source category.

As a result, one important focus for dealing with the issue of non-point source pollution in the future is the use of new tools to expand our ability to respond to both old and new problems (see Table 1). For abandoned mine drainage, for example, there has been much discussion about new good samaritan liability protection; tradable discharge permits may also be effective. An example of a sensible trade would be where a city is required to reduce metal discharges, but accomplishes this by contracting with an abandoned mine located upstream to clean up the pollution at the mine; the same investment dollars are spent on cleaning up more pollution at the mine than at the city outfall. For agricultural drainage, tools may include input pricing and tradable discharge permits in conjunction with total maximum daily loads (TMDLs); the latter approach is currently being used in one area of the Central Valley. For grazing, financial incentives for riparian protection can be provided; for dairies, performance bonds. If we open up our thinking a little bit, perhaps we can start applying some interesting new tools to expand our ability to respond to both old and new non-point source problems.

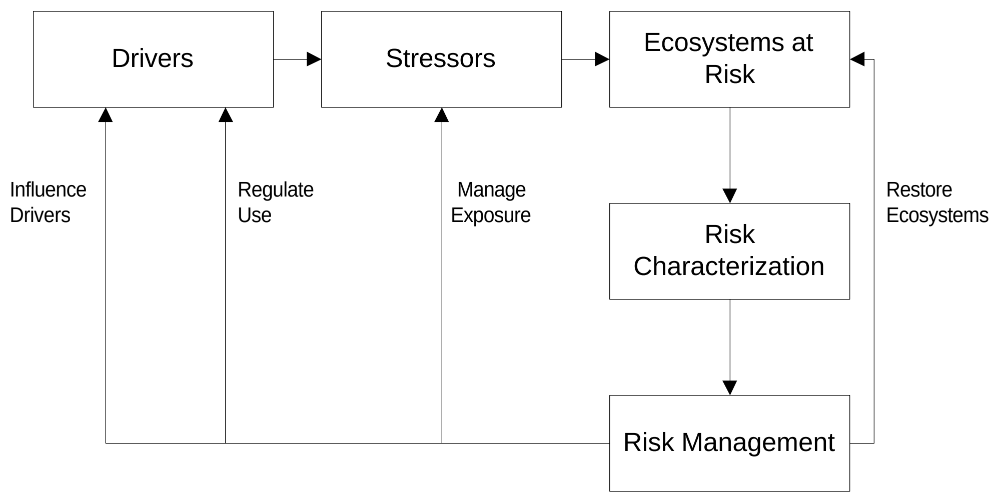
Table 1. Selected New Tools

Abandoned Mine Drainage	"Good Samaritan" Liability Protection Tradable Discharge Permits
Agricultural Drainage	Input Pricing Tradable Discharge Permits (with TMDL's)
Grazing	Financial Incentives for Riparian Protection
Dairies	Performance Bonds

The second category of non-point source pollution problems are those that are predictable from current trends. What might these be? The Environmental Processes and Effects Committee of the U.S. Environmental Protection Agency's (U.S. EPA) Science Advisory Board has developed the conceptual model for futures analysis shown in Figure 1. The model shows that drivers lead to stressors, which in turn lead to learning about the ecosystems at risk. Problems can be addressed by dealing with the drivers, dealing with the stressors, or restoring ecosystems after the fact. Another way of looking at this model is to start with the effects observed in ecosystems (the "ecosystems at risk" box), and look for some clues about what might be causing these adverse effects.

We can apply the model in forecasting some future non-point pollution issues, first by examining the drivers. The Environmental Processes and Effects Committee compiled a list of the drivers of ecological change. Primary drivers include population, resource utilization per capita, economics, technology, education, and government laws and policies; secondary drivers are the patterns of resource use and availability -- land, water, air, biomass, minerals and energy. Taking population growth as the driver, let us examine its effects on one part of California, using information from the Sierra Nevada Environmental Project.

Figure 1. Conceptual Model for Futures Analysis



Adapted from U.S. Environmental Protection Agency, 1995. *An SAB Report: Ecosystem Management – Imperative for a Dynamic World.* EPA-SAB-EPEC-95-003.

The Sierra Nevada population has doubled between the years of 1970 and 1990, and is predicted to triple by the year 2040. Much of the population is anticipated to consist of commuters and retirees. What impact might this have on ecological systems? Population growth means that there will likely be significant additional habitat destruction and fragmentation from construction; there will be invasion of exotic species -- one of the major threats from this kind of development; there will also be changing patterns of water use, which will change not only surface flows, but also the ways in which groundwater recharge occurs in these areas. With regard to direct non-point source pollution which may result, there will likely be more leaking septic systems in the foothill and mountain regions; there may be more or less sedimentation -- if development replaces grazing lands, there may be less sedimentation; and, there will certainly be additional runoff. In other words, many of the same familiar non-point source problems will occur, but they will affect new areas and result in new kinds of impacts, particularly on ecological resources. The same types of chemicals that have been associated with non-point source pollution will affect cold water areas, as opposed to warm water areas, impacting completely different ecological systems in terms of fish. Different types of responses from those animals may be elicited. Having the non-point source pollution problem creep closer to sources of drinking water supply will also be a concern. On the positive side, shifting populations into areas such as the Sierra Nevada may actually increase public interest in local water quality, and naturally create a stronger mandate for some of the protections that have been very difficult for State agencies to fully implement.

Effects seen in ecosystems may also be used as early warning signals of environmental problems. Using the same conceptual model illustrated above, one can start with the ecological effects and attempt to identify the source of these effects (stressors and drivers), allowing efforts to be directed at these sources.

For example, the first column of Table 2 lists major threats to California's biological diversity identified in the book, *In Our Own Hands: A Strategy for Conserving California's Biological Diversity,* by Jensen, Torn and Harte. The double lines in the table separate the top threats from the less significant ones. There are, of course, other aspects of ecological health besides biological diversity. A similar exercise was undertaken more recently by the Science Advisory Board of U.S. EPA, with a broader focus on nation-wide ecological threats (second column of Table 2).

Table 2

Primary Threats to California's Biological Diversity*	Primary threats to the Nation's Ecological Resources
land development	habitat destruction
water diversions	hydrologic modification
logging in old-growth forests	harvesting living marine resources
desert/riparian grazing	exotic species
water pollution	global climate change
global climate change	
Pesticides	sedimentation/turbidity
Stratospheric ozone depletion	pesticides
exotic species	habitat fragmentation

It is interesting to note the extent of overlap between the two lists, indicating a need to focus attention on these areas. By looking at what types of factors are having the greatest impact on the environment, we can start to prioritize our efforts.

Water diversions (also known as hydrologic modification) are on top of both lists above. In the near future, some small dams in California are likely to be removed upstream (i.e., in the higher elevations) in order to re-regulate and make more efficient use of the water. Removing small dams, however, may have some unintended consequences, including movement of contaminated sediment load that has built up behind the dams over the years. Of the impaired stream segments in California, DDT, PCB and mercury together account for about 38 percent of the contamination. These chemicals adsorb to soil, and are likely potential problems that will be moved from one place to another if dams are removed. Another area of overlap is global climate change – stronger, more frequent storms will move contaminated sediments downstream. Logging and grazing cause sedimentation and changes in temperature as a result of the removal of riparian vegetation.

Systems that assess the health of ecological resources and allow the detection of early warning signals will be valuable tools for proactively addressing emerging non-point source problems. An example of an early warning system of ecological indicators is now under consideration by the CalFed community for the San Francisco Bay Delta area and its watershed.

Finally, the third category of non-point source problems are the complete surprises. It is certain that there are going to be surprises in the future, and perhaps the best strategy for addressing these would be to position ourselves so that we are prepared to respond.

There are four ways by which we can be prepared to respond to surprises:

Maintain a diversified portfolio of tools. In addition to simply thinking about the issues, we should set a goal to use each of the tools mentioned earlier (see Table 1) in at least one demonstration program in order to get acquainted with how they work.

Use early warning information systems, such as the CalFed system of indicators of ecological integrity mentioned above. This set of indicators has been specifically designed to assess ecological integrity independent of conventional wisdom regarding existing problems.

Stay flexible. This includes identifying and applying tools that solve multiple problems. In the Central Valley, for example, instead of focusing on using selenium removal technology for selenium-contaminated drainage, efforts need to be directed toward reducing the amount of all pollutants; this way, many problems may be solved at once.

Maintain professionalism. The very high degree of professionalism and commitment that exist among the staff in California state agencies is perhaps our best insurance policy.

CHALLENGES IN INTEGRATED HUMAN EXPOSURE ANALYSIS

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There are certain emerging ideas that will influence future approaches to environmental health protection. First, there are changing ideas about risk management. One widely discussed issue involves how chemical exposures are addressed -- should we address exposures one chemical at a time? We have dealt with agents on a one-by-one basis in the past, and have been quite successful in some cases. Given the number of chemicals that must be addressed, however, it is doubtful that this approach will address all chemicals of concern within a realistic timeframe. There is an increasing recognition that making small reductions in the worst individual risks is not necessarily the best strategy, and that efforts should instead be directed toward reducing total aggregate risks. The latter certainly poses a difficult challenge, necessitating the development of approaches that can be applied where appropriate.

Related to this is the exposure analysis component of risk analysis. Exposure analysis plays a pivotal role not only in risk analysis, but also in risk management. Where no exposures occur, there is no risk. We need to know if people are exposed, and at what levels. Indoor environments are also closely related to this idea of exposure, but is an area that has not received enough attention. There is an emerging recognition of the importance of assessing "total exposure."

Finally, new products and technologies are continually being introduced, and will impact total exposures.

Exposure analysis is the interface between transport and transformation in the environment and health effects. "Exposure" has been traditionally defined as contact at a boundary between a human and an environmental agent at a specific concentration and at a specific interval of time. Exposure analysts tend to use time weighted exposure concentration in the contact medium as a related measure of exposure. Exposure is not the same as dose; it is not the same as the concentration measured in a medium which never comes into contact with a human being. Further, exposure modeling is not the same as environmental fate and transport modeling. Environmental fate and transport modeling is a component of exposure modeling, but the latter also considers human activities and how human receptors come into contact with the environment.

Figure 1. Pivotal Role of Exposure Analysis

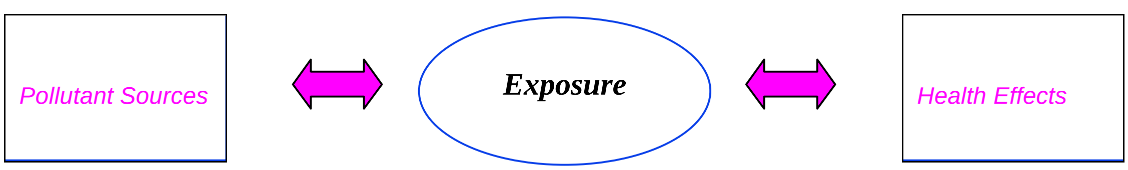

Figure 1 illustrates the pivotal role of exposure analysis. At one end, exposure analysis helps provide an understanding of the causal relationships between exposures to environmental pollutants and the adverse health effects (risk analysis). At the other end, there are concerns about the sources of exposures -- if an exposure causes a risk, the exposure will need to be reduced (risk management). Exposure analysis deals with both the areas of risk analysis and risk management. There are methods that need to be developed in order to better understand exposure and the sources of exposure, as well as the health effects.

More integrated analyses involve evaluating population exposures and subpopulations. Traditionally, the focus has been on the maximally exposed individual and, in some cases, on the average exposure. These data are not very difficult to obtain. The difficulty lies in obtaining data on the tail of the distribution, where the high exposures are. There may be subpopulations that get very high exposures, yet it is unlikely that many members of these subpopulations will be selected in a random sampling of the population. Random sampling tends to select individuals around the middle area of the curve. It is not known whether individuals at the tail of a distribution -- the high end of the exposures -- are more likely to be highly exposed to other agents as well. It is not known what those other agents are. We know there are differences in exposure for different parts of the population by age, gender, ethnic background, but we do not have the full picture. We need to understand these differences better because they are important in identifying the individuals at the highest risk. These are important issues that need to be dealt with in assessing total exposure to multiple agents.

The term “total or integrated exposure” is used in a number of ways. In some contexts, the term refers to the sum of exposures to an individual agent by all routes -- inhalation, ingestion, dermal absorption. We may be concerned about all exposure pathways or media -- which relates to the routes, and to the sources of exposure -- or about all micro-environments (indoors, outdoors, in transit), or about specific activities that affect exposure (smoking, certain hobbies, etc.).

Another way to define “total exposure” is in terms of multiple chemicals or combinations of chemical, physical, and biological stressors. The U.S. Environmental Protection Agency (U.S. EPA) is undertaking a project to look at cumulative exposures using measurement data (where available), or modeling data in an attempt to characterize exposures for some chemical agents. It is not feasible to do this for the universe of chemical agents, and a possible approach would be to group agents together in some logical way.

There are a number of options for grouping agents together. One would be by mechanism of action. This is particularly true for pesticides. This has also been done for dioxins, where congeners have different potencies, and exposures have been quantified by taking a weighted sum of the congeners involved. While there is some uncertainty as to how this would relate to health effects, this approach is certainly a reasonable one. Another way of grouping agents is by their source or cause. Such a grouping provides a rational basis for controlling exposures, should there be an adverse effect associated with these; it may be much more economically efficient to control groups of chemicals from certain types of sources. A more novel approach involves inferring exposure metrics for multiple chemicals using advanced statistical analysis methods. This approach enables linking to health effects directly to the sources of exposure.

An exposure metric is a measured agent or combination of agents -- or, in some cases, a surrogate of the agent(s) -- causing the adverse health effect. Exposure metrics that are needed are those that can deal with complex mixtures of chemicals and combined exposures. Where a single chemical is involved, the exposure metric is a measurement of the concentration of that agent in the media that come into contact with the individual, based on a sampling time appropriate for the health effect of interest. It is still unclear how measurements will be done for complex mixtures.

The exposure metric relates to what is measured, how it is measured, and how multiple agents are combined mathematically. It is not uncommon to see measurements for a hundred compounds in the environmental literature; these measurements need to be characterized, and decisions made about how this information can be used and combined appropriately.

As an example, let’s examine the development of an exposure metric for mixtures of volatile organic compounds (VOCs) in office buildings. The health effect of concern is “sick building syndrome." Forty to 60 VOCs were measured in the indoor air of randomly selected buildings (rather than problem buildings), each at a low level. VOCs are suspected to be factors in causing the symptoms, but it is unclear how the available data could be used to test this hypothesis. A number of different approaches in using the data were investigated. One approach was to weight each VOC based on irritancy to determine if this can be related to the symptoms. Although this did not prove to be useful for our data set, this may still be a reasonable approach. The metric that has been most widely used is total VOCs, which is simply a sum of VOC concentrations (by mass), without taking biological potency into account. There is evidence that when the total VOC concentration exceeds 2 - 3 mg/m^3, symptoms occur. However, symptoms have also been observed below this level, and the symptoms have not been related in any quantitative or scientific way to the total VOC metric. How, then, do we account for those symptoms? Of course, there is a need to examine multiple factors that may influence the symptoms, such as socio-economic factors, job classification, and others.

By using factor analysis on the available set of measurements – a large database of measurements is needed to do this – VOCs were grouped by their sources. This reduces the number of factors from the initial 40 to 60 compounds to 4 or 5 factors, called exposure metrics. The data were used as the basis for generating combinations of VOCs which are the factors.

In the next step, a standard multivariate logistic regression analysis of the four or five exposure metrics -- and the other influential factors -- against the symptoms was conducted. This approach was used for the California Healthy Buildings Study, in which we found a subset of VOCs for which there was a statistically significant association with the irritancy symptoms: the subset of VOCs from cleaning products and water-based paints seemed to account for most of the symptoms. While it may not be appropriate in every situation, this approach may prove to be useful as one tool in deciding how to group chemicals together.

In conducting total exposure analyses, one must take into account the fact that people spend a significant percentage of their time indoors. Data generated by the California Air Resources Board, Indoor Air Division, show that, on average, Californians spend about 90 percent of their time indoors. The data for California are similar to those for the rest of the country: 62 percent of the time is spent in the home; 25 percent at work; 7 percent in enclosed transit; and about 6 percent outdoors. These data do not imply that the outdoor, ambient environment and the pollutants in it are unimportant. It indicates, however, the need to consider how outdoor pollutants enter the indoor environment, and whether the latter has a mitigating or enhancing effect. Indoor sources will also need to be considered as possible contributors to exposure to pollutants. If we want to have effective risk reduction methods, we have to look at the whole picture.

There are many sources of chemical and biological pollutants in indoor environments that elicit the same symptoms and health effects that outdoor air pollutants do. Environmental tobacco smoke is an example; it has particles and vapors that represent additional exposures of concern. There are multiple air toxics from some of the materials and products used in homes (clothing, carpets, paints, and others). Radon, of course, is another concern. The indoor concentrations of some of these pollutants are often two to ten times higher than the outdoor levels, and should clearly be taken into account.

Figure 2. Comparison of Concentrations of Selected Air Toxics from Environmental Tobacco Smoke (ETS) and from Outdoor Air in a Residential Building

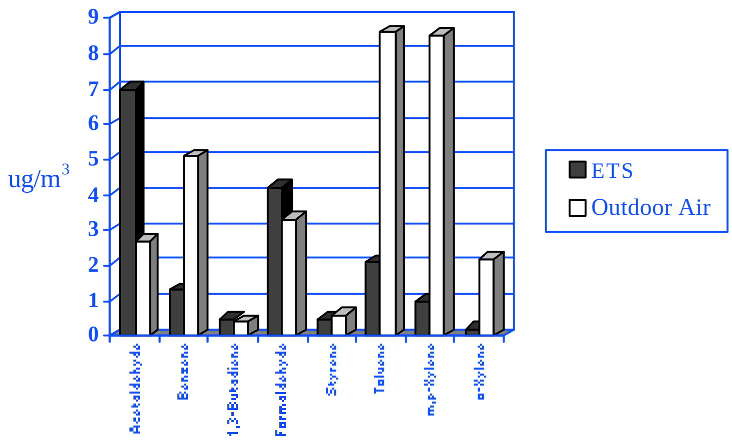

Figure 2 compares the indoor concentrations of air toxics from environmental tobacco smoke (data based on a moderate [one pack/day] smoker) and average outdoor air measurements. The concentrations are certainly of the same order of magnitude. For some compounds, outdoor air is more important, and for others, environmental tobacco smoke is more important. There are likely to be other agents for which the indoor sources are much more important or, alternatively, the outdoor sources are much more important. In order to effectively reduce total health risks from exposures to chemicals, it is necessary to understand all the sources and their significance.

Finally, there is the issue of anticipating the impacts of changes in products and technology on environmental exposures. One of the points I want to make about exposure analysis which makes risk analyses and reduction difficult is that products are constantly changing. This is true for outdoor air, as it is for indoor air. The changes are sometimes made to reduce risks; sometimes they are brought about by other factors, such as changes in the prices of starting materials. When changes are made to reduce risks, sometimes they achieve the objective, and sometimes they don't. This is the law of unintended consequences. For example, with the use of MTBE as a fuel additive, the objective was to reduce air pollution; an unintended consequence was water pollution. On the other hand, the removal of lead from gasoline was intended to reduce outdoor air pollution; ozone levels did decrease, as anticipated, but a side effect that was not anticipated is that blood lead levels were reduced in children throughout the U.S. The bottom line is that we need a more systematic analysis of new products and technologies, and better predictive tools for exposure analysis.

SYNERGISM, ANTAGONISM AND OTHER TOXIC INTERACTIONS

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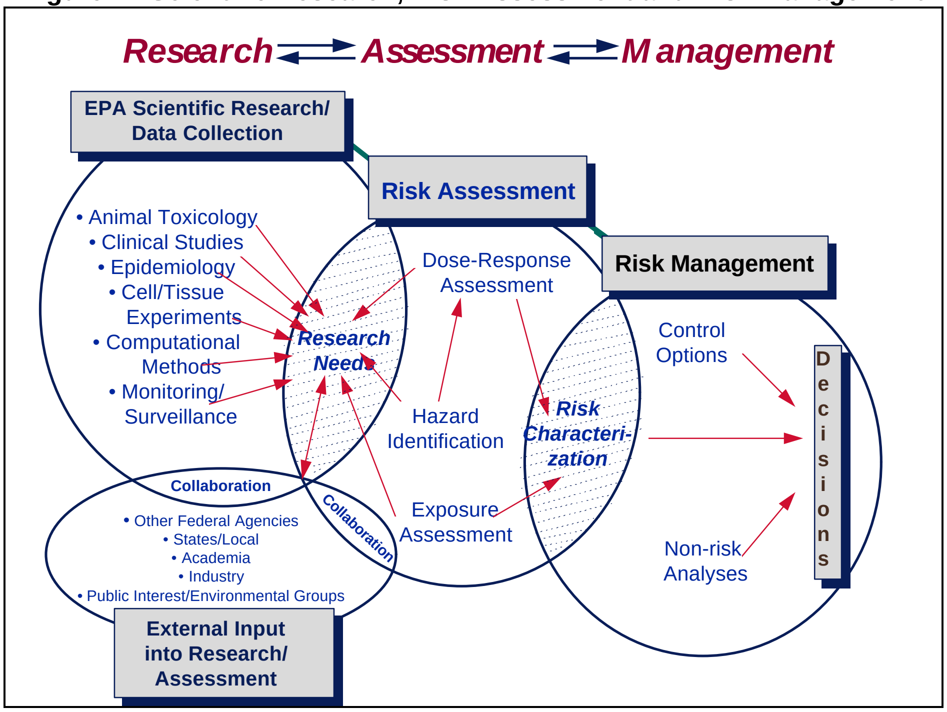
As illustrated in Figure 1, risk assessment interfaces with scientific research and data collection, as well as with risk management. Risk assessment represents one of the inputs into risk management decision-making. Through a formalized process, risk assessment also feeds into scientific research and data collection by identifying information gaps requiring further studies. New scientific data, in turn improve the input into risk management. A critical element of the paradigm is external input, leading to collaborations among federal agencies, states and local government, academia, industry, and public interest or environmental groups.

Figure 1. Scientific Research, Risk Assessment and Risk Management



In the 1970's, when the early tools and approaches for conducting risk assessments were just being developed, much of the emphasis was placed on the oral route of exposure. This was not surprising, given that the existing approaches to regulating chemicals at the time had mostly been developed by the U. S. Food and Drug Administration for food-related exposures. In the 1980's, guidelines and basic methodologies for conducting risk assessments were developed, efforts were spent on dosimetry, and databases on exposure and toxicity were established. Today, new tools, databases, and innovative approaches are being developed for dealing with some of the more challenging issues: mechanisms of action, sensitive subpopulations, and complex mixtures.

Historically, the field of risk assessment has focused on uncertainty. In 1983, in its seminal publication (*Risk Assessment in the Federal Government*), the National Research Council (NRC) referred to uncertainty as the "dominant analytic difficulty" in decision-making. This uncertainty relates to the various types, probabilities and magnitudes of health effects, of the extent of current and possible exposures, and of the economic impacts of actions to manage exposures.

More recently, the NRC (in *Science and Judgment Risk Assessment*) noted that people are at risk based on their exposure to mixtures of chemicals, yet in many cases, the focus has been on simply testing for a single endpoint, or testing a single chemical. The NRC stressed the need to best characterize and estimate the potential aggregate risk posed by exposure to mixtures. The NRC further pointed out that the quality of risk analysis will improve with improvements in its inputs. In other words, as additional information is collected and the understanding of how chemicals work and interact is enhanced, the ability to assess risks will improve. The continual evolution of risk assessment will be dependent on new models and new data.

This evolution in the understanding of exposures and toxic interactions has led to some legislative mandates. The 1996 amendments to the Safe Drinking Water Act incorporate two points that are particularly relevant to toxicologic interactions among chemicals: (1) a proposed national primary drinking water regulation should consider the effects of the contaminant on the general population as well as on other subpopulations (some of which might be considered sensitive), and exposure to contaminants in drinking water on a holistic basis, from all the chemicals that might be present; and, (2) an analysis should be conducted of the potential for increased health risk arising from compliance with drinking water regulations (such as disinfection), including co-occurring contaminants.

The Food Quality Protection Act, also promulgated in 1996, explicitly requires that the risk associated with pesticide residues specifically address cumulative effects on infants and children of such residues and other substances that have a common mechanism of toxicity, and that there is reasonable certainty that no harm will result to infants and children from aggregate exposure to the residue.

Both these laws suggest a movement toward regulatory approaches that take into account mechanisms of action, sensitive populations and complex mixtures. For these issues to be adequately addressed, there are four key areas requiring increased emphasis and advancements over the next few years: (1) research and data collection on interactions in mixtures and mechanisms of action; (2) databases that will allow the question of mixtures risks to be addressed, including data from interactions studies and guidance in carrying out mixtures assessments; (3) new tools like artificial intelligence that will aid in addressing issues of chemicals mixtures in the absence of complete data; and (4) regulatory approaches that take into account multi-chemical exposures and their potential interactions.

Different and better data on interactions and mechanisms are needed. This will require a shift from traditional toxicology testing that focuses simply on endpoints, to studies that focus more on mechanisms of action, and the development of biologically-based inferences for how chemicals produce their effects and what types of endpoints might be expected. Also needed are data on naturally occurring and synthetic mixtures of chemicals of interest. The big question will be what mixtures to test, given the infinite number of mixtures. How will we provide surrogates for actual mixtures as data are being developed? The concept of dose additivity has been demonstrated and is clearly reasonable in exposures involving low doses -- it makes sense that chemicals with the same mode of action produce effects that are additive. The question is, at what point do interactions start to occur? At what point do chemicals working through different modes of action produce more or less than additive effects? Responding to these questions will involve determining not only whether chemicals are working by the same mode of action, but also how they interact with one another to modify effects in potentially greater (i.e., synergistic) or lesser than additive (antagonistic) responses.

Mechanistic data refine the interpretation and extrapolation of dose from exposure, and response from dose, and are particularly important in characterizing risks. How does the chemical mixture produce its effect? Are there mechanistic data to support the hypothesis? Have other mechanistic hypotheses been considered and rejected? Are there common mechanisms of action among co-occurring contaminants? What are the expected interactions among co-occurring contaminants?

Databases of mixtures data and interactions studies will be necessary tools in applying mechanistic approaches. The U.S. Environmental Protection Agency (USEPA) has been working on the development of databases for complex mixtures. The agency is currently looking to expand its “MixTox” database of interactions studies to enhance its usefulness in providing information for analyzing mixtures with regard to both content and pharmacokinetics.

Currently, USEPA evaluates mixtures by applying a weight-of-evidence approach and, based on the evidence of interactions across studies, assigning a numerical score --. “a composite potency factor” -- that could then be used in a hazard index to modify the simple additive approach that has been used in the past. An “interactions hazard index” -- which modifies the hazard index to include interaction magnitudes and weight-of-evidence scores -- can be developed to reflect the effects of interaction on the hazard index of each chemical in the mixture; this interactions hazard index is a much useful and more biologically relevant way of characterizing risk.

MixTox

02/06/97

Total Interactions of TOLUENE and STYRENE

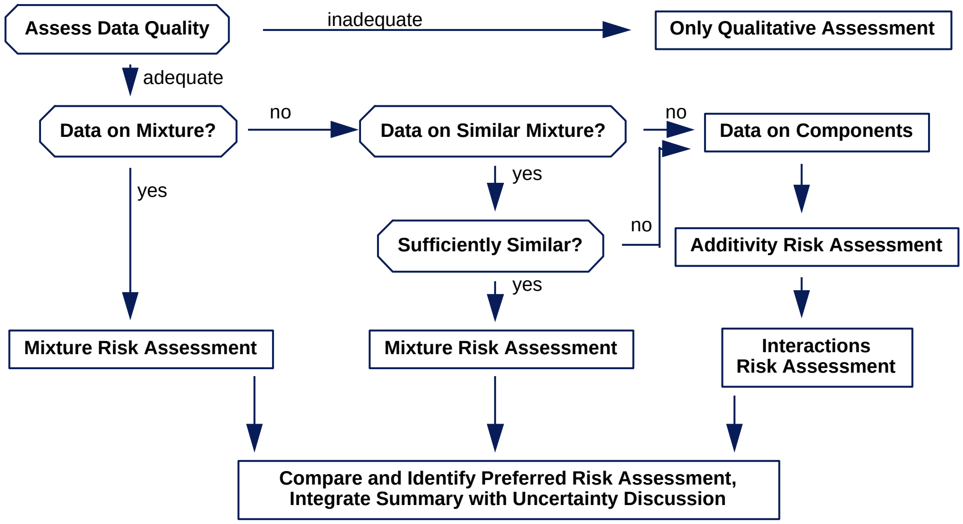
As expected	1.
Greater	0.
Less	10.
Articles Represented	**3**

A sample output from the MixTox database on interactions between toluene and styrene is shown above. In this case, three articles showed eleven different outcomes that could be evaluated with regard to interactions between toluene and styrene: in one case, the expected additive outcome was observed; in ten cases, the data suggest a less than additive outcome. The basis upon which one develops an argument for why the results might show less than additivity is one that becomes the most difficult. These are simply the empirical data that are being evaluated, and will need to be backed up by a discussion of mechanisms of action.

Historical approaches to dealing with chemical mixtures, unfortunately, have tended to ignore multi-chemical characteristics and assume no interaction, focusing instead on a single chemical -- often the one producing the highest exposure level, or the one which is the most toxic or which produces the effect of greatest concern. For the most part, this conservative approach has provided public health protection and, as mentioned earlier, is not an unreasonable approach for low levels of exposure. However, the growing body of data, particularly with regard to receptor-mediated responses, raises a question about whether, even at low doses, some interactions might be more than additive for some chemicals.

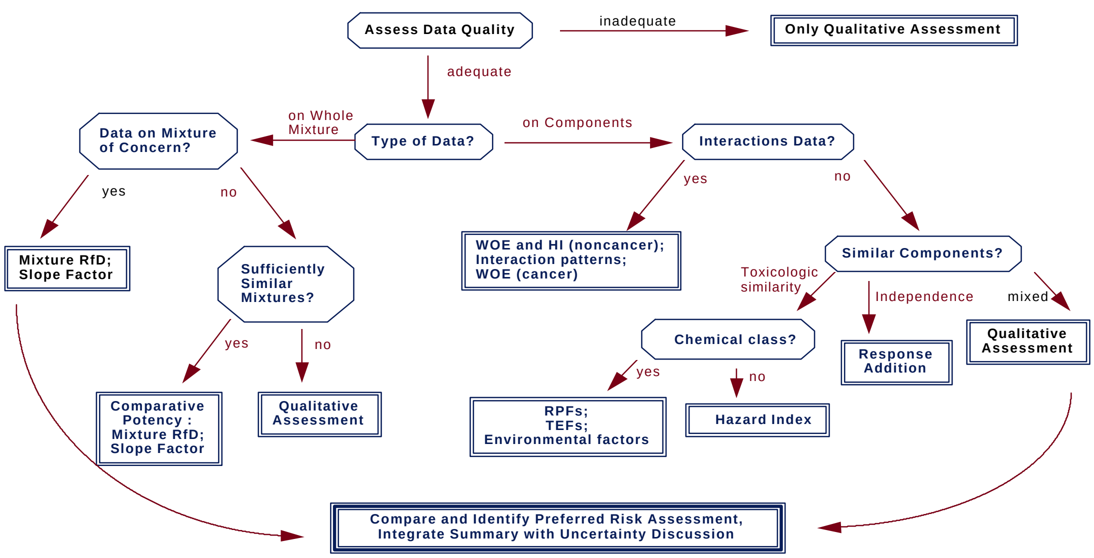
In 1986, the USEPA published chemical mixtures guidelines that were fairly simple (Figure 2). First, the quality of the available data was assessed in order to determine whether they were adequate to address the question of chemical mixtures. If the data were inadequate, only a qualitative assessment was conducted; this was what was done most frequently. Where there were adequate data on the mixture, the next question was whether they were on the mixture of interest or similar mixtures, or simply data on components of the mixture. In almost all cases, application of the guidelines resulted in a mixture risk assessment based on additivity of dose.

Figure 2. 1986 Chemical Mixture Guidelines



The different types of mixtures assessments based on the availability and quality of the data. All three assessment paths should be performed. U.S. EPA, 1986, 1990.

Figure 3. Proposed Revised Chemical Mixture Guidelines



The different types of mixtures assessments based on the availability and quality of the data. All possible assessment paths should be performed.

The revised guidance currently under development (Figure 3) takes more of the biology into account. Like the 1986 guidelines, the first step involves assessing data quality to determine their adequacy for conducting a quantitative assessment of interactions and relative responses. Depending on the type of data available, various mixtures assessment approaches (displayed in double boxes in the above diagram) are prescribed, e.g., weight-of-evidence (WOE) and hazard index (HI) evaluation, comparative potency, toxicity equivalence factors, and response additions. These approaches are intended to reflect how the data and the biology come together to provide an interactive characterization of potential for risk and an integrated summary of the associated uncertainties.

The updated chemical mixtures guidance is intended as an addendum to the 1986 guidelines. The guidance will undergo peer review in a workshop format in September, 1998, with a report from the USEPA's Risk Assessment Forum expected to be issued by the end of 1998.

Other tools being developed utilize advances in statistical and computer techniques to deal with complex mixtures and interactions. These techniques use artificial intelligence to draw conclusions in the absence of complete data on mixtures. Two examples of these are the Integral Search System for Assessing Carcinogen Interaction of Chemical Mixtures, and the Integrative Approach of Combining Complementary Short-term Tests as Supportive Evidence for Carcinogenicity, both being developed by the Office of Pesticides and Toxic Substances. These techniques allow the prediction of how chemical mixtures might act, based upon physico-chemical characteristics, structure-activity relationships, and data on interactions. Both of these are knowledge-based, rule-based systems (expert systems), that consider different types of information in a weighted approach to dealing with mixtures.

The Integral Search System for Assessing Carcinogen Interactions of Chemical Mixtures uses as input the physical characterization of the chemical mixture, and generates binary pairs -- pairs of two of the mixture components. For each binary pair, a determination is made as to whether there is a possibility of synergism or antagonism; whether there is a promoter-carcinogen interaction; or whether there is inhibition. A "carcinogen interaction weighting ratio" for the overall chemical mixture is calculated based on the ratio of positive responses (i.e., synergism and promotion), to negative responses (i.e., antagonism and inhibition) for the binary pairs.

The Integrative Approach of Combining Complementary Short-term Tests as Supportive Evidence for Carcinogenicity is more qualitative in nature. It also uses a rule-based artificial intelligence system, an expert system that is an integrative approach for combining complimentary short term test data. These are data that are not simply genotoxicity tests or other tests that directly relate to carcinogenicity, but also data from acute toxicity and shorter term toxicity tests that are relevant to the carcinogenic process and provide a qualitative description of the interaction between initiation, promotion, and progression in carcinogenicity, combining chemicals with different modes of action that will lead to the same effect.

Finally, regulatory approaches are now increasingly emphasizing multiple chemicals and their potential interactions. The toxicity equivalence approach has been used for dioxins and related compounds, although the adequacy of such an approach is in question. For instance, the dioxin-like PCBs are always accompanied by the non-dioxin-like PCBs in mixtures: what impact do the latter have on this complex mixture analysis? The surrogate mixtures approach has been used for PCBs; regulation of environmental PCB mixtures has been based upon assessments of technical PCBs mixtures as reasonable surrogates for weathered PCB mixtures. Comparative potency approaches have been used for diesel and PAHs. This involves developing comparative potencies for various mixtures -- such as coal tars, cigarette smoke, and others -- through the use of toxicity tests, and attempting to use these as the basis for developing comparative potency estimates for complex mixtures such as diesel or PAHs.

One of the more challenging examples of a regulatory context within which complex mixtures issues will have to be dealt with involves disinfection by-products. This issue will extend into the question of how to balance the risks associated with disinfection by-products versus the risks associated with the microbiological agents that might be present if the disinfection by-products are not present in sufficiently high levels.

In summary, risk assessment has been evolving to focus on the “real world” needs of addressing complex chemical mixtures and their interactions in the environment. To meet this challenge, there need to be better and different data and innovative tools and approaches. Based on current trends, future regulatory mandates will use and further the development of such assessment approaches. Clearly, a partnership of environmental health professionals in the public and private sectors will be needed to address these particular emerging environmental challenges.

ENDOCRINE DISRUPTORS

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The issue of endocrine disruptors and potential health effects presents a concern that is not limited only to California and the California Environmental Protection Agency. This is a national and international issue which draws much interest from a wide range of sources. This presentation will include a brief overview of the endocrine system, its beauty and complexity, and then examine how certain environmental chemicals may interfere with endocrine-mediated processes. Some of the health effects associated with exposure to endocrine disrupting chemicals will be briefly discussed, and finally future challenges in evaluating human and ecological risks of endocrine disruptors will be presented.

The hypothesis has been advanced that certain synthetic chemicals that are persistent in the environment are producing adverse effects in wildlife and in humans by interfering with the endocrine system. These effects include reproductive and developmental abnormalities, increases in certain hormone-related cancers (breast, prostate, and testis), and declines in wildlife populations.

The Endocrine System

The endocrine system includes the ductless glands that release chemical mediators, known as hormones, into the circulation to exert their action away from their sites of origin. The endocrine system functions to control and integrate normal physiological processes, such as reproduction, growth and development, and maintenance of the internal environment. Because small disturbances in endocrine function, especially during development, can lead to profound and lasting effects, understanding of dose-response relationships at environmental exposure levels is critical in evaluations of risks from environmental endocrine disruptors.

Table 1. Some Mammalian Hormones

Source	***Hormone***	***Effect***
Thyroid	thyroxin; triiodothyronine	regulate growth and development
Testes	testosterone	stimulates development and maintenance of male reproductive structures and 2^o sexual characteristics; stimulates spermatogenesis
Ovaries	estrogen	stimulates development and maintenance of female reproductive structures and 2^o sexual characteristics, stimulates growth of uterine lining
	progesterone	prepares uterus for embryo implantation
Hypothalamus	releasing hormones	regulate pituitary secretions
Pituitary	TSH	stimulates thyroid
	FSH	stimulates growth of ovarian follicles, stimulates growth of seminiferous tubules
	LH	stimulates follicles → corpora luteum, stimulates secretion of sex hormones by ovaries and testes

* Dr. Lucier was originally scheduled to speak, but was unable to attend. Dr. Melnick delivered this presentation.

Most of the emphasis on endocrine disruptors has focused on perturbations of thyroid and gonadal hormones (Table 1). Hormones produced by the thyroid (thyroxin), the testis (testosterone), and the ovaries (estrogen and progesterone) regulate growth and development; stimulate the development of secondary sexual characteristics; stimulate spermatogenesis; stimulate growth of the uterine lining; and prepare the uterus for embryo implantation. In considering these hormones, one must also take into account the organs that regulate their production -- the hypothalamus and the pituitary gland. The hypothalamus produces the releasing hormones, gonadotrophic releasing hormone and thyroid releasing hormone. Secretion of releasing hormones from the hypothalamus stimulates the pituitary gland to release thyroid stimulating hormone (TSH), follicle stimulating hormone(FSH), and luteinizing hormone (LH).

An example of a negative feedback system involves the hypothalamus-pituitary-thyroid axis. The pituitary gland produces the TSH, which stimulates the thyroid secretion of the thyroid hormones, thyroxin and triiodothyronine (T3). These hormones act at the pituitary level to control secretion of TSH by a negative feedback mechanism. Secretion of pituitary TSH is stimulated by thyrotrophic releasing hormone from the hypothalmus and is inhibited by somatostatin. The thyroid hormones also stimulate secretion of somatostatin. Consequently, when circulating levels of thyroid hormones rise, the pituitary secretion of TSH is inhibited; however, when thyroxin levels are low, the pituitary secretion of TSH is increased for more production of thyroid hormones.

Another example of a negative feedback control system involves the hypothalamus-pituitary-testis axis. This system concerns the pituitary secretion of LH and FSH. LH acts on Leydig cells of the testis, stimulating the conversion of cholesterol to testosterone. Testosterone and FSH stimulate spermatogenesis in seminiferous tubule cells. High concentrations of testosterone and inhibin inhibit secretion of gonadotropin releasing hormone by the hypothalamus, and they inhibit pituitary secretion of LH and FSH. If an environmental agent mimics or antagonizes any phase of these feedback control systems, it can alter processes regulated by the affected hormone.

Receptor-mediated Mechanisms

At the cellular level, there are different receptor-mediated mechanisms by which hormones may regulate physiological functions. Some peptide hormones in the blood bind to surface receptors activating an effector process to generate a secondary intracellular message (Figure 1). By binding to the surface receptor and not even entering the cell, such hormones can regulate activities of various metabolic enzymes as well as DNA synthesis, RNA synthesis, or protein synthesis.

Figure 1. Membrane Receptor Mechanisms

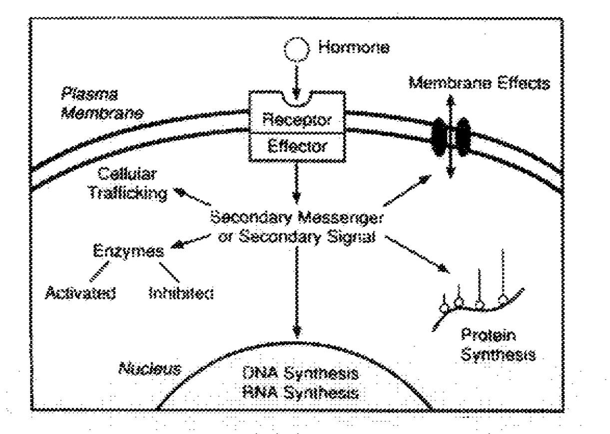
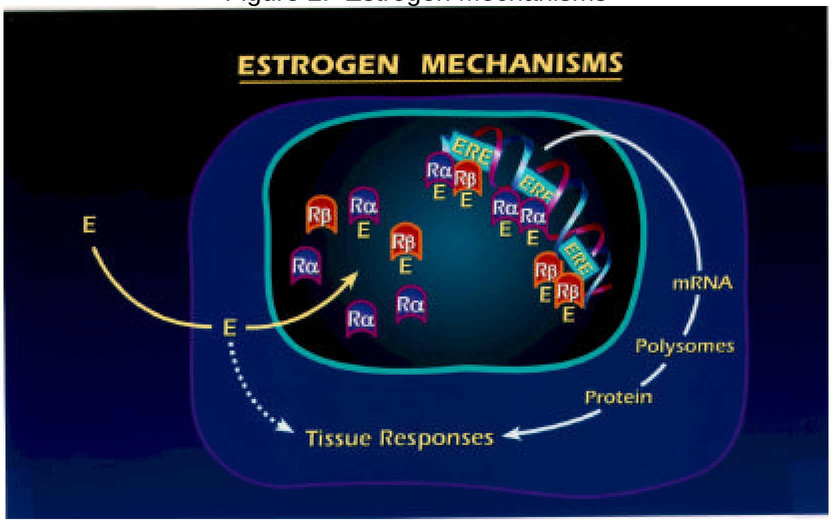


Figure 2. Estrogen Mechanisms



Other hormone receptors are located in the cell. The estrogen receptor is actually located in the nucleus. When estrogen enters the nucleus, it binds to its receptor, producing a complex that can interact with certain response elements in the DNA (Figure 2). This interaction leads to increased transcription (mRNA synthesis) and increased protein synthesis, resulting in cellular behavior that reflects patterns of gene expression and biologic responses characteristic for a given hormone-receptor interaction. Understanding hormone-receptor interactions and their mechanisms of transcriptional activation is a very active field of research. At least two estrogen receptors have been identified, the alpha receptor and the beta receptor, and ligand-receptor units have been shown to exist as heterodimers or homodimers. In addition, accessory receptor proteins have been identified, some of which act as coactivators and others as corepressors of the hormone mediated response. The complexity of the hormone mediated transcriptional activation process makes it difficult to predict what activity various hormone mimicking agents may have -- in one tissue an agent may activate the estrogen receptor, while in another tissue it may act as an antagonist. For example, tamoxifen is an estrogen antagonist in the breast, whereas in the uterus it acts as an estrogen agonist. Predictions of such complex patterns will require a more thorough understanding of the involved cellular/molecular biology.

Endocrine Disruption

The term "endocrine disruptor" has been used to describe a chemical, synthetic or natural, that may mimic or antagonize hormone-mediated processes. The definition developed at an Environmental Protection Agency (U.S. EPA)-sponsored workshop was that an endocrine disruptor is an exogenous agent (synthetic or natural) that interferes with the production, release, transport, metabolism, binding action or elimination of natural hormones in the body responsible for maintaining homeostasis and regulation of developmental processes. Because hormones and hormone receptor systems are phylogenetically similar, effects observed in one species raise concern of potential effects in other species, including humans.

An endocrine disruptor may act by mimicking or antagonizing the interaction of the natural hormone with its receptor. If an environmental agent binds to a hormone receptor and the receptor recognizes that agent as the natural hormone, then the ligand-receptor complex may activate the same processes as the natural hormone-receptor complex. Alternatively, an agent may bind to the receptor, blocking the binding with the natural hormone; the consequence of this interaction is inhibition of the normal signaling pathway.

Over 60 different chemicals have been described as having hormonal activity. These chemicals include: insecticides (DDT, methoxychlor, lindane, and dicofol), fungicides (vinclozolin), herbicides (atrazine, 2,4-D, and 2,4,5-T), several polychlorinated diaromatics (dioxins, polychlorinated biphenyls or PCBs, and polychlorinated dibenzofurans), alkyl phenols, phytoestrogens (genistein), plasticizers (phthalates and bisphenol A), drugs (diethylstilbestrol), and organometals (methylmercury, tributyltin). The effects of these compounds depend on factors such as their concentration in the environment, half-life in the body, and binding affinity with various hormone receptors. Some wildlife effects that have been attributed to environmental endocrine disruptors include: decreased fertility in birds, fish, shellfish, and mammals; decreased hatching success in fish, birds, and turtles; feminization of male fish, birds, reptiles, and mammals; immune deficiency in birds and marine mammals; and abnormal thyroid function in fish and birds. Most wildlife effects have been recognized when populations decline and detectable levels of endocrine disrupting chemicals were found in tissues of affected animals or in their environment. Experimentally, many of the chemicals that have been found to affect fish and wildlife in their natural habitats have been found to produce similar adverse effects in laboratory animals under much more controlled conditions.

Several adverse human health effects have been suggested to be linked with exposure to environmental estrogens, however, attributing some of these effects to specific endocrine disrupting chemicals is difficult. The incidence of breast cancer in the United States has increased dramatically over the last three decades. Whereas lifetime risk was estimated to be 1 in 20 in 1960, the incidence is now about 1 in 9. Approximately 180,000 women will be diagnosed with breast cancer this year, and 46,000 will die from it. Endometriosis, an overgrowth of uterine tissue in the peritoneum, may also be affected by environmental estrogens. Declines in male reproductive health, including increased frequencies of reproductive malformations, reported reductions in sperm counts, and increases in testicular and prostrate cancer may also have an environmental influence. This year, about 240,000 prostate cancers will be diagnosed in the United States and about 40,000 men will die from it. Whether endocrine disruptors contribute to these diseases is uncertain. Some of these effects have been attributed to improved screening techniques; however, screening does not account totally for the increased incidences of these diseases.

Human experiences with diethylstilbesterol, hormone replacement therapy, and oral contraceptive use has shown that estrogen produces health benefits such as reducing the risk of osteoporosis, Alzheimer's disease, and cardiovascular disease. However, there are also increased risks associated with estrogen use, including increases in breast cancer, endometrial cancer, vaginal cancer, liver disease, and abnormal development. Impacting on the benefits and risks of estrogens is the fact that there are major differences in sensitivity among subpopulations. There are genetic differences with respect to enzymes that metabolize environmental chemicals, affecting their dosimetry. There are differences in enzymes involved in repair processes. Age is an important factor: children are not simply little adults. The sensitivity of the developing fetus is the factor which leads to the greatest concern of irreversible effects following exposure to endocrine disruptors. Gender, nutritional status, and previous exposures are additional factors contributing to differential sensitivity among subpopulations.

What do we know about endocrine disruptors? We know that there are chemicals in the environment that possess hormonal activity; however, the magnitude of human exposure is not well quantified. We also know that exposures to endocrine disrupting chemicals can adversely affect wildlife. Since hormone receptor systems are similar in animals and people, effects seen in wildlife raise concern for human health. The developing fetus and children are likely to be more sensitive to the adverse effects of endocrine disruptors than are adults. Disease and dysfunctions at some hormonally sensitive sites are increasing; examples include breast cancer, testicular cancer, and declining sperm counts. These trends have not been clearly linked to endocrine disrupting chemicals, but they send a very strong warning.

One conclusion that can be drawn from currently available information is that the endocrine disruptor hypothesis has validity. Environmental estrogens clearly constitute a potential hazard to humans and wildlife, as evidenced by effects in wildlife species exposed to various organochlorine compounds, and from human experiences with diethylstilbestrol (DES), hormone replacement therapy, and oral contraceptive use. Although exposure information is generally lacking, it is likely that endocrine disrupting chemicals are contributing to some extent to human disease, although the contribution could be small.

Table 2. Current Research Findings

Exposure to endocrine disrupting chemicals in the environment has been associated with:

- Decreased fertility in birds, fish, shellfish, and mammals
- Decreased hatching success in fish, birds, and turtles
- Feminization of male fish, birds, reptiles, and mammals
- Immune deficiency in birds and marine mammals
- Abnormal thyroid function in fish and birds

Toxicity Studies in Experimental Animals

In utero exposure to endocrine disrupting chemicals causes:

- Birth defects
- Reproductive deficits
- Altered brain function
- Altered immune function
- Cancer

Adult exposure to endocrine disrupting chemicals causes:

- Reproductive deficits
- Altered brain function
- Altered immune function
- Cancer

Future Challenges

The Committee on Environment and Natural Resources, a subcommittee of the President's National Science and Technology Council, identified endocrine disruptors as one of its five high priority environmental issues (global climate change is another example of a high priority environmental issue). This committee developed a research planning framework for human health and ecological effects of endocrine disruptors (the framework document and other information on endocrine disruptors are posted on the Internet at www.epa.gov/endocrine), conducted an inventory of ongoing related research in the federal government (and found there to be about 400 research projects relating to endocrine disruptors), and is devising a plan to coordinate research to address the major data gaps and guide policy decisions.

What are the future challenges in evaluating human and ecological risks?

Identification of endocrine disruptors and their range of effects. Congress has mandated the U.S. EPA to develop a program to screen and test chemicals for their potential to disrupt the endocrine system. The plan being developed by U.S. EPA's Endocrine Disruptors Screening and Testing Advisory Committee (EDSTAC) will likely involve several short-term screening assays as well as multi-generational studies (to capture prenatal and postnatal effects) over very wide exposure ranges.

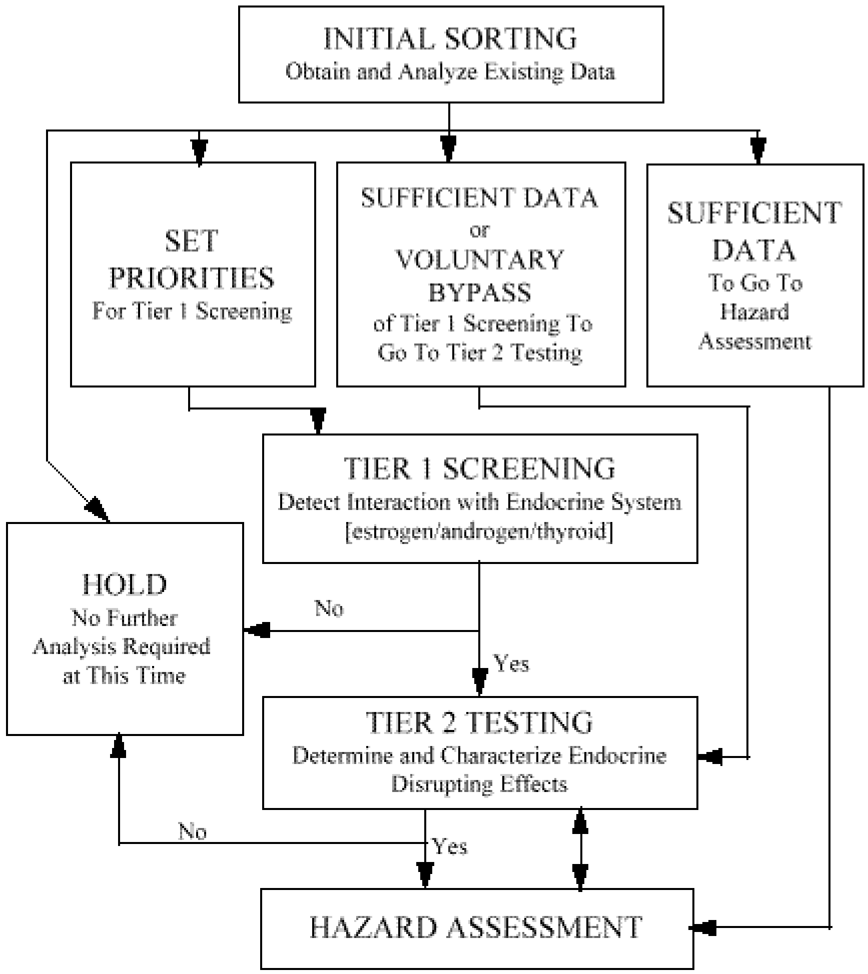


Figure 3. EDSTAC Conceptual Framework Providing the Structure for Screening and Testing for Endocrine Disruptors.

Improved exposure assessments of humans and wildlife. There is a definite need for better quantitative data on ambient concentrations in the environment and peak levels.

Trans-species extrapolations of animal data or experimental models. How do we conduct human health risk assessments from effects observed in animals? *In vitro* model systems are available for testing whether a chemical blocks or elicits estrogenic activity. Empirical data from large multi-generational studies and mechanistic data will need to be used in evaluations of health effects in humans or wildlife.

Evaluation of dose-response and characterization of effects at environmental exposure levels. This issue involves evaluations of dose-response relationships and shapes of dose-response curves at environmental exposures. Are adverse effects observed at high doses reflective of risks at environmental exposure levels? To protect the public health, is it sufficient to identify no effect levels and utilize safety factors to ensure no risk at low doses, or do we need a greater understanding of the biological processes involved in order to better estimate low-dose risk ?

Evaluation of risks in sensitive subpopulations. How do we account for genetic variability and other factors contributing to differential sensitivities among subpopulations?

Evaluation of risks from mixed exposures. People are never exposed to only single toxicants. How should risk assessments address complex interactions?

Many of the above issues may be addressed with validated mechanistic models that describe quantitative relationships among the processes controlling normal development and maintaining homeostasis, that characterize how various chemical agents perturb normal endocrine functions, and that quantitatively link chemically induced perturbations in endocrine homeostasis and function with adverse outcomes. The development of such mechanistic models is a challenge for the public health and regulatory communities.

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INTEGRATED APPROACHES TO RESOURCE MANAGEMENT

WILLIAM SHIREMAN
Global Futures

My organization, Global Futures, exists to resolve conflict among business advocates, environmental advocates and social activists of various stripes. We often engage in challenging roundtable discussions involving individuals with quite different views of the world and seemingly contradictory objectives about what to do about that which some perceive as problems and others perceive as opportunities.

This process of resolving conflict between adversaries has brought us into contact with a wide variety of corporate leaders, as well as environmental leaders and leaders in the social activist community. A few years ago, some of the leaders within these communities joined with us to form a new kind of a business network that we call the Future 500, a network of business executives that work with visionaries and futurists in the environmental, scientific and technology communities to try to find opportunities to reduce the amount of pollution and the amount of waste associated with today's business activities. This is the trend that I would like to discuss with you, and perhaps begin a dialogue to identify where the opportunities are for shifts in environmental regulation.

The major participants in Future 500 include Mitsubishi Electric, Nike, Coors, Hallmark, ACX Technologies, Hitachi Foundation, and the California Integrated Waste Management Board. The trend that the organization is hopefully taking advantage of is the shift in the global economy from an industrial model to a post-industrial, information-based, information-driven model. This shift in the nature of the economy is as fundamental as the shift from agriculture to industry, and before that, the shift from hunting and gathering to agriculture.

This transformation is substantiated by the emergence of information in the last quarter century as the new "primary fossil fuel," the new stimulus to economic growth. An economy that is grown on information is fundamentally different from an economy that grows on the basis of consumption of physical resources. This implies changes in all of our institutions, and certainly changes in the way that government agencies regulate those institutions.

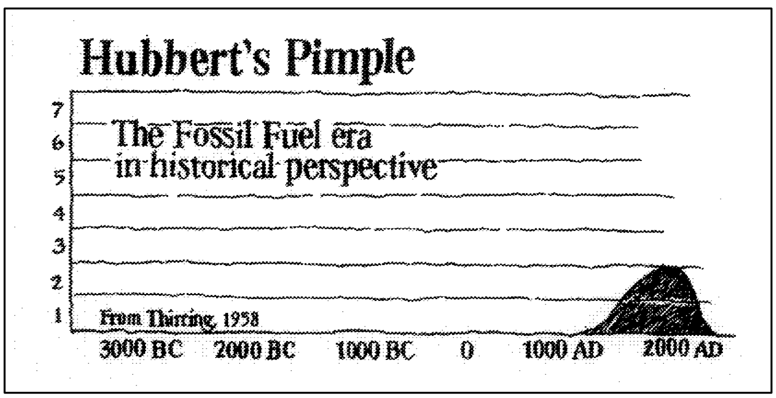
We all are well aware of some of the negative environmental consequences of the closing edge of the industrial economy; we are not as cognizant of the potential environmental advantages of the emerging economy. These environmental advantages may or may not emerge in time to serve as antidotes for the problems that we are generating. However, among the advantages of this shift from an industrial to an informational economy is the capacity to increase, by a radical proportion, our resource productivity -- the amount of value that we derive from every unit of fossil fuel and material resource that we consume. The objective of Future 500 is a "factor four," or four-fold improvement in resource productivity, although this target may understate the capacity of the technologies and the values of the emerging economy to reduce our need for physical resources.

The challenge for Cal/EPA, for other regulatory bodies, for the corporate sector, and for environmental organizations is to shift from machine models of operation, to living systems models of operation, founded on the principles of an emerging field called industrial ecology. Industrial ecology takes advantage of the technologies, the measurement tools, the management approaches, and the policy approaches that mimic the capacity of living systems to drive waste continuously toward zero. In nature, complex systems have the capacity to begin in very consumptive modes, much like the industrial economy has, and gradually evolve into structures that are far more efficient. The objective of the practice of industrial ecology is to facilitate this transition and find ways to organize businesses and governmental institutions so that they operate less like machines, more like living systems.

The industrial economy is founded on the use of machines to multiply human muscle. This economy supports big, highly centralized, hierarchical institutions. Large, centralized corporations, standardized companies like Standard Oil, Standard Brands, General Electric, General Motors, in tall hierarchies, are formed to manufacture standardized products which roll along a standardized production and distribution process, manufactured by standardized employees in standardized factories and offices, where they all perform standardized jobs that are designed to be relatively simple and interchangeable. Everyone arrives at a standardized time, from their standardized homes in a standardized suburb, where they have a standardized family structure -- the traditional nuclear family -- with a standardized male as the producer, and the female as the nurturer, and the standardized two or three kids who go to the standardized schools at standardized times, arriving at 8:00 a.m. and leaving at 3:00 p.m., so they have this sense of structure that fits well into an industrial culture, so that their mom can go and buy the standardized products from the standardized stores and then, of course, all these lead to an accumulation of waste at the standardized dump. There is a limit to the amount of growth in this machine-like manner.

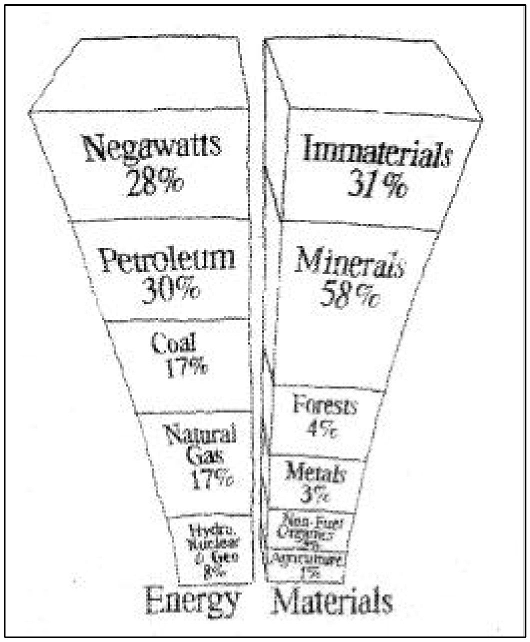
“Hubbert’s Pimple” (Figure 1) is a graphical representation of the fossil fuel era in historical perspective. As the figure illustrates, no matter how we measure the amount of fossil fuels in the earth, the radical increase in consumption of fossil fuels will lead to a very short-lived fossil fuel era. Whether that era comes to an end in ten years or in a hundred years, it will come to an end, and we will survive past it.

Figure 1



One of the trends that we have seen is rather than the continued growth in the per capita or per-unit of growth of gross national product consumption of physical resources, we have found ways to replace those resources with better design and more knowledge integrated into products and into the processes of the economy. Consequently, “negawatts” and “immaterials,” the energy and the materials which come from efficiency and from creativity, have emerged now as the fastest growing sources -- and the cheapest source by far -- of fuel and materials (Figure 2). In fact, so successful have we been at finding efficiencies that we have created an overabundance of the resources themselves, and kept the price of oil and of commodity materials down for the most part over the last generation.

Figure 2. Biggest Sources of Energy & Materials

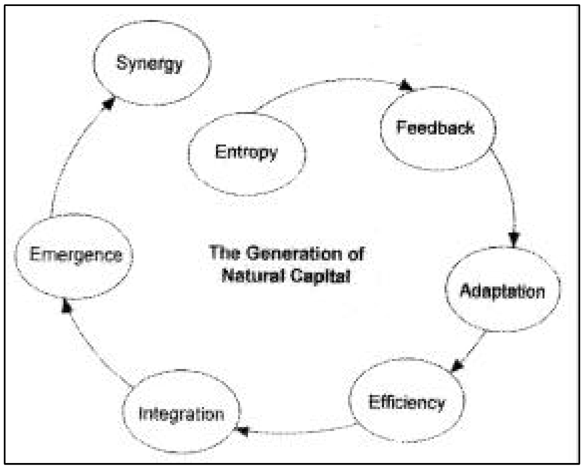


Conceptually, this transition parallels the process of succession in nature. In a natural ecosystem such as a forest, when a field is burned clear, the pioneer species to emerge (such as the grasses and the fast-growing species) are the R-strategists; they are highly consumptive and highly fertile, consuming the available resource base very quickly. Over time, those species compete with one another as they reach the outer boundaries of their rapid growth. That competition leads to adaptation, and adaptation leads to a gradual diversification of the forest, with more organisms in more niches, more specialization in those niches, less competition, more integration, and more interdependence. Gradually, a system emerges which is far more efficient and far more creative than the initial one. Some would say that the human ecosystem is in this process of transition as well -- from a period of rapid, physical growth, to a period of potentially rapid but non-physical growth in efficiency and in creativity -- mimicking the forest, although nowhere near what would be called a climax forest (the current thinking in biology is that there really is no climax forest, and that the progress is more of a spiral than a linear system that leads to climax).

A change that I find particularly useful in business and in public policy design is the change in the concept of what capital is. Natural capital consists of the physical resources of the earth, such as the oil and the ores, that are used to manufacture products. However, natural capital is more a function of structure and of design than it is of physical mass. Natural capital can be thought of as the resource itself, but what gives the hard resource value is the structure of that resource -- how the components of the resource are brought together. For example, the elements hydrogen, carbon, nitrogen, and oxygen are the “hard capital” which, when brought together in various combinations to produce “soft capital,” exhibit specific characteristics or emergent properties, generating value. With the correct structure, hydrogen and oxygen form water, which has distinct properties that give it value. By taking physical resources and applying patterns, designs or arrangements, value emerges. Nature, businesses, and government create value in this manner.

Figure 3 illustrates the spiral of natural capital generation. All uses of resources lead to entropy, or a loss of order. This is what the environmental community and the rest of us are so concerned about. As we use physical resources, we may not necessarily spend them physically, but we spend their design, their capacity to provide us with service. In natural systems, this leads to feedback. Feedback mechanisms in the system trigger adaptation in the way resources are used which, in turn, results in more efficient use of resources, or integration. In economic systems, this is analogous to a diversification of the economy. With diversity -- i.e., more people doing different things, or more businesses serving different niches -- individuals or businesses become more interrelated and integrated with one another. As those functional relationships increase and reach certain points of integration, new values emerge as people, ideas and resources are brought together in the right combinations. Distinctive new creations emerge from this creative process. For 3.8 billion years, synergy has given natural systems the capacity to evolve continuously, with a set supply of material resources and solar energy, into forms that are increasingly more creative and productive.

Figure 3



Industrial ecology is a relatively new discipline that applies concepts derived from ecological systems to the economy, business, and regulation. One working definition for industrial ecology is “the application of ecological principles to business and industrial practices.”

Industrial ecology has three objectives:

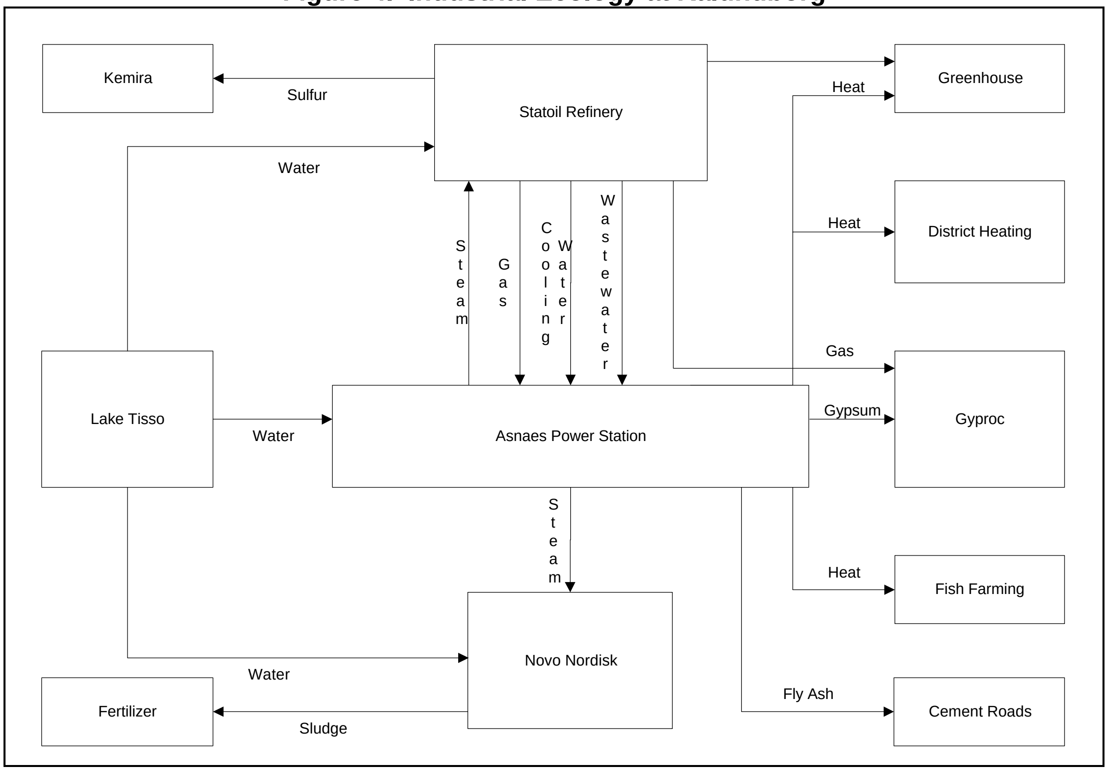
(1) to minimize loss -- i.e., to cut costs and consumption. This has been where the environmental community and government regulation has focused much of its attention. Industrial ecology recognizes the costs associated with the consumption of resources, and aims to cut these costs. Often, rules and regulations are imposed in an attempt to cut and minimize loss.

(2) to maximize gain -- i.e., to add value, to foster creativity, to increase net profit. No system can survive long simply by minimizing its expenditures; it must have an income source as well. The other half of the environmental movement that needs to be cultivated is the creation of gain through natural processes.

(3) to promote sustainability, where sustainability is the capacity to create more than is consumed so as to flourish for the long term. The previous two objectives lead to this third one.

The idea of natural ecology was popularized by a community called Kalundborg, in Denmark (Figure 4). This is a fairly close-knit community with a refinery, a power station, and other industrial facilities that were polluting the local water supply and the air. Gradually, through feedback mechanisms, local citizens became more aware of the resource costs of the operations of these plants; likewise, the plant managers became aware of these costs. The facilities began to work together spontaneously, to find ways to share their wastes. Wastes from one facility became a resource for another. Steam from the power station was piped to the refinery for use there. Heat was extracted and used for the district heating system, for the fish farm, and to heat greenhouses. The natural gas from the refinery -- which before had simply been off-gassed into the air -- was shifted to the gypsum plant; however, its sulfur content was too high, so the sulfur was extracted and sent to a sulfuric acid plant. There are an amazing number of relationships built up in this community spontaneously, not as consequences of government regulations, but as consequences of the community feeding back information about these costs to itself, and finding creative ways to deal with those costs.

Figure 4. Industrial Ecology at Kalundborg



A great example of industrial ecology in the United States comes from Coors Brewing Company. Coors invented the recyclable aluminum can (Table 5). It also has recycled its ideas from its facilities to design new products and services -- advanced materials, high-tech ceramics used in electronics, and in the manufacture of super-efficient engines, solar photovoltaics and organic plastics -- that together are far more profitable than the brewery. Over time, Coors has moved from an industrial company that was becoming increasingly less profitable, to a post-industrial company that is increasingly more profitable by relying on the utilization of ideas, rather than resources.

Table 5. Coors Industrial Ecology: How waste reductions trigger new products, companies, and profits

Waste led to…		**…a new idea or process…**		**…that turned into a new company, facility, or partnership….**		**…that reduced resource consumption, waste and costs**
Spent Grains	⇨	Fertilizer and Feed	⇨	ZEAGEN	⇨	**$** ü
Aluminum Can Waste	⇨	Drawn & Iron	⇨	Golden Aluminum	⇨	**$** ý
	⇨	Continuous Casting and very high recycled content	⇨	Aluminum Mill in Fort Lupton	⇨	**$** ý
	⇨	Downweighted	⇨			**$** ý
	⇨	Recycling	⇨	BICS	⇨	**$** þ
Secondary Package Waste	⇨	Recycled Content Partnerships	⇨	Recycling agreements with suppliers	⇨	**$** þ
Solvent Waste	⇨	Bio-T	⇨	New product for Golden Technologies	⇨	**$** þ
Wood Waste	⇨	Compost (w/ spent grains)	⇨	New product for Coors	⇨	**$** þ
Plastic Waste	⇨	Organic Plastics	⇨	Future Graphics Packaging product	⇨	**$** þ
Ceramic Technologies	⇨	Advanced Materials	⇨	Coors Ceramics	⇨	**$** þ
	⇨	Lightweight engines. Better pollution controls. Energy/materials efficiency	⇨			**$** þ
Environmental Research	⇨	New solar tech	⇨	Golden Photon	⇨	**$** þ

Future 500 has been pulling together roundtables of representatives from the business community and from the environmental community to discuss three topics:

(1) **measurement** tools that track the economic and ecological costs of business, and that can be used as feedback mechanisms that allow businesses to continually reduce their consumption of resources, to accrue the resulting cost benefits, and to improve their environmental profiles in the process;

(2) **management** systems that adapt and evolve to minimize costs and maximize gain -- extremely important for companies in a rapidly changing economy;

(3) **policy** framework -- a system of laws, regulations, and public policy that rewards efficiency, creativity and innovation.

The “polluter pays” principle provides the basis for many of the public policy approaches that have been developed for use by various state agencies. This principle promotes more systems-oriented, market-based policies, assigning the responsibility for consumption to the entity most directly responsible for generating it, so that any increase in consumption leads to higher costs, and any decrease in consumption leads to lower costs, for that person, team or organization.

Application of this principle is changing the nature of regulations from the command-and-control approach to a systems-based approach in which efficiency is rewarded, and consumption is penalized. This principle is very important for California, given its role as the birthplace and the leader of the emerging information-based economy. To the extent that we can switch our regulatory approach to a systems-based approach that encourages reduction in the use of materials, we can help to facilitate the growth of that sector, which is most important to the future of the California economy. The industries of California are providing the technologies and, in many cases, exemplifying the management approaches that lead to creativity and innovation, and that radically reduce the amount of resources required for performing any function.

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EXOTIC ORGANISMS

ANDREW N. COHEN, Ph.D.
San Francisco Estuary Institute

In 1852, Commodore John Sloat of the U.S. Navy arrived in San Francisco on a special mission from Washington. His task was to find a site for the first U.S. naval base on the Pacific coast. His orders directed him to select a location that was "safe from attack by wind, by waves, by enemies and by marine worms."

The "worm" that the U.S. Navy was concerned about was the Pacific coast shipworm. It is not actually a worm, but rather a kind of clam with a long, skinny naked body and some small shells at its anterior end that it uses to bore into wood: wood like the hulls of wooden ships, and wood like the pilings that hold up wharves and piers. Shipworms can be very destructive of wooden structures — in San Francisco Bay, for example, dense infestations of the shipworm frequently caused pilings to break off at the mud line.

To avoid problems such as these, Commodore Sloat decided to locate the naval base on Mare Island in the northern part of San Francisco Bay, where the water was too fresh for the Pacific shipworm to survive. The base was established and thrived, without attack from any of its feared enemies for several decades, until the year 1913, when an Atlantic shipworm arrived on the Pacific coast, where it was, ironically, first discovered in a piling at Mare Island.

The Atlantic shipworm is more tolerant of fresh water, and over the next few years it became increasingly abundant in the northern part of San Francisco Bay. It eventually came to the attention of the general public, when beginning in the year 1919, a major wharf, pier or ferry slip collapsed into the waters of San Francisco Bay at an average of one every two weeks over a period of two years. The damage from this one long-forgotten and little-recognized introduction, in this one estuary on the Pacific coast comes out to somewhere between $2 and $20 billion in current dollars. It destroyed the entire maritime infrastructure in the northern part of San Francisco Bay.

If we were to take a tour of the San Francisco Bay system today, what organisms would we find? In the marina at Berkeley, we have pulled a styrofoam float or boat bumper out of the water, and found it completely covered with a variety of marine organisms: sea squirts from Asia and the Atlantic; sponges and bryozoans from the Atlantic; and mussels, which might be native to the Pacific Coast, or might have come from the Mediterranean. Such an assemblage of organisms is typical of what we find in the central part of San Francisco Bay, growing on hard surfaces or on the docks -- virtually every organism comes from some other part of the world and is not native to this ecosystem.

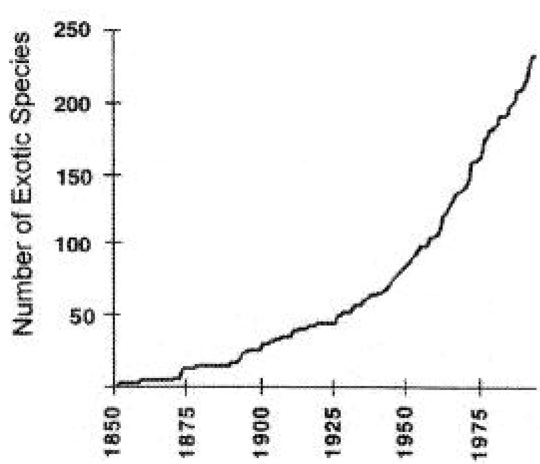
A little farther north in the Bay, in fresher or brackish water areas, we find a different set of organisms growing on the sides of the docks and hanging from the bottoms of boats and buoys: long, dangling, silt-covered strands that consist of an Atlantic hydroid (an early life stage of a jellyfish), covered by an Atlantic bryozoan, and crawling in amongst these, small, crustacean isopods from Asia.

Moving into more protected waters, we find the sides of the docks and the rocks often coated with reef-like agglomerations of white calcareous tubes. The tubes are built by a worm from the Indian Ocean. When we break these masses apart, we often find within them a little brackish water crab from the Atlantic coast of the U.S., and in recent years, alongside this crab can be found the juveniles of the Chinese mitten crab which arrived in San Francisco Bay a few years ago. Here we have a typical California story: the Atlantic crab meeting up with the Chinese crab in a structure built by an Indian Ocean worm on the side of a dock in San Francisco Bay.

Meanwhile, in the marshes, in many places around the Bay we find expanding clumps and patches of a tall, robust Atlantic cord grass that outcompetes the native California cord grass. The Atlantic cordgrass also grows much farther out into the mudflats, covering them with this exotic vegetation, which has raised concerns about the huge populations of migratory shorebirds that come here to feed on the mudflats each winter. These shorebirds — the sorts of birds that you often see probing in the mud at the water's edge — will only feed on open mudflats, not within vegetation, and if they lose the mudflats of San Francisco Bay, there is really no place else for them to go.

The mudflats themselves are often covered with small snails, the Atlantic mud snail, which is the most common snail in San Francisco Bay. The most common clam in the Bay these days is what is often referred to as the Asian clam (a recent arrival from China), the Japanese little-neck clam, and the Atlantic gem clam. In recent years, we have likewise found that the microfauna has been taken over by a Japanese foraminifera, a shelled protozoan which arrived in the 1980s. It is now the most common foraminifer in San Francisco Bay, and has spread up and down the Pacific coast. In 1995, Jim Carlton and I completed the first part of a study (which we have revisited in the last couple of years), in which we identified over 200 exotic species that have become established within the San Francisco Bay and Delta system. Beyond the sheer number of these organisms, we have been impressed by how they dominate many habitats and biological communities -- in terms of the number of organisms, the number of species, or the biomass. These two things together -- the number and the dominance of exotic organisms -- led us to suggest that the San Francisco Bay system may be the most invaded estuary in the world. However, even more striking to us than their number and dominance is the rate at which these organisms are coming in (Figure 1). The data clearly show that the rate is dramatically increasing. During the period prior to 1960, over California's history, we find roughly one new species arriving in the system and becoming established every year; since 1960, there are about four new species every year.

Figure 1. Increasing Rate of Invasions



How are these organisms coming in? There are several mechanisms. Historically, an important mechanism that still operates to some degree is that organisms come attached to the hulls of ships (or, in the case of wooden ships, bored into the hulls like the shipworm), and then release their young, which may become established on the new coast. Sponges, seaweeds, barnacles and some mussels were introduced in this manner. Another important mechanism was the importing of oysters into San Francisco Bay from different parts of the world. Oysters from the Atlantic coast and from Japan were laid out in vast rearing beds in shallow areas around San Francisco Bay, fenced off from the bay to keep out oyster-eating leopard sharks and bat rays. These oysters never became established, but many other organisms that were attached to the shells of oysters, or that were in the mud or the water that the oysters were carried in, did become established within San Francisco Bay and in other bays along the Pacific coast.

These mechanisms do not operate very much anymore, but we have developed new and ever more effective mechanisms for moving organisms around the world. One mechanism that has received a good deal of attention in recent years involves the transport of ballast water in cargo ships travelling about the world. When a ship is empty of cargo or light in cargo, it sits high in the water and can easily be knocked over by wind or by waves. Since this is unsafe for travelling across oceans, ships that are light in cargo will pump aboard vast quantities of water in order to sink the ship down to a more stable level. Upon arriving at its destination, a ship will then dump its ballast water out into the coastal water, before taking on cargo.

Table 1. Types of Organisms Collected in Ballast Water

Vascular plants	Gastrotrichs
Bacteria	Annelid worms
Blue-green algae	Peanut worms
Green algae	Molluscs
Red algae	Crustaceans & mites
Diatoms	Tardigrades
Dinoflagellates	Bryozoans
Flagellates	Starfish, brittle stars, sea urchins & sea cucumbers
Forams	Phoronid worms
Radiolarians	Arrow worms
Ciliates	Lancelets
Jellyfish	Acorn worms
Comb jellies	Sea squirts
Flatworms	Fish
Ribbon worms	
Round worms	
Rotifers	

In the last 15 years or so, biologists have begun to examine ballast water, and have found that it contains virtually all types of marine organisms (see Table 1). Within these groups, probably thousands of different individual species have now been identified as live organisms in ballast water. For example, organisms that live on the bottom of the ocean -- the clams, the mussels, the barnacles and so forth -- release larval forms that are microscopic and float in the water, and we tend to find these, sometimes in great numbers, in ballast water. In addition to small organisms, we sometimes find larger organisms, such as fish or crabs.

There have been some spectacular invasions over the last 15 years via ballast water, which have focused attention on this issue. Probably the most publicized is the arrival of the European zebra mussel in the Great Lakes. The zebra mussel has become so abundant that it has covered beaches with sharp-edged shells and rotting masses of mussel flesh, closing them. The mussels attach to hard surfaces such as the hulls and surfaces of boats, ships and buoys, weighing them down, increasing the fuel consumption of boats and ships, and increasing their maintenance costs. The mussels imperil many types of native clams and other organisms. The most damaging economic impacts result from their tendency to grow inside water pipes, in enormous densities -- one mussel growing on top of another -- to the point where they clog the flow and sometimes entirely block pipes, causing water systems to shut down. They have hampered municipal and industrial water operations and reduced the flow of cooling water in nuclear and coal-fired power plants. The estimated damages within the Great Lakes region alone are in the billions. The zebra mussel has now spread throughout much of eastern North America.

Another impressive invasion involves a comb jelly -- a small, jellyfish-like organism. This one is about two inches long, semi-transparent and iridescent. It was introduced from the western Atlantic into the Black Sea in ballast water. It eats zooplankton **--** the fish food in the water -- and is insatiable. It became abundant enough in the Black Sea to eliminate virtually all the zooplankton. The fisheries have been closed, probably in substantial part because of the arrival of this organism.

Yet another recent invasion is that of a Japanese sea star that has arrived in estuaries in Australia. It has become very abundant, though not yet widespread. Where abundant, it has been helping itself to the clams that once supported a clam fishery. Efforts are under way to do something about it, but no one knows what.

In recent decades, biologists have recognized what has been described as an epidemic of noxious algal blooms and red tides around the oceans. These blooms of microscopic algae are harmful to marine life, and some of the red tide organisms produce human neurotoxins. These neurotoxins become concentrated in the tissues of clams and mussels, and can cause illness and death when these shellfish are eaten by humans. There are probably a number of factors contributing to this epidemic of algal blooms and red tides around the world, but accumulating evidence suggests that at least some of them are due to the introduction of these organisms into new parts of the world in discharges of ballast water.

In addition to red tide organisms, we also now know that cholera can be moved about the world in ballast water. It appears that in the 1990s the epidemic strain of South American cholera was transported in ballast water into the Gulf of Mexico, where it was found in oysters and fish along the U.S. coast.

San Francisco Bay has also been host to a recent spectacular invasion. In the fall of 1986, three Asian clams, a species never before collected on the west coast of North America, were found in San Francisco Bay by a community college biology class. By the summer of 1987, nine months later, it had become the most abundant clam in the northern part of the bay, with average densities of over 2,000 clams per square meter. Clams were packed practically side by side, over tens of thousands of acres of muddy bay bottom. This clam is so abundant that it is capable of filtering out of the water virtually all of the phytoplankton **--** the microcopic floating plants that are one of the basic foods in the estuarine food chain. Phytoplankton blooms, which had characterized this system up until the arrival of the clam, no longer occur in this part of the ecosystem.

There are things that we can do about the problem of exotic organisms. The San Francisco Bay Regional Water Quality Control Board recently listed exotic species released by ballast water as a priority pollutant impairing the health of the ecosystem. We can require ships to exchange their ballast water at sea, as is done in some parts of the country. Another technically feasible option is to move ballast water on-shore and treat it to kill or remove the organisms in it, much as we treat water or wastewater. I am currently working on assembling a team of water and wastewater engineers, shipping experts and regulators to investigate this approach.

I should emphasize that invasions have occurred on the land as well as in the sea. Table 2 provides a rough compilation of the numbers of exotic species reported in California. Several of these groups are underestimated, and other important groups are missing entirely, but even from this rough tally it is clear that there must be well over 300 species of macroscopic animals (we know virtually nothing about the microscopic ones), and something on the order of 1,000 plants that have been introduced into the State of California from other parts of the world.

Table 2. Exotic Species in California*

Mammals	22
Birds	24
Reptiles and Amphibians	10
Fish	55
Marine and Freshwater Worms	25
Snails and Slugs	43
Clams and Mussels	14
Crustaceans	66
Insects	??
Other Marine/Freshwater Invertebrates	38
Other Terrestrial Invertebrates	??
Animals	>> 297
Plants	1029

*Sources: Hanna 1966, Moyle 1976, Carlton 1979, Taylor 1981, Laudenslayer *et al.* 1991 (updated by Ron Jurek), Hickman 1993, Cohen & Carlton 1995, Cohen 1996

The story that I have told here of a rapidly accelerating rate of invasions into the bays and estuaries of the world **--** in the areas that are the first to feel the effects of expanding international commerce and shipping **--** may simply be a preview of what to expect on the land. Virtually all of the mechanisms that transport exotic species around the world are likely to increase in scale as we further liberalize international trade, open new global markets and accelerate the movement of goods and people. The accompanying movement of exotic organisms will not only involve those that affect natural environments, it will also introduce new crop pests, livestock pests, and human parasites and diseases. Yet when policymakers discuss mitigating the impacts of trade liberalization, they never address these obvious, direct and predictable consequences. As a state and a country, we are failing to make the investments needed to enhance our capacity to prevent, to monitor, to quarantine, to investigate and to respond to the invasions of harmful organisms that will inevitably come. In general, we know what needs to be done. In most cases, we do not need to develop whole new technologies. But we do need to face up to this problem squarely, and begin to take the steps that are necessary to deal with it.

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MANAGEMENT OF WATER RESOURCES

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Sustainable resource management is defined as managing our natural renewable resources in a way that enhances and ensures their continued existence and quality, while contributing to our economic and social development. Sustainable water resource management (see Figure 1) integrates three components: hydrology, ecology, and production and consumption activities. Much of the interest is in the intersection among these three components. Models are generally used to predict and examine the interactions among these components, and the impacts of potential decisions on each of these.

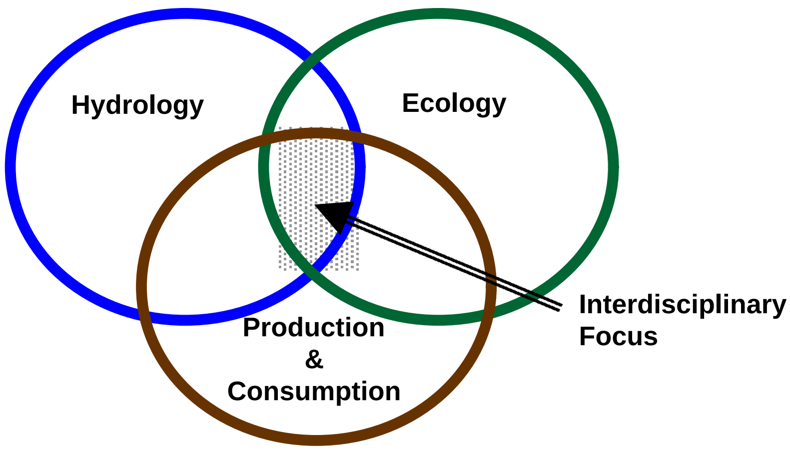

Figure 1. Sustainable Water Resource Management.

Sustainable water resource management involves bringing all the stakeholders involved in a particular watershed or river basin together to reach a consensus on how the watershed or river basin functions, and on how it should be managed. The U.S. Army Corps of Engineers uses the term “shared vision” to refer to efforts to assemble all the groups with an interest in a watershed or a river basin with the goal of developing a common vision of how the system works and how it should be managed. As new knowledge and information becomes available, or as new stakeholders are identified, these shared vision exercises may need to be repeated.

Research agencies such as USEPA and NSF are currently supporting research on the interactions among the socio-economic factors that are driving decisions relating to land and water use, the hydrology of the watershed, and how all of this impacts the ecology.

For our discussions in this workshop, I have tried to identify various issues involved in water (especially water quality) management. I have grouped them under the following categories: effective resource management, protection and use; government agency issues; conflicts and conflict resolution; public involvement; data, research, science and technology; institutions and innovations; and what I call the ‘underlying’ issue, especially related to sustainability.

Some of the issues in effective resource management are:
1. Lack of integrated conjunctive management and protection of surface-groundwater quantity and quality;
2. Endangered Species Act allocations;
3. Tradeoffs between ecology and other benefits;
4. Needs of people vs. needs of endangered species, ecology;
5. Aquatic nuisance species control -- how and how much?
6. Toxic persistent organic pollutants (POPs) control;

7. Dredging costs and disposal of toxic sediments;
8. Balancing environmental, economic and social values; and,
9. Non-point source pollution -- erosion control.

With regard to government agency issues, the following are derived from reports dealing with western issues as well as eastern issues:
1. Coordination and consistency among government agencies and programs;
2. Coordination of local initiatives with federal agencies;
3. Federal erosion of state authority (may not be applicable to California);
4. Federal agencies working within state laws;
5. Federal agency objectives, authority and accountability;
6. Cost recovery of public projects;
7. Increasing project operation, maintenance and repair costs and decreasing budgets;
8. Increasing regulations and decreasing funding; and,
9. Transferring federal projects to state/private projects.

Issues relating to conflicts and conflict resolutions include:
1. Interstate and international conflicts;
2. Uncertain jurisdictional interests and authorities;
3. Upstream vs. downstream conflicts;
4. Need for more information and knowledge;
5. Need for “shared vision” among stakeholders;
6. Alternatives to litigation in the courts; and,
7. Need for certainty in property rights.

Some public involvement issues are:
1. Increasing effective public participation;
2. Keeping the public informed and involved;
3. Coordinating Federal, State and local involvement;
4. Setting priorities on multiple objectives;
5. Improving communication and collaboration;
6. Creating a “shared vision” among stakeholders; and,
7. Creating community-based water quality protection groups.

One of the challenges that has been identified at this workshop is the need to have the science available when the window of opportunity arises for making a decision based on that science. The challenge for the research community is to have the research available when the need for it arises. Other issues relating to data, research, science and technology include:
1. Better decisions based on better science;
2. U.S Geological Survey and U.S. Environmental Protection Agency data collection programs;
3. Smaller and cheaper technology for waste removal;
4. Better operation of existing projects;
5. Evaluation and communication of environmental values;
6. Improved models and standards;
7. Appropriate research and development funding; and,
8. Ecological research on invasive aquatic species impacts and control policies.

If I were asked what the biggest constraint is in water management, it would not be the science or the technology, it would be the institutions and the people, and getting them organized. Often, the big problems are these institutional ones. Some of the issues involving institutions include:
1. Watershed focus: Who represents outside interests in watershed planning?
2. Place-based, bottom-up approach to watershed planning;
3. Preservation of state’s rights;
4. River basin authorities and watershed councils;
5. Local management of groundwater;
6. Legislative authorities that constrain actions, cooperation;
7. Regulatory approaches vs. cooperative approaches;
8. Water marketing opportunities and limitations; and,

9. Tradable pollutant discharge permitting.

What is the underlying issue? A lot of time and money have been expended on building infrastructure to control natural water resource systems, and we can do a good job at that. We can -- from an engineering perspective -- build infrastructure, maintain it, and provide end-of-pipe solutions for our pollution problems; no doubt this activity will continue.

One of the ideas I had yesterday at the breakout session was to eliminate the need for sewers and wastewater treatment plants by developing the technology that takes care of the waste when it is produced. That would be a technology that would have a major impact. Given enough funding, engineers can and do develop technologies such as that.

Today, however, many of our water resource management problems cannot be solved by investing more money in infrastructure. Further, it seems we have less money to spend. We have learned that we can over-control natural water systems to the long-term detriment of both the ecology and the economy. Now we find ourselves using the talents of a lot of biologists and engineers and a lot of money in deregulating regulated rivers, allowing rivers to become, once again, 'living rivers' supporting diverse ecosystems. The result, we predict, will be cleaner and healthier water and less flood control problems, and so on. This cycle of regulation-deregulation appears to be like a pendulum, swinging back and forth. The real dilemma is -- especially in California, where the weather is great and where everybody wants to move to – there is insufficient amount of useable water in areas where people need it. So what happens? The engineers are asked, and paid, to go out and get the water, to provide water in areas where there is the demand. This, of course, makes these areas even more attractive for people who want to live there. This of course creates greater demand for even more water. We have been too good at meeting the short-term regional demands of society for reliable supplies and qualities of water at relatively low costs. This has made those regions even more attractive for continued population growth and continued calls for increased water resources. This practice is not sustainable.

What is the alternative? Not to meet the demands? Keep the standard of living low? If people really want to live someplace and the water is getting so scarce that it must be imported from two states away or that ocean water needs to be desalinated, the water will cost more, and perhaps the cost will determine who can afford to live in such areas. Now we have an equity issue. None of these alternatives appear to be very optimal. Such issues are worthy of much more debate than they are getting so far.

If we are to achieve a more sustainable economy and better management of our water resources, we must modify our management objectives and eliminate the production of pollutant residuals at their sources. This will require a change in our production and consumption habits, and a greater awareness of the long-term impacts of our current decisions.

How can we solve today’s problems when spending money to build things is not sufficient? One option is to regulate. Regulation works to some extent, but the public has been demanding less regulation, not more. Another alternative might be the use of economic incentives. It is not obvious, however, how this could be done effectively.

Sustainability requires us to take a broad, prospective look into the future. Charles Vest, the President of the Massachusetts Institute of Technology, said the following:

> “Creating systems that protect the natural world, while continuing economic growth -- a condition called sustainability -- may well be the biggest challenge of our time. To meet these challenges...all of us must commit to furthering the search for long term solutions by making the environment a major priority. We must devote extensive resources -- both financial and intellectual -- to this area.”

At the recent meeting of the American Society of Civil Engineers in Chicago, Paul Busch, the Chief Executive Officer of Malcolm Pirnie, Inc., an environmental engineering firm, stated that to achieve sustainability, we need to dream. He said part our job should be dreaming. We need to have big dreams about how to create smaller, cheaper, more efficient environmental control facilities requiring fewer staff, producing less waste solids, noise and odor, and using less energy and chemicals, and so on. We need a technology that eliminates the use of water as a carrier of waste problems. Pollution prevention, recycling, energy conservation, water conservation, water reuse, land use, water quantity and quality management, ecosystem enhancement, should all be considered in a coordinated, comprehensive, integrated, holistic manner.

According to Paul Busch, “For sustainability, optimization of the larger system is a whole lot more important than individual optimization of the pieces…Sustainability is about making a lot of tough choices -- many about our quality of life and what we're prepared to commit to achieve it.”

In conclusion, we can solve some of our problems by spending money to build things, and we know we can do that, and do it well. We can solve other problems by regulating and changing people’s habits; this is more difficult, and we do it poorly. Our understanding of the current problems suggests we cannot solve all of them by spending a lot of money on construction. Our understanding of current water issues suggests we will have to change ourselves. This will not be easy. It will take leadership.

We have the power to manage our resources any way we want to. The question is just how should we be managing them, for us as well as for our descendants. Do we have the wisdom and the will to try to find the answer?

WORKSHOP BREAK-OUT SESSIONS

The workshop was an initial, information gathering step in a process designed to identify, select and characterize future issues for Cal/EPA. All ideas presented at the workshop were recorded for incorporation into these workshop proceedings. A complete compilation of the ideas collected at the workshop can be found in Appendix D.

GOALS

The break-out group sessions provided workshop participants an opportunity to present their individual ideas about possible future environmental challenges for Cal/EPA in the next five to ten years. More specifically, the break-out group sessions were intended to achieve the following **goals**:

1) to collect participants' ideas regarding possible environmental challenges which may confront Cal/EPA; and

2) to identify the challenges which are perceived by the group to be of greatest concern, based on impact and unexpectedness (i.e., degree of its element of surprise or novelty).

PROCESS

Participants were asked to...
- ☞ prepare and present responses describing future environmental challenges;
- ☞ review responses presented; and,
- ☞ use vote dots to determine group's view of highest impact and most unexpected challenges.

Instructions provided to workshop participants can be found in Appendix C.

The following question was posed to workshop participants:

> Cal/EPA's mission is "to improve environmental quality in order to protect public health, the welfare of our citizens, and California's natural resources."
>
> **Identify a critical event or trend and the resulting challenge it may present for Cal/EPA in the next five to ten years.** Focus on the subject matter assigned to your break-out group. Be prepared to elaborate on how that trend or event and its resulting challenge might occur in the future.
>
> Try to be as specific as possible about the event or trend, and its resulting challenge. For example, it is better to say "continued population growth in California will increase the volume of municipal wastes generated, and consequently increase the need for alternatives to landfill disposal," rather than stating that "California's biggest environmental problem will be population growth." **Please remember that, at this time, we are not looking for proposed solutions to the challenges identified.**

Participants were given some time to formulate a response to the question, and write down their responses on forms called "snowcards" (see Appendix C). One snowcard was used for each response. During the first day of the workshop, participants were asked to think of challenges that focus on the subject area assigned to their group (i.e., those assigned to "Session I," were asked to focus on the environmental impacts of new technologies, and those in Session II, on sources, releases and transformations of chemicals). On the second day, participants were encouraged to identify <u>any</u> future environmental challenges.

Snowcards were posted on the wall, as participants presented and explained their contributions. Snowcards were organized as they were posted, with input from the entire group. General headings for groupings of similar snowcards were noted. At the end of the idea presentation period, the group reviewed the categorization of ideas to determine whether reclassification was necessary.

Some time was allotted for a "pre-voting step," during which participants could review the ideas posted and add their own comments or questions. Participants were encouraged to walk around the room and discuss the posted ideas with others.

Each participant was given six "vote dots" to express their judgment on each of two independent parameters: impact (the power of the event or trend to produce changes in the quality of the environment in a manner that could affect the public health, public welfare, and California's natural resources) and unexpectedness (the element of surprise, or novelty, of the event or trend). **Red dot stickers represent impact votes, and green dot stickers, unexpectedness votes.** Vote dots could be distributed among up to six ideas for each parameter. For each idea, a score was calculated by multiplying the total number of impact vote dots by the total number of unexpectedness dots. The three ideas with the highest scores were presented before the plenary group.

The outcome of voting was used only for purposes of narrowing down the number of ideas presented before the plenary group, and was not intended to represent recommendations to Cal/EPA as high priority challenges.

<u>IDEAS COLLECTED FROM THE BREAK-OUT SESSIONS</u>

Appendix D is a compilation of all the ideas presented by the workshop participants during the break-out session. Participants were also invited to write down their thoughts about future environmental challenges for Cal/EPA on the "Idea Wall" posted in the plenary room. These ideas are also included in Appendix D. A summary of the ideas which received the highest scores from each break-out group can be found in Appendix E. Major themes that emerged from the workshop include those listed below. (OEHHA staff will organize all the ideas collected from the workshop, and apply screening and selection criteria to identify those which appear to warrant further attention. The results of these efforts will be issued as a separate document.)

Unintended consequences and their environmental impacts need to be thoroughly examined. Often, new chemicals and new technologies are introduced without a thorough examination of the potential consequences of their use. Prior to their introduction into the market, the focus of efforts to evaluate these new chemicals and technologies is usually only on the desired purpose or application. New chemicals and new technologies can provide solutions to existing environmental problems, but at least as much attention to their potential to cause harm should be given.

Increasingly complex environmental issues require innovative, collaborative approaches. The environmental issues of today and of the future will require moving away from the traditional command-and-control regulatory model in which jurisdictions are compartmentalized in a number of agencies at different levels of government. New approaches, such as industrial ecology, generational pollution penalties (i.e., where the size of the penalty is based upon the number of generations the pollution is anticipated to affect), results-based environmental management, and others, are available and should be explored as alternatives to existing approaches. Regulatory agencies, working in collaboration with each other, with the industries they regulate, with the public, and with academia need to view environmental challenges with a holistic, multimedia perspective. Communication of environmental information between and among these entities needs to be improved.

Effective environmental protection will require good characterization of the sources of environmental pollution. Efforts will need to be directed toward identifying and characterizing activities, operations and products that produce environmental pollution, in order to formulate effective control measures. Particular attention should be given to unregulated sources such as consumer products, fertilizers, home use pesticides, and even the human body (e.g., drug metabolites in urine)!

The consequences of California's projected population growth will undoubtedly impact environmental quality. The State's population is projected to grow from the current 32 million to almost 35 million by the year 2000, and 41 million by 2010. This growth will be accompanied by economic expansion. There will be increased demands on California's resources, and increased stresses on California's environment. Residential developments will need to built closer to agricultural lands to accommodate the growing population.

While new scientific understanding will improve the outputs of risk assessment, use of the information generated by risk assessments will likely involve more complicated decision-making in risk management. More scientific data will become available to elucidate the mechanisms which mediate toxic responses in humans (e.g., the genetic basis of susceptibility to environmental contaminants; environmental modulators of gene activity; and toxicological interactions in multi-chemical exposures). New tools and data (e.g., for determining the contribution of indoor air exposures to total exposures and for quantifying an individual's exposure levels to an environmental contaminant) will also enable better quantification and characterization of exposures. With more information available about risks, risk management will involve more complex decisions regarding how to control exposures to adequately protect populations (or subpopulations).

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SUMMARY OF OPEN DISCUSSION

Wendy Schultz led the discussion at the end of the workshop. Dr. Schultz expressed the view that all conferences are opportunities for networking, for learning new things, for meeting new people, and for engaging in the cross-fertilization of ideas and developing strategic partnerships. She observed that the theme of collaboration was a dominant one at this workshop, and posed the following questions to the participants: How can we continue the spirit of collaboration created by this workshop? What do Cal/EPA's stakeholders need from the Agency? And what do you think you can contribute to an ongoing collaboration? What sort of activities and information or communication from OEHHA would be helpful to keep this dialogue alive?

Keith Smith (California Integrated Waste Management Board) pointed out that what is needed is to build enduring structures around real, shared issues, so that it becomes part of the way we do business. He suggested that the issues that participants share a common interest in be identified – e.g., data about environmental impact, multimedia issues, or ISO 14000 issues – and "build a structure" around such issues to achieve collaboration. For example, the boards, departments and office in Cal/EPA might identify common areas where they share data, and establish the best data system in Cal/EPA.

Steve Lewis (Exxon) suggested the establishment of a specialty group within the Society for Risk Analysis on emerging environmental issues, or of a new professional society such as a Society of Environmental Futurists to institutionalize the notion of looking forward.

Robert Howd (Office of Environmental Health Hazard Assessment), speaking on behalf of a participant who had to leave, recommended that OEHHA staff select the ten most important issues identified at the workshop, develop a paper explaining the rationale for these choices and capturing other highlights of this workshop, and submit this for publication in an article about the future issues, possibly in the Journal of the Society for Risk Analysis; the paper should also be posted on the Internet. Dr. Howd indicated that the essence of the idea was to take the products of the workshop further as quickly as possible.

Peter Loucks added that instead of "burying" the paper in a professional journal, why not aim for a wider audience by publishing in Newsweek or Time; the subject of emerging issues is one that the public needs to be made aware of.

Bobbie Garcia (California Integrated Waste Management Board) indicated that the Waste Board conducts a lot of public meetings and outreach efforts, and if the intent is to get a broad audience and a large participation to get all views, then Cal/EPA should convene small meetings, not expensive conferences, throughout the state in strategically targeted locations. She further stressed the need to make a conscientious effort to incorporate as many views as possible, and to keep people aware of the information being compiled. As OEHHA goes through different phases of their emerging challenges program, it needs to keep interested parties informed to encourage dialogue.

Susan Knadle (Office of Environmental Health Hazard Assessment) proposed the creation of a publication for distribution to businesses, universities and the public about interactions; given the emphasis in State government or in academia on generating work products, efforts to develop articles for a publication would provide legitimate opportunities to communicate and foster interaction about such topics as the top ten issues in regulation or the top ten issues in research.

Keith Smith (California Integrated Waste Management Board) offered another suggestion, which is to select one issue identified from the workshop that is interesting and that Cal/EPA in particular can do, establish a baseline for where we are today on the issue, commit the resources of this agency, specify a target and an outcome, and work toward moving the benchmark closer to that target or outcome. He noted that this would be the only way to make progress.

Steve Lewis (Exxon) announced that Bill Farland had agreed with his proposal to serve as a "network reprocessors" for Cal/EPA on the East Coast, to disseminate information about the emerging challenges program and to provide suggestions on individuals who should be informed about the program. He requested that an e-mail directory of the workshop participants be made available.

CLOSING REMARKS

JOAN DENTON, Ph.D.
Office of Environmental Health Hazard Assessment

First, I want to thank my OEHHA staff for their work in organizing this workshop: Carmen Milanes, David Morry, Karin Ricker, Tom Parker, David Siegel, Karen Randles, Susan Knadle, David Chan, Arlene Nishimura, Julio Salinas, Laurie Monserrat, Tonya Turner, Sharon Davis, and Ed Evans. One of the reasons for the success of this workshop is the amount of hard work that has gone into it. I would also like to thank the CSUS staff for their assistance.

What are all you doing June 25th and 26th, 2010? Can you check your calendars and see if you're available on those two days? Wouldn't it be an interesting idea for us all to gather in 12 years? We've spent the entire time looking forward, but what if we plan to be here 12 years from now, and we're looking back at the discussions that we had today and yesterday. Maybe you can indulge me in some of the thoughts I have about what the world might be like in 12 years.

We'll all be a little older, but we won't be grayer because there will be a new cream that was discovered that maintains your hair color. And we'll be able to get rid of those ten pesky pounds that we've been carrying around since Christmas because we've just discovered a new pill which alters our taste buds to crave carrots and broccoli, and shun things like potato chips, ice cream and large servings of pasta. We'll all be wearing a small skin patch which will keep our muscles fully toned, no need to exercise.

And so we fast-forward and we look at what has happened in the environment in the last 12 years. What if we're able to say, Joan cited projections that California will have 42 million people by 2010, and that, in fact, happened. What didn't happen was the gridlock that was anticipated to accompany population growth, and there are all kinds of reasons that we could speculate about to explain this. Maybe there was a new virus which made people allergic to driving by themselves. Hopefully not, but what if we're able to say that gridlock did not materialize? Or yes, people are living longer, but we're not detecting pharmaceuticals in water because these new pharmaceuticals were developed in the early years, 2005 or so, which were automatically metabolized into water and oxygen. Or the siting of industrial facilities became so popular, that lotteries were held to determine what communities they would be sited in? I think all of these kinds of scenarios sound unbelievable. But could we have imagined 10 or 15 years ago, or even in a previous generation, that more people now are fed on less acreage? There are definitely more people, yet there are fewer acres under agricultural cultivation and more food in the United States than ever. In fact, over 50 percent of Americans are obese. In California, we have more cars now than ever; 24 million automobiles are out on the road, but we have the cleanest air recorded in California's history. Ten, 15, or 20 years ago, would that have made sense to us -- that we would have more people, more cars, and yet we have the cleanest air ever recorded in California's history? Today, there are more forest lands in California than there were ten years ago. And some individuals are working on the idea and the goal of returning California's natural forests and fisheries to the level found in the 1800s, and there is a possibility that this will be accomplished.

The point that I'm trying to make is one that I want to emphasize at the very end of this workshop: human ingenuity, the ability to solve problems, is our greatest asset. We often underestimate ourselves in that regard. Surprises, environmental challenges and problems will occur, and things that we cannot foresee now will occur over the next 10 to 12 years. We live in a can-do state, in a can-do country, where all things are possible.

I'd like to close by saying that this workshop has brought together a unique group of individuals for a very unique topic. Each of us -- whether we're in government, whether we're in industry, whether we're in environmental groups, whether we serve as consultants -- has a responsibility in whatever role that we play to pass along a greater environmental future to the next generation. That is possible and it is doable. So see you in 2010.

Thank you very much.