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EDITORIAL

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Hurricane Katrina rekindles thoughts about fallacies of a so-called "natural" disaster

Introduction

My brother recently reminded me that thirty years ago I wrote an article about drought in West Africa. I called it "Nine Fallacies of a Natural Disaster" (Glantz, 1976). In light of the impacts of Hurricane Katrina on the Gulf Coast states, he proposed that I revisit these fallacies. For the record, a fallacy is a plausible but unsound reasoning that some people may think is true, but for the most part is either not true at all or is partly true only in certain circumstances.

Until Katrina and the ensuing cascade of negative impacts struck, it had not crossed my mind to look at other disasters in terms of fallacies. Also, I am not a hurricane expert. However, like millions of American citizens following the plight of victims of Katrina and the crumbling levees, I have been glued to newscasts about the horrifying situation. In fact, I have had many discussions about it with coffee salespeople at the local Starbucks, cashiers in supermarkets, clerks in computer stores, and numerous others. The disaster in New Orleans and along the Gulf Coast of Mississippi and Alabama — and now the abysmal government response to it is on everyone's mind. It is THE ultimate reality show.

Taking my brother's advice, I did some thinking about what fallacies have reappeared in Hurricane Katrina's wake. Here is my list, followed by a brief discussion of each item.

Fallacies

1. Poor people want to live in dangerous places
2. Technology is the answer (but what was the question?)
3. All's well that ends well
4. Education is the answer
5. Forewarned is forearmed
6. People learn from their mistakes
7. Global warming has nothing to do with disasters
8. The Third World is more vulnerable to hazards than the rich countries
9. Government leaders say what they mean and mean what they say
10. America does not need help from other countries to cope with its disasters
11. The impacts associated with Hurricane Katrina were the result of a natural disaster

Fallacies Discussed

1. Poor people choose to live in dangerous places

People live in places at elevated risk of natural hazards for a variety of reasons, many beyond their personal control. Some individuals do it because of the surrounding vistas. These people, generally speaking, have funds to rebuild if their property is damaged. They also have the wherewithal to "get out of town in a hurry" in the event of untoward circumstances. We all saw on the television news the lines of cars and trucks leaving New Orleans the day before the hurricane was due to arrive. However, many of the city's residents could not leave: No cash in hand, no access to cash, no money for gasoline, no way to move possessions, nowhere to go, and so forth. Complicating the responses of those who were at-risk, there had been several recent hurricane warnings and close calls (such as Hurricane Georges in 1998). For a while before Katrina struck, there was uncertainty as to the exact location of landfall, and the impacts were not expected to be very threatening. So, many "stayed the course" to a tragic end. The combination of psychological, financial, and political factors—together with a direct hurricane hit, the breakdown of the levees, and the subsequent cascade of disasters underscored the vulnerabilities of the poor, the elderly, children, and racial minorities. It also underscored the importance of educating people about the range of local hazards that they may face. Many of the at-risk people living along the Gulf Coast do not choose to live in harm's way; they are forced to by circumstances they cannot control.

2. Technology is the answer

Americans in general (myself included) tend to have a blind faith in technology. We believe that a hightech solution can be found to save us from any problem. And, to date, technology has frequently come to the rescue. Often, however, technological fixes are used as band-aids, as temporary solutions to chronic underlying problems. They do not erase the problems, but rather circumvent them—at least for a while. A famous economist once suggested that technology actually helps to increase the total amount of misery because when problems eventually reappear, there are more people around to be harmed.

Now, I tend to believe that technology is neutral. What determines whether it is a positive or a negative tool is how, and whether, it is used effectively. As we are seeing, once the emergency response phase to Hurricane Katrina ended and reconstruction began, debates ensued about whether the levees should have been reinforced according to plans that were not only on the table, but already being undertaken. Clearly, the need to shore up the levees had been recognized at all government levels, local to national. The citizens in the Gulf States elected their official representatives and had the right to expect them to operate in society’s best interest. Nevertheless, an available, effective technological solution to the flooding expected to accompany a Category Five hurricane was not used. The funds that the U.S. Congress had authorized to improve the levees had not been made available. Technology may prove to be the answer, but one must ask, “What is the question?” Should that question be about decision-making related to the use of technology?

3. All’s well that ends well

Different perceptions had already appeared within the first few weeks of Katrina and its associated aftermath. Some official statements were chosen to put a positive spin on the government’s hesitant response to thousands of victims’ immediate needs. The government initially suggested it did the right things, given the uniqueness of the event, the lack of expectation of flooding, and the severity of the cascade of impacts. Government spin doctors have claimed that the number of people affected was surprising, as well as unexpected, that the actual strength of the storm was not forecast, that National Guard units were dispatched as fast as possible, and that neither state nor city officials had asked for assistance.

Toward the end of the first week, after Katrina had made landfall, it seemed that the Federal government was starting to respond effectively. Evacuation from the convention center and the football stadium was in progress, to some extent. Deliveries of food and water were increasing. The National Guard and regular Army units were policing the streets. People were being airlifted to cities around the country and receiving care. So, it seems that all is ending well. But how did we get here?

The response was poor prior to landfall. The response was poor during the hurricane. The response was sluggishly slow during the first days afterward. At least a thousand people are dead. Hundreds of thousands are homeless and penniless. Families have been devastated. People were still being plucked off of rooftops after several days. Why so sluggish? For survivors, perhaps “all’s well that ends well” are comforting words. Not so, though, for those who suffered or died in the earlier days, when quick responses from the President, the Secretary of Homeland Security, and the head of the Federal Emergency Management Agency might have alleviated the death, destruction and misery.

While the adage “all’s well that ends well” sounds comforting, it suggests another problematic adage—that the ends justify the means.

4. Education is the answer

Educating the public is a very important and a very difficult task. This is true whether you are talking about K-12 kids, college students, older citizens enrolled in over fifty learning activities, or the general public. For some reason, it seems especially hard to teach people about the specific aspects of hazards that they might someday face. However, education is not a process that ends when you reach a certain grade or age, or attain a certificate or degree. It is a life-long learning process, which means that it requires repetition, as well as additional education on issues about which new information becomes available. It is not just an intergenerational problem. It is a problem that can also be addressed by passing on knowledge—in this case disaster-related—within today’s generations. Continual reminders are needed of the risks people live with at the local level. Following Hurricane Camille in 1969, the National Oceanic and Atmospheric Administration printed brochures about how to prepare for hurricanes. These are just the tip of the proverbial iceberg of more than a century of warnings and educational material about coping with hurricanes along the Atlantic and Gulf coasts.

5. Forewarned is forearmed

“Forewarned is forearmed,” an old adage that speaks well to early warnings and to knowledge in general. It is based on the popular belief that more information about the future enables at least partial preparation.

The projections and speculation about Hurricane Katrina’s category, landfall location, and potential damage were, in essence, forewarnings. However, those with the power to encourage or force people to move out of harm’s way did not heed them. Warnings are not enough. Actions must take place in response to them. A reliable forecast of a hurricane’s strength and trajectory is only one part of a more encompassing warning system, which also encompasses the effective use of that forecast to take appropriate responses to the hazard that has been forecast.

6. People learn from their mistakes

That people learn from their mistakes is generally accepted as a truism supported by the saying, “Once burned. Twice shy.” Unfortunately, all too many disaster response examples from different countries, cultures, and times suggest that lessons are indeed identified, but not necessarily learned. By learned I mean that the lessons would have to influence future behavior in some significant way. With regard to disasters, the public, as well as disaster experts, identifies problems encountered from warning to reconstruction that hinder effective response, and draw up plans to overcome them. However, reviews of the reconstruction phases that follow major disasters show that many of the lessons that had been identified and acknowledged remained unapplied. Any one of a variety of reasons—excuses really—from political to economic to cultural, are used to explain why known solutions to expectable, recurrent hazards have not been implemented. The bottom line message is that while people and societies sometimes do learn from their disaster-related mistakes, often they do not.

We must not assume that people will automatically do the right thing by learning from their own experience or that of others who had faced similar situations elsewhere or in earlier times. People have to be encouraged to apply the requisite lessons. We have to break the cycle of denial, as people seek to get back to a semblance of normal, when it was "normal" that had put them in harm's way in the first place.

7. Global warming has nothing to do with disasters

Some researchers believe that the frequency, as well as the magnitude, of climate and weather-related extreme events will increase as a result of the warming of the earth's atmosphere. Others suggest that there is no definitive proof. They argue that records are being set every year, and that we are to expect such extreme blockbuster episodes even under normal climate conditions. Climate varies from seasons to years and decades and centuries and so on. Systematic observations over long time periods are hard to come by. Scientific uncertainties notwithstanding, mounting evidence suggests that stronger extremes are linked to a warmer atmosphere. Whether these deadly extremes, like Hurricane Katrina, are the result of natural variability or human-induced changes to the atmosphere's chemistry provides little comfort to the victims. In either case the "precautionary principle," as well as the historical hurricane record, needs to be taken into account.

Large computer models have produced many climate change scenarios for the year 2050. They are suggestive and illustrative, but not definitive. Researchers on social issues are then expected to determine how best society might prepare for and react to such an eventuality. However, Hurricane Katrina—and Ivan, Georges, Mitch and Andrew—have underscored the fact that societies are not well prepared to cope with climate, weather, and water extremes under present conditions. In this regard, improvements in the way we deal with contemporary hazards and disasters can help to prepare future generations.

Bill McKibben (2005) recently wrote in *Grist Magazine* that,

> [N]o single hurricane is 'the result' of global warming , but a month before Katrina hit, MIT hurricane specialist Kerry Emanuel published a landmark paper in the British science magazine Nature showing that tropical storms were now lasting half again as long and spinning winds 50% more powerful than just a few decades before. The only plausible cause: the ever-warmer tropical seas on which these storms thrive.

8. The Third World is more vulnerable to hazards than the rich countries

A prevailing view among climate scientists and policy people (both those who believe in global warming and those who do not) has been that developing countries are more vulnerable to climate change impacts than are the industrialized countries. I continue to believe that this belief is unrealistic. I think it relates more to the self-deception of people in rich countries who are surrounded by technologies that they think can protect them, technologies that those in developing countries can only dream about.

We have watched from a distance as superstorms of one kind or another have impacted societies in developing countries. A recent geophysical event (not weather-related) was the December 26, 2004 killer tsunami in the Indian Ocean, when hundreds of thousands perished. Another was Hurricane Mitch in late 1998, with over 17,000 dead. Yet another was the 1999 SuperCyclone in Orissa, India, with 20,000 dead. Super Typhoon Maemi hit South Korea in 2003. The number of blockbuster, record-setting, killer natural disasters seems to be increasing since the late 1980s, including tropical storms, winter storms, fires, and the biggest most damaging El Niño event of the century in 1997-98.

In most of these cases we have watched on television or viewed in newspapers poor people in great numbers sifting through the debris that was once their homes for anything that they could salvage. A sad difference between poor and rich countries is that people in poor countries are accustomed to adversities and are often left on their own to cope with the devastating deadly impacts of natural and other disasters. In the rich countries, however, people expect, and usually get, help from their governments because they have resources and money that many poorer countries do not have. Rich countries, however, have much lower thresholds of tolerance for inconvenience.

This argument about the relative vulnerability of rich versus poor countries has been difficult to prove—until now. Hurricane Katrina in late August 2005 slammed into the Gulf of Mexico coasts of Louisiana, Mississippi, and Alabama and exposed just how vulnerable all societies are, regardless of their level of technological development.

9. Government leaders say what they mean, and mean what they say

It is not possible, when forecasting, as well as when coping with, disasters and their aftermaths to get through the entire early warning process perfectly. It is inevitable that some part of the disaster early warning system will fail, and those in charge will attract blame. Even if some of that blame is not deserved, it is probable that some of it will be. Nevertheless, those in power will unleash what are called "spin doctors" to put a positive light on the entire process, from hazard forecast, to the response, to its impacts, to reconstruction. Platitudes invariably abound about the fantastic job done by governments at all levels. However, close scrutiny reveals half-truths, cover-ups, attacks on critics of the disaster response.

In the case of Hurricane Katrina it remains to be seen if the Federal government follows through on its various pledges to help the victims, rebuild the cities, and protect them from future disasters. Meanwhile, the spin doctors have praised the government for its "quick response to the victims needs" although public surveys indicate that few members of the general public believe those claims. The battle that has been playing out in reviews and reports from, and about, the relevant government agencies from local to national is between "disaster management" and "disastrous management."

10. America does not need help to cope with its disasters

In my lifetime, America has always been a superpower, and has acted as such. It had been one of the political poles in a bipolar world, opposing the Soviet Union. We were the leaders, often with troops, in foreign conflicts. Representing the West, the United States had dominated the workings of the United Nations General Assembly and the Security Council, often (though not always) a leader in calling for aid to victims. It offered food aid to Cuba, considered a major political enemy, during recent drought-related severe food shortages.

I had never imagined, based on the past few decades of dealing with various types of disasters, that I would see such a dire situation in the United States following a natural disaster. Several countries—including Cuba and Venezuela which the United States consider unfriendly—offered assistance, especially during the first few days following the hurricane's landfall. To me it was at first embarrassing that foreign governments, even governments of developing countries, would feel the need to offer whatever disaster assistance they could afford to one of the seemingly strongest and wealthiest nations on earth. But they did, and sadly their offers of assistance were really essential in the initial week following Katrina.

11. The impacts associated with Hurricane Katrina were the result of a natural disaster

Hurricane Katrina reached Category Five status at or about the time it made landfall in Louisiana, Mississippi, and Alabama. It was called a massive hurricane, a top-strength storm, an incredibly strong storm, and a superstorm. Such a natural hazard was sure to have brought about some level of death and destruction. However, the damage from this event was much higher than even the experts expected. Much of the reason for extreme levels of death, destruction, and human misery rests with society's contribution to the adverse impacts of the naturally occurring hurricane. The poor, for example, often live in high-risk locations relative to likely natural hazards. The levees in the New Orleans area were known to be in need of urgent repair, as well as upgrading. The impacts of a Category Five hurricane hitting New Orleans specifically had been projected in many scenarios over the years. This event was foreseeable. In fact, there had been several near hits in the past few decades, raising the question about which of the deadly horrendous impacts of this "natural" disaster should be blamed on nature, and which on societal—especially political—decision making. To be sure, there will be considerable discussion for the next several years, finger pointing and blame, as well as spin doctoring and claims of success, but in America there is a popular political expression that the "buck stops at the US President's desk."

Concluding Comments

In sum, the reason for pointing out what I consider to be fallacies or misconceptions is that even if such views are proven to be incorrect, the actions taken by individuals and governments based on those views will be real and will have real consequences. When it comes to disasters, people have to be careful about making sweeping generalizations, because they will not necessarily be evaluated for their validity. Myths of all kinds, like unfounded rumors, are very misleading and can have dangerous long-lasting consequences for societies, as well as for the victims of natural hazard-related disasters in the distant, as well as near-term, future.

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About the Author

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ARTICLE

Obstacles to and potentials of the societal implementation of sustainable development: a comparative analysis of two case studies

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Currently, a growing societal awareness of problems in the context of unsustainable development meets with conflicts of interest, and the actual implementation of sustainability research, and sustainable innovations and technologies, has only been mildly successful. Sustainable development demands nothing less than a radical change in our modes of consumption, production, technology, and decision-making. We have investigated the obstacles to and potentials of such a change in two representative case studies, one focusing on the role of sustainability research within science, the other on the energy-efficient refurbishment of old buildings. A short presentation of the methodological approaches, and the respective results, is followed by a comparative systemic analysis of the two fields of investigation. Finally, we discuss possible implications of the discovered systemic comparisons for societal transition processes.

KEYWORDS*:* sustainable development, case studies, social responsibility, environmental awareness, social attitudes, conflict of interests, decision making, appropriate technology, innovations, energy efficiency, research, social change

Introduction

Sustainable development demands nothing less than a radical change in our current modes of consumption, production, technology, and decision-making (Rammel, 2003). On the one hand, this demand for a sustainable transition is based on growing societal awareness[1] and on the considerable support of NGOs, governments, and the business community, and moreover is corroborated by an increasing body of literature and data in the field of sustainability research. On the other hand, the actual implementation of sustainability research, sustainable innovations, and technologies is frequently characterised by lack of interest and minor success. Compared to the claimed urgency of appropriate and radical changes, the overall transition towards ecologically and socially sound societies is alarmingly slow. In particular, the pace at which green technologies and sustainable innovations are being implemented reveals a present need for well-aimed action in a field of complex interdependencies across various social dimensions and fields of practice.

As an attempt to analyse the barriers and potentials inherent in such processes of societal transition towards sustainability, the following article focuses upon the results of a series of research projects undertaken in Austria 1999-2004 by an interdisciplinary research group[2]

[1] The article uses the term "societal", like "gesellschaftlich" in German, to refer to a certain society or social system, whereas it uses "social," like the German "sozial", to refer to the social dimension (additive to the ecological and economic dimension in the context of sustainable development) of a given system.

[2] Co-ordination: Roland Albert (bio-ecology), Fritz Schiemer (limnology), Peter Weish (human ecology); core team: Michaela Egger-Steiner (sociology), Karen Kastenhofer (bio-ecology), Christian Rammel (ecological economics); together with: Anja Götz (psychology), Christoph Hahn

sponsored by the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management (Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, BMLFUW). The assumption underlying the following discussion is that the potential for change through singular and one-dimensional approaches is insufficient and too narrow. Hence, this article draws a wider scope, taking the specific systemic contexts relevant to the problem in their multidimensional and complex identity into account. Only in a second step, and after an in-depth analysis, can the systemic perspective be reduced to a model open to further and carefully directed interpretation. In this way, hindrances relating to attributes of the complex systems structure are taken into account, hindrances that would otherwise suffer from a reductionist approach.

We chose two very different contexts for our two comparative case studies, to give an example of the variety of problems the implementation of sustainable development may encounter. Nevertheless, the two cases share a presently perceived unsustainable state, resistance to direct control due to complex interdependencies, and a perceived need for steering intervention, or, in other words, for governance. We will try to represent the heuristic benefit of such a comparative view in the last section of this paper.

Choosing a systemic view

Societal problems in the context of reduced sustainability can be characterised by the following aspects:

- They are caused by a combination of effects of actions undertaken on diverse societal levels.
- Those who suffer from the subsequent negative impacts often differ from those causing them.
- Information, communication, and awareness play a crucial role in possible participatory solutions.
- Win-win-solutions are limited: There is no pre-defined absolute optimum to be aimed at, but only procedural compromises between different interest groups who share some of the normative guidelines.
- Ecological, economic, and social subsystems, as well as multi-dimensional ones, have to be taken into account.

A variety of players and actions, the fragmentation of interests, decision processes, power and responsibility, interactions on local, regional, national and global levels, the complex cause-effect relations, and other prominent aspects in the field of sustainable development call for integration on a wider scope, i.e., a complex-systemic analytical approach. Such an approach would draw attention to the specific characteristics of complex systems: a multiplicity of legitimate perspectives, non-linearity, emergence, self-organisation, multiplicity of scales, and irreducible uncertainty (Gallopín, 2001).

Looking at a particular complex-systemic case from a scientific viewpoint raises the following introductory question: How can a possible system model be developed, a model which is still complex enough to show the critical players, interrelations, and structures, and which at the same time has enough explanatory power to lead to helpful conclusions?

In reacting to this challenging situation, we have chosen a comparatively open approach, similar to sociological methodology. We have concentrated on two additive case studies, one on sustainability research within the science system, the other on the reduction of CO_2-emissions caused by the energy-efficient refurbishment of urban buildings. The common point of departure is the formulated problem situation, namely conceivable and socially undesired environmental degradation, lower life quality, social imbalance, and a failing attempt to contribute to the problems' reduction. The formulated goal of the research series is to look for ecologically, as well as socially sound, possibilities to deal with these problem situations and contribute to sustainable societal transitions.

The resulting projects differ from traditional scientific research, as the research question has been raised not by the scientific enterprise of cumulative knowledge production, but by public concern. Furthermore, the fields of interest have not been defined beforehand, but are open to subsequent discussion so as to fulfil the specific need to clarify, and help to solve, the given problem. Accordingly, the research projects are not restricted by any disciplinary boundaries, but rather undertaken by an interdisciplinary team in close interaction with experts from various practical fields. In this article, two exemplary case studies are briefly presented. Their results are discussed in a comparative approach, and their relevance for the broader context of sustainability research and policy is highlighted in the concluding remarks.

Case study I: Sustainability research in Austria

Case study I focuses on a specific societal subsystem involved in the process of sustainable development, i.e., scientific research and education in Austria (Egger-Steiner et al., 2002).

Objectives

An increasing societal and political awareness of problems caused by unsustainable situations in our present society has led to intensified scientific research and education. Specific research programmes and funding schemes have fostered sustainability research on both national and international scientific levels. Much has been said and done under the label of 'sustainability research' during the last decade. Nevertheless, attempts to estimate the overall efficiency of these science-based efforts have left us with some doubt as to their success in triggering a socio-economic transition towards sustainability that would meet the currently estimated necessity for change.

On the one hand, this shortcoming can be explained by a lack of societal awareness and interest in scientific results (an assumption addressed in case study II); on the other hand it can be interpreted as a failure of the scientific community to take a leading role in the process of sustainable development.

Case study I deals with this second assumption, which has already been discussed on a broad theoretical basis in science research for inter- and transdisciplinary

(vegetation ecology), Astrid Kuffner (environmental economics), Markus Staudinger (biology).

science (Funtowicz & Ravetz, 1993; Gibbons, 1994; Häberli & Grossenbacher-Mansuy, 1998).

Basically, three modes of explanation for the hermetic failure of science are conceivable (Kastenhofer, 2002):

(a) The scientific system fails to communicate its results successfully to societal players (decision makers, stakeholders, consumers, etc.). A possible solution to the problem can be achieved by a better presentation of scientific results to the public by making use of the education system and mass media.
(b) Despite the high *quantity* of sustainability research, there still is a lack of a *qualitative* scientific grounding, which results in a lack of scientific understanding of crucial points of intersection in the complex factor pattern of sustainable development. Building on a traditional approach, additional research projects on disciplinary and interdisciplinary bases are called for.
(c) The prevailing paradigms of classical scientific analysis are *generally* not apt for an understanding of the overall causal relations of societal sustainability and the formulation of suitable steering processes. This interpretation result calls for transdisciplinary research and post-normal science.

Research area and methods

In case study I, an investigation on Austrian universities and extra-university research institutes was conducted (see chapter 7 of this research report for further details). The aim was to obtain a general view of the quantity, quality, and dissemination of sustainability research within the public sector.

In a first step, a nationwide survey identified relevant institutions and scientists engaged in sustainability research. A short questionnaire was sent to all heads of public scientific institutes (n = 1093, response: n = 311).[3] It inquired about the involvement of the respective institution in sustainability research and/or education, and about relevant players within this institution.

In a second step, a detailed questionnaire, addressed to the mentioned players, raised a wide range of questions about the quantity and quality of the researchers' involvement in sustainability research and education, and about their perceived obstacles and potentials (n = 832; response: n = 246).[4]

In a third step, the results of this survey were presented to the scientific community during a one-day workshop, which was also open for individual reactions and for plenary discussions on the central findings, especially between well-established scientists (primary orientation mostly disciplinary) and 'new-comers' (primary orientation often transdisciplinary).

An integrative analysis of all three steps resulted in a concluding report compiled by the interdisciplinary research team. Herein, additional in-depth interviews with selected experts helped to clarify some specific questions raised throughout the process.

Results

The results of step two (detailed questionnaires, n = 246) can be roughly summarised as follows:

- The survey results (step 1) show a dominance of techno-science in sustainability-labelled projects: 34% of the involved scientists come from the technical sciences and 26% from natural sciences. Only 14% hold a degree in economics, 12% in social sciences, 7% in the Arts, 2% in law, and 1% in medicine.
- Most researchers started with sustainability research in 1995 (12%), others between 1990 and 1992 (20%), in 1985 (6%), and in 1980 (5%), respectively.
- The assumed relative importance of the topic ranks highest in the technical sciences, followed by economics and the social sciences, lower in the natural sciences and the science of art, lowest in law, medicine, the humanities and theology.[5] It is more important for the individual scientists than for the institutions they work for (mentioned most often: financial and researchers' share per institute lower than 50%). This is true especially for university institutes, while several institutions specialising in sustainability research are to be found on an extra-university level (covering an overall share of 4%).
- The individual motivations of scientists to work in sustainability research can be divided into 3 clusters of similar size: topic-centred, ethically oriented or player- and network-oriented. Percentages of relative working time range mostly between 20% and 80%.
- The theoretical definition of sustainability is most frequently built upon the "three pillar model," emphasising the equal shares of ecological, economic and social factors. In practice, such a joint definition is not seen as central. Moreover, it is not totally reflected by a corresponding interdisciplinary setting of the undertaken research and education projects (only 26% of the mentioned sustainability projects integrate all three spheres, while 41% integrate two of the three aspects).
- Interdisciplinary communication occurs most frequently between technical and natural sciences, as well as between economics and social science. Least often, cooperation with the arts, law and medicine are mentioned, although the interest in cooperating with the other sciences is equally high.

[3] All research institutes (including natural, technical and social sciences, arts, humanities, medicine and law) were addressed. The short questionnaire was not very time-consuming for the interviewees and responses came mostly from departments active in sustainability research. With a response rate of 28%, response bias is presumably limited, with non-response mostly due to the specific institute being inactive in sustainability research. Random tests support this assumption.

[4] The detailed questionnaire covered 19 pages and required between 30 and 90 minutes to complete (according to the interviewees' accounts). A response rate of 30% may result in a response bias, while causes for non-response are unclear (though a lack of time is to be presumed in most cases). Quantitative representativity and qualitative completeness of the resulting data can be questioned to a certain degree. Nevertheless, the response rate is relatively high and the gathered detailed material overall satisfying.

[5] The survey follows the structure of the Austrian university system in 2001, comparable to German structures and differing from Anglo-American specifications in some points (especially in the Austrian labelling of the Arts and Humanities as 'Wissenschaften', i.e., 'sciences').

- The main focus of the mentioned research projects lies in limited natural resources (especially technical and natural sciences), followed by acceptance and diffusion (especially social sciences and interdisciplinary research), and implementation and operationalisation (technical sciences and interdisciplinary research).
- Sustainability research is mostly financed by national ministries, the European Community (EC) and national research funds. Self-financing by the institutions' basic public income is only mentioned in fifth place, funding by industry in sixth place.
- Transdisciplinary cooperation throughout research projects focuses on the communal level, NGO's, and private enterprises.
- The major effects of sustainability research on the scientific system can be defined as: interdisciplinary cooperation, the development of new qualification profiles for scientists, critical reflection upon one's own discipline, improved cooperation with clients from outside the scientific system (funding institutions, target groups), and the blurring of disciplinary boundaries. Negative impact is mentioned for the scientists' disciplinary affiliation and careers, and the chances to attract high level investments.
- Major obstacles to sustainability research are defined as:[6] low financial support (68%), differing priorities (63%), lack of interdisciplinary cooperation (50%), lack of publicity (47%), and a diffuse understanding of the term 'sustainability' (42%). Considerable pro *and* contra votes were given for lacking cooperation between research institutes (37% pro, 37% contra) and work overload (36% pro, 36% contra) as the causes. Lack of a common language and mutual understanding (32% pro, 38% contra), a scientific community for sustainability research (29% pro, 43% contra) and political steering (23% pro, 43% contra) were also considered to be relevant obstacles to sustainability research.
- With regard to the qualitative shortcomings of present sustainability research, the following areas were seen as lacking: holistic thinking and integrative solutions, inter- and trans-disciplinary cooperation, societal and political implementation of knowledge about natural systems, and the effects of interference. Other shortcomings were the lack of a methodological basis, precise indicators and criteria for sustainable development, the lack of relevance for the fields of practice, and the outsider position of sustainability research within the scientific community.
- Major obstacles to the societal implementation of sustainable development are seen in the economic growth paradigm, present price signals, the political framework, and the lack of empowerment of affected parties. Societal awareness, individual preferences, knowledge, public information and media coverage are also mentioned as areas of likely interference with the science system, but ranked considerably lower. Hence, the scientists themselves see major obstacles to change in essentially extra-scientific domains.

Conclusions

Beside the overall effect that societal awareness is only partially translated into motivation for action and change, as it has to compete with other and conflicting individual and societal aims, sustainability research struggles with structural barriers that are specific to the scientific (sub-)system itself. Research on sustainable development relies on the crossing of boundaries between the disciplines, as well as those between science and society. A mutual motivation for cooperation, mutual awareness of the restricted contribution of single disciplines to the problem solution, as well as a mutual ability to cooperate and communicate successfully across these boundaries, are necessary preconditions. So far, the corresponding time-consuming and personally challenging processes have drawn their motivation from the awareness of the general need for a societal shift towards sustainability alone. Furthermore, they have to compete with the traditional, mono-disciplinary approach for funding and for their status in individual scientists' careers. Science and scientists are trapped in an either/or-situation, which results in strengthening the boundaries between traditional and post-normal science rather than in fostering joint action.

Case study II: Energy-efficient refurbishment of old urban buildings

Case study II takes an even broader view: It is meant to analyse the relevant societal sub-system(s) involved in the implementation of sustainable development in the case of the energy-efficient refurbishment of old buildings (Egger-Steiner et al., 2003a; Egger-Steiner et al., 2003b). Existing obstacles and potentials are examined, and possible strategies discussed.

Objectives

The development and diffusion of sustainable innovations strongly depend on societal priorities and are particularly sensitive to the political and economic framework. Counterproductive interests and badly-directed/aimed incentives can be seen as selective filters in the process of sustainable development. They characterise an obvious deficit in the interactions between sustainability-oriented science and societal players.

Referring to this deficit, the Forum of Austrian Scientists for Environmental Protection (Forum Österreichischer Wissenschafter für Umweltschutz) was commissioned by the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW) to analyse socio-economic barriers to the communication and implementation of sustainability. In detail, the analytical focus of this project was on energy efficiency in the context of refurbishing old buildings. Its objective was to highlight the current barriers and chances for the market launch and implementation of energy-efficient refurbishment. Additionally, the links to

[6] multiple choice questions

general aspects of sustainable development were emphasized.

Research area

The energy-efficient refurbishment of old buildings is one of the major fields where energy-efficient technologies are applied to reduce unsustainable dependency on fossil energy, as well as unsustainable emissions of greenhouse gases. Leutgöb et al. (2001) emphasize that the energy-efficient refurbishment of old buildings is one of the most important strategies for fulfilling the objectives of the Kyoto-Protocol, with an overall potential to achieve one-third of the Austrian share of the desired CO_2-reduction. Consequently, its implementation plays a major role in all policies aimed against climate change and is of high importance to the national strategy of sustainable development. About 60% of the total energy consumption in Austria takes place in the area of residential buildings and in the service sector; of this 60%, 80% is allocated to residential housing. Overall, 80% of the energy in Austrian households is used for heating (Leutgöb et al., 2002).

Methods

Increasing the share of energy-efficient buildings in Austria is an accepted aim of our national environmental policy. As the factors in question for steering interventions reflect a wide spectrum, from legal requirements over individual criteria of living comfort to efforts of maximisation in business management, a diversified and gradual methodological approach was chosen. An integrative and interactive scenario-workshop (Weinbrenner & Retzmann, 1998) represents the central methodological instrument of the case study.

In this workshop the participants – chosen from all pre-defined areas related to the energy-efficient refurbishment of old buildings – discussed the interdependencies and crucial interfaces, from technological and institutional innovations (heat isolation, contracting, etc.) up to their actual implementation (from installation to everyday operation). Possible future scenarios, worst case as well as best case, were developed in mixed working groups.

In summary, the scenario-workshop technique has shown a strong capacity to integrate the relevant key players and interfaces of the implementation process in terms of highlighting the wide spectrum of insider knowledge, their respective points of view, and the individual interests of the players concerned. Additionally, the workshop supported a dynamic learning process in the addressed field, thus fostering communication far beyond the workshop period.

Results

Pre-workshop investigations (including interviews with experts in the fields of practice and various feedback loops) led to a systemic model of the relevant player-fields and their modes of interaction. With regard to the scenario-technique, they can be divided into four spheres of influence characterised by three major variables each: technology (quality of products, potentials of production, costs of production), supply (integrative planning, know-how, flexibility), demand (user groups, degree and quality of information, financing) and political steering (legal framework, national housing programs, environmental policy). For each variable, both a qualitative and a quantitative descriptor have been formulated, yielding a list of 24 descriptors (e.g., for demand/information: 'information available to user-groups' and 'actual criteria for decisions made by user-groups').

During the scenario-workshop, this descriptive model, agreed upon in advance by all 19 participants, was elaborated. The result is a factor-matrix displaying the 12 variables, and the estimated impacts exercised on and caused by each variable, in relation to all other variables in a quantified mode (assigning 0, 1, 2 or 3, depending on strength of impact). The matrix allows us to calculate the sums of the passive and active involvement of each variable, indicating active, reactive, buffering or critical roles within the system (see Figure 2).

These findings were integrated into both best- and worst-case scenarios, and later on by the options to all players involved, both formulated by the experts invited to the workshop. Additionally, all discussions between the various experts arising throughout the workshop were recorded and considered in the final analysis of the workshop results.

Conclusions

The problems of a successful implementation of the energy-efficient refurbishment of old urban buildings reflect to a high degree the crucial aspects of the current barriers to initiating and guiding sustainable socio-economic transitions. Particular aspects are:

- The deficit of information and communication between the particular stakeholders across the different levels of decision-making and implementation processes.
- The dominance of short-term economic optimisation, with a tendency to support cost-efficient processes characterised by minimum transaction costs.
- The existence of routines blocking innovations.
- The lack of a participative integration of all relevant players and respective fields of action.
- The confusion of responsibilities and the incoherence of legal guidelines.
- The complexity of a process that is highly dependent on socio-economic, institutional, and political dynamics.

Referring to the previous aspects, the following options are open to national politics and public administration:

- Legal requirements should establish a clear framework.
- Well-directed subsidies help to enhance innovative pioneers and examples of best practice.
- Systemic intervention helps to make use of possible synergies.
- Clear, long-term, and reliable political statements improve future planning options and increase societal support of sustainable development.

- A gradual, anticipatory and integrative process supports the involved players in taking immediate actions towards sustainability.

Systemic integration of the two case studies and their interpretation in a wide societal context

The use of exemplary case studies as a methodological approach towards the analysis of general problem situations became increasingly popular in the last decades of transdisciplinary research in general, and sustainability research in particular. The underlying assumption is that general patterns of system behaviour can only be identified by taking a closer look at specific, localised processes. The studied case serves as a meeting point of theoretical concepts and practical experience. A growing body of knowledge and insight drawing on this interaction-oriented and experience-grounded method confirms its value for our understanding of society and sustainability.

On the other hand, inter- and transdisciplinary research is confronted with constraints additional to those of traditional scientific enterprises (Abel, 1998). As sustainability research is mostly oriented towards public goods and public welfare, financial support by the private industrial sector is scarce. Since sustainability research is a cross-disciplinary science with low chances for institutionalisation within the traditional science system, there is no regular public funding to rely on. Research projects are planned in a context of limited resources and high procedural demands. As they are based upon the close cooperation of scientists from different disciplines, and a successful interaction between science and other societal fields, and as sustainability research is to a great extent unable to retreat into a neutral and interest-free sphere of objectified knowledge, but rather confronted with complex, normative questions, the estimated workload and working time are frequently exceeded during the research process (Kastenhofer et al., 2003). Moreover, throughout a period of intensifying contact between the researchers and their fields of research, the former tend to loosen their grip on the 'big questions' and general theoretical considerations in favour of the specific characteristics of the case at hand. Consequently, the last step of the research projects, i.e., the discussion of the results in a broader scientific and integrative context, is likely to be reduced to a minimum – even more so if the success of the project depends on the satisfaction of the funding institution and the field of study alone, and is not embedded in a strong scientific community.

In the following section we will try to add such an integrative discussion to a series of projects on 'science and sustainability,' concentrating on the two case studies presented above. Though it offers not much more than a sketch of general ideas and hypotheses, we hope it might trigger similar interpretative attempts in this field. The opportunity to do so we owe to the favourable fact that an interdisciplinary research group with a stable core team has been working on the same central issue, namely the role of scientific and societal differentiation in sustainable development, in three consecutive projects within a period of five years.

A comparative systemic analysis

With regard to the interpretation and discussion of the gained results, applying a systemic view – as done and illustrated in case studies I and II – has several advantages. Systems analysis and integrative modelling can serve as heuristic tools to deepen the understanding of the characteristics of the present situation. They can be used for prognostic reasons and help to draw a picture of possible steering interventions. The steering of systems as such can refer to particular qualities of the system elements, to relations between these elements (i.e., the system structure) or to patterns of such relations (i.e., the system character or identity; Gunderson & Holling, 2002).

Given the two different analyses of societal interactions in the context of perceived unsustainable development (case studies I and II) and a preceding claim that society needs to change towards sustainability, a broader discussion on a higher level of integration looks promising.

Before we start with this integrative system analysis, the preconditions for such integration need to be clarified: Both case studies focus on specific societal sub-systems in a broad sense, and both are situated within the Austrian political and administrative system. Both take a closer look at individual players, at their multidimensional interrelations and at intersections of relevant fields of practice. They try to identify the obstacles to joint activities towards sustainability, and to formulate potentially helpful modes of intervention. Still, the two case studies do not strictly follow the same logic. Rather, they represent two snapshots taken from two distinct angles, showing two facets of our present societal system. To achieve an in-depth integrative analysis of the two cases we will have to bear in mind, and make use of, their complementary character. The centre of the following discussion is a comparative approach that develops the differences and similarities of the two cases, thus taking a further step towards the understanding of societal processes in the context of sustainability.

Whereas for case study I we have chosen the science system as an already (institutionally and culturally) well-differentiated sub-system of our society, in case study II no such 'sub-system,' in the strict sense of a semi-autonomous functional part of society,[7] exists. The second 'object' of our study has only developed throughout the research process itself: it can be seen as the result of a certain question we initially asked (i.e., how to foster the implementation of energy-efficient refurbishment) related to a certain problem perceived (i.e., climate change). Hence, case study I deals with a societal sub-system *sensu stricto*[8] and the efforts required to open it up for external objectives (i.e., sustainable development), while case study II deals with external effects of various, loosely linked

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[7] A system is characterised by a functional unity, i.e. "an entity capable of performing certain tasks which relies on the functional integrity of all of its parts for maintaining that capacity." (Bonsack, 1990 as quoted by Thellefsen & Thellefsen, 1998)

[8] "Systems are most generally characterized by their complexity, their coherence and relative permanence, and their tendency to seek their own survival. These general conditions dominate the whole concept." (Thellefsen & Thellefsen, 1998)

societal player-fields according to their varied objectives, which result in a socially perceived problem situation and a solution-oriented definition of a sub-system suitable for sustainable change. In the following sections, these results of the comparative analysis are described in greater detail.

The science system: an 'ex-ante-system'?

Scientific research and education in Austria is embedded in scientific networks on international levels and can be seen as the result of a historical process of institutional differentiation (Stichweh, 1994). Presently, it is located either within the university system, within public but extra-university departments, or within private industry. Case study I is restricted to the former two, which are more easily accessible for data collection and, moreover, directly linked to the public authorities. The university system, as a place of scientific education and socialisation (Huber, 1990; Grün, 1994), as well as the international scientific community, as the respective context of validation and reference, are both organised in a hierarchy of 'science sets' (natural sciences, technical sciences, social sciences, etc.), disciplines, sub-disciplines and specialised research fields (Figure 1). These units on different levels of aggregation are characterised and continuously re-confirmed by their specific social structures, rules and community cultures (Pinch, 1990; Austin, 1990). Research projects are traditionally localised within one such research field and embedded in the corresponding discipline belonging to a certain set of sciences. In contrast, sustainability research is primarily oriented towards the solution of societal, non-scientific problems (Funtowicz & Ravetz, 1990). This may lead to interdisciplinarity, also extending across scientific cultures. It certainly leads to transdisciplinarity, because it transcends the (sub-) system borders towards society, from the formulation of the research interests to the presentation of the results to the public.

Thus, in sustainability research the societal struggle for increased sustainability meets an already well-defined and highly-structured societal and institutional (sub-)system, functioning relatively autonomously, and stabilised by self-organising processes of community building, gate keeping and boundary work (Gieryn, 1983) on the various levels of integration. Science as a societal sub-system had already existed before the societal objective of sustainability developed. At the same time, its functioning is of fundamental relevance to the pursuit of the objective. We therefore call it an ***'ex-ante system,'*** as it is related to the societal efforts towards sustainable development.

At the same time, sustainability research depends upon opening the (sub-)system to its societal environment. It emphasises a science system that perceives the need for sustainable change and initiates transitions, rather than a science system that uncritically collects more and more data and directs all scientific and educational efforts mainly towards hermetic insights or economic efficiency. Hence, it often leads to blurring boundaries between the scientific objectives of knowledge production, verification and accumulation, and the societal objectives of dealing with urgent problems, normative issues and opposed interest groups, as well as between the scientific quest for truth and the societal quest for justice.

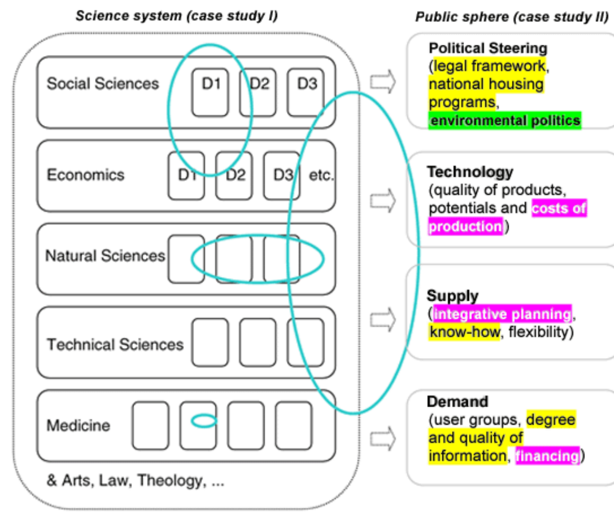

Figure 1. The science system as an 'ex-ante system', characterised by its social and institutional differentiations. Each set of sciences (e.g., 'social sciences') consists of different disciplines (D1, D2, D3, etc.) which are again split up into sub-disciplines and fields of research. Scientists and research projects (represented as blue circles in the figure) are traditionally located within such fields of research. Sustainability research crosses the given boundaries and adds interdisciplinary and transdisciplinary projects to the system.

Such indistinct boundaries present a certain threat to the autonomy and integrity of the (sub-) systems. It will – under normal circumstances – be met by processes of increased boundary work and gate keeping due to the self-regulatory capacity of the (sub-) systems. If so, we need to ask not only how the science system can be adapted to the present needs of sustainable development, but also how sustainability research can be integrated into the existing social structures in a sustainable way. Such sustainable integration has to consider the present role of science in our society (Wynne, 1993; Felt, 1999), its integrity as a semi-autonomous sub-system, and the societal preconditions and benefits of this differentiation (Fischer, 1999).

The player field of energy-efficient refurbishment: an 'ex-post-system'?

When compared to the science system described above, no similar social/societal coherence and systemic identity exists for case study II and the player fields involved in energy-efficient refurbishment. The relevant sub-system identified and analysed throughout the research process (Figure 2) has developed only as a heuristic construction related to the raised research question, and the problem situation, as perceived by society. Therefore, it does not represent a system in the strict sense of the meaning. We call it an '***ex-post system***' as related to the unsustainable syndrome of climate change (Figure 3).

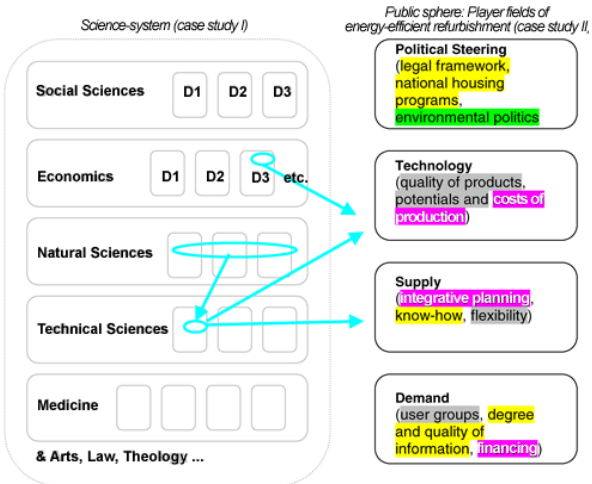

Figure 2. Player fields and related variables of energy-efficient refurbishment. To convey an idea of the results of case study II, both qualitative and quantitative variables of the four identified player fields are given: critical variables are marked red, buffering variables green, active variables yellow, reactive variables grey. To show the connection to the science system analysed in case study I, the integration of disciplinary research within technology and supply is indicated in an exemplary sketch.

The progressive construction of the ex-post system model starts with the perceived problem of climate change and the scientific identification of the causal connection to green house gases, especially CO_2. It is followed by a political decision to reduce CO_2-emission loads within the household sector via steering interventions on a national level. Case study II aims to identify all players involved in the implementation of this task, and to analyse their actual and potential roles, be they beneficial or restraining, buffering or critical. Hence, a central aspect of the research process has been to build a systemic model of a section of our society, which *should* (in the context of sustainability), *but does not yet* function as a semi-autonomous, self-regulatory sub-system. It consists of various, loosely linked player-fields, variables, players and actions, and, respectively, effects. In a best-case scenario, political steering, technology, supply, demand, social, economic and environmental effects would be linked by direct and indirect connections, resulting in an iterative process of sustainable development. Therefore, causes and effects, presently separated by the lapse of time and a lack of integrating mechanisms and structures, need a link stronger than the merely passive contributions to a common external effect. Examples of strengthening social links are community building, participatory processes, and rising awareness. Other steering interventions, such as legal restrictions formulated by players external to the field of practice, and restrictions that change unpredictably (without feedback loops), result in a loosening of internal links, and prevent the formation of a self-regulatory sub-system. They direct the players' attentions towards an unpredictable environment, instead of raising their awareness of the predictable effects of their actions within particular fields.

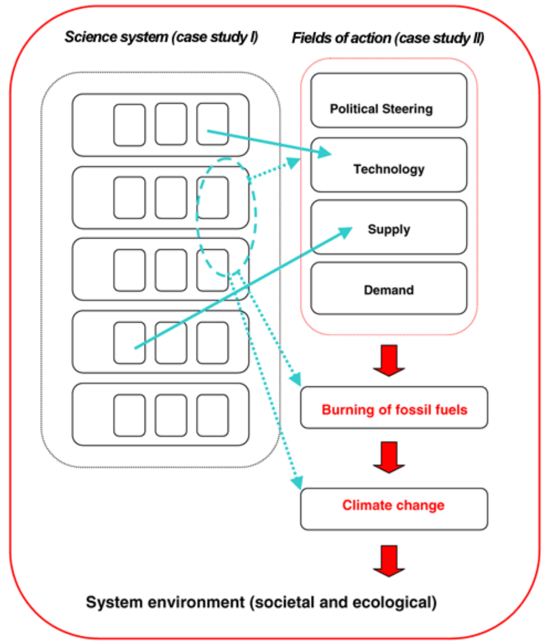

Figure 3. Player fields of energy-efficient refurbishment as an 'ex-post system' in the context of an unsustainable syndrome (climate change) . The systemic connection is only evident from bottom to top, starting with the effects perceived, then analysing the related causes, and finally identifying the relevant players and fields of action. Otherwise, the players form a loosely linked network without any perceivable systemic connection.

Far from giving preference to one or the other political instrument, we aim to highlight their systemic dimensions. One significant result of case study II is the crucial role of international environmental policy and national legal restrictions (as mentioned repeatedly in expert interviews and during the workshop), both operating on crucial variables, such as production costs and modes of planning and implementation. Consequently, a rather passive picture of the fields of practice, depending upon external factors, is drawn. A complementary description arises, given the fact that know-how within the supply field, the degree and quality of information within the spectrum of demand, and national housing programmes can play an active role. They are likely to do so if the crucial variables are handled with care, and planned and formulated with a long-term view and in close connection to the fields of practice.

Concluding remarks

By presenting our comparative systemic analysis of the two case studies and proposing a distinction between 'ex-ante' and 'ex-post' systems, we have tried to focus especially on societal structures and sustainable change. Without doubt, this distinction is only one among several. It draws one's attention to systemic differentiation and complex interactions. The overall goal of this particular perspective is to clarify the present problems and potentials in the context of sustainable development in greater detail and, hopefully, to enrich the debate on societal transitions.

As mentioned above, the analysis in hand can be no more than a first step towards an integrative theoretical discussion of societal differentiation and sustainable change. Nevertheless, we have endeavoured to illustrate that obstacles to and potentials of sustainable development can be identified in greater detail if the specific systemic character of the field of implementation is taken into account, that transition management can be improved by carefully directed systemic intervention, and that we need to deepen our understanding of sustainability research and sustainability policy with regard to the roles they play in various systemic societal contexts.

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ARTICLE

The use of science in environmental policy: a case study of the Regional Forest Agreement process in Western Australia

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This paper explores the notion of pluralism as it relates to the involvement of science in processes of environmental policy formulation. In particular, it focuses attention on the dominance of normal science within the Australian debate on commercial forest use, management, and conservation. It presents case study information from the Western Australian Regional Forest Agreement (RFA) process, a policy initiative designed to end a long-running conflict over public forestland. It then analyzes the use of science within this political process, along with the respective impacts of different voices within science on the RFA outcomes. The case study data highlight the vulnerability of reductionist science within complex political debates and support arguments for a widening of the scientific basis of policy processes to include alternative ways of understanding nature-society relations. The paper contends that such a broadening will make science not only more robust, but also more valuable as a problem-solving tool in future decision-making processes on land use, conservation, and broader sustainability questions. It also considers the obstacles facing pluralism.

KEYWORDS*:* environmental policy, forest management, policy reform, decision making, conservation, science policy, politics, human-environment relationship, conflict resolution, common property resources, sustainability

Introduction

Science has become a much-traded commodity within the media, commerce, and politics (Jasanoff, 1986; Salter, 1988). In fact, science and scientists are at the center of public life, assuming the role of society's principal problem-solving authorities (Cotgrove, 1982; Milbrath, 1989). Although science's absolute claims to autonomy and truth have increasingly come under attack, and critics have pushed it into a far more relativistic stance (Irwin & Wynne, 1996; Jasanoff, 1996; Felt, 2000), science continues to enjoy a preeminent social status and to play a central role within democratic processes.In the political realm, there is a discernible preference for input from the *hard,* normal sciences (after Kuhn, 1962). These sciences, which are closely linked to the political and economic status quo, are highly prescriptive in nature with a particular, yet largely undisclosed, set of policy preferences and outcomes (Lackey, 2004). In general, they are highly codified and quantitative and, therefore, often privileged to receive the objective label, which is favored in public and political life (Deetz, 1996). In contrast, *soft* sciences are given the subjective label because of their more qualitative orientation, dealing with interpretations of an interpreted world (Giddens, 1984). As a result, these disciplines are commonly considered less credible and reliable and are drawn upon less frequently within policy processes (Deetz, 1996).

The centrality of science in public life is not disputed, because experts are needed to advise on policy for an increasingly complex world (e.g., Yankelovich, 1991; Waller, 1995; Lubchenco, 1998). The point of contestation in this regard, however, concerns the kind of science required to provide needed answers to today's messy social, ecological, and economic problems. In recent decades, there has been a noticeable trend toward a greater reliance by society on scientific rationalism to form the basis for the actions of government and public administration (Harmon & Mayer, 1994). This rationalism, also termed "technical rationality" (Schön, 1983), is promoted largely by what can be called the dominant sciences. Such sciences as economics posit themselves as positivistic and linear in nature, promising full knowledge, and thus full mastery, over the social and natural world (while enacting a reductionist approach) (Schön, 1983; Özel, 2002). This characterization refers to the *hard*, normal sciences previously described and stands in contrast to other disciplines and schools of thought (e.g., ecology, ecological economics) that are often seen as unscientific. This paper casts doubt, however, on the capability of this orthodox strand of science to deal effectively with the issues of complexity and change. Its disciplinary myopia and rigidity may be at odds with inherently wicked problems—for instance those often encountered in natural resource management—thus preventing the holistic treatment of complexity and instead resulting in higher levels of uncertainty. For this reason, the extent to which dominant, rational sciences alone should be employed in policy contexts such as these need to be questioned.

This paper explores questions about the need for "scientific pluralism" within environmental policymaking. It also critiques calls for changes within science in light of growing environmental challenges and the need to inform and guide political debates and decision-making. To this end, it analyzes an Australian experience in forest policy. More specifically, case study data are introduced from the Western Australian Regional Forest Agreement (RFA), with the aim of providing insights into RFA stakeholders' perceptions of the scientific credibility of this policy process. The Western Australian RFA sought to balance the conflicting claims of conservation and development on public forestland. In this context, science was called upon to diffuse an emotionally charged forest debate with facts and to give credibility to a political process. Against this background, the case study data provide detail on the use of science within a complex policy process and prompt a wider discussion on the use and usefulness of science within the political arena. Consideration is also given to demands for changes that could better equip science for future sustainability challenges.

Background on the Western Australian Regional Forest Agreement

In the 1960s, public disquiet arose over the use and management of Australia's native forests. Back then, the intensification of industrial forest exploitation coincided with the emergence of new cultural and social values (Lothian, 1994; Worth, 2004). These attitudinal shifts led to calls for a new forest politic and forest management prescriptions, and resulted in an escalation of the conflicts between Australian state governments, the Australian Commonwealth government, conservationists, and the country's timber industries. By the early 1990s, the forest debate was the country's most controversial environmental issue, with strongly contested ecological, economic, and socio-political dimensions (see Carron, 1985; Australian Conservation Foundation, 1987; Dargavel, 1995; Mercer, 1995; Calver & Wardell-Johnson, 2004).

In an attempt to end the conflict, the Australian Commonwealth government initiated what came to be known as the Regional Forest Agreements (RFAs). These accords were designed to operationalize the 1992 National Forest Policy Statement (NFPS) by offering a mechanism whereby the Commonwealth and the State governments could negotiate the long-term management and use of selected forest areas. Officials promised that these 20-year agreements would deliver resource security for an internationally competitive forest products industry, as well as comprehensive, adequate, and representative forest reserve systems and ecologically sustainable forest management (ESFM) (Commonwealth of Australia and Government of Western Australia, 1999).

RFAs were widely portrayed as "agreements backed by science, science and more science" (Commonwealth of Australia, 2000). A total of AUS $115 million was spent on Comprehensive Regional Assessments (CRAs) (Commonwealth of Australia, 2000), which were scientific studies that sought to determine the environmental, heritage, economic, and social values within delineated forest areas. These studies were purported to have been the most detailed and comprehensive scientific assessments ever made in Australia (Commonwealth of Australia and Government of Western Australia, 1997). Such claims gave rise to the argument that RFAs were science-based, and that science provided the footing for sound decision-making on forest use and conservation measures (Hill et al., 1997; Forests Taskforce, 1998).

Government officials also promoted the scientific grounds of the Western Australian RFA. The public was assured that the State and Commonwealth governments had sought high-caliber scientific input via workshops, expert panels, and commissioned CRA research projects. More than 500 scientists and experts were reported to have been involved in the RFA process, producing a total of 38 CRA reports over a period of three years and providing advice to responsible ministers and to the Steering Committee overseeing the entire endeavor (WA Parliamentary Debates-Hansard, 1999). Nonetheless, despite these assurances, the science of the Western Australian RFA did become a point of contention. Questions arose over the scientific credibility and use of the underlying data and the bureaucratic censorship of dissenting perspectives (e.g., Horwitz & Calver, 1998). Growing disputes concerning the RFA's science contributed to an erosion of public faith in forest management, resulting in the widespread rejection of the RFA process and the outcomes it delivered.

When the Western Australian RFA was finalized in May 1999, the agreement triggered an enormous public backlash, including petitions, mass protests, and rallies. Although the RFA was described as an extensive scientific process that could "not be overturned overnight" (WA Parliamentary Debates-Hansard, 1999), public pressure forced the Western Australian State government to repudiate the agreement only eight weeks after it had originally been signed. Because the changes to the initial RFA lacked discernible reference to the scientific process, the credibility of both the science and the process it was intended to buttress were damaged. In summary, it seems that the Western Australian RFA failed to gain public acceptance partially because of a lack of scientific credibility, even though science was said to have been underlying its entire development.

We examine this conundrum below in light of the well-entrenched scientific controversy about forest management in Western Australia and its impact on the science of the RFA. More specifically, what follows gives insight into the bureaucratic institutionalization of rational forest science in Western Australia in the years preceding the RFA process. Subsequently, we present RFA stakeholders' perceptions of the credibility and acceptability of this scientific-cum-administrative alliance within the context of social and environmental change.

Comments on Method

The information presented in this paper is derived from a broader investigation of the Western Australian RFA (see Brueckner, 2004). Case study data was obtained from 59 interviews conducted with RFA stakeholders between 1999 and 2002. Research participants were chosen using snowball sampling to enable the inclusion of a wide range of stakeholders (see Goodman, 1961; Babbie, 1992). The investigation involved politicians, RFA process managers, conservationists, and timber workers, as well as forest industry representatives, scientists, and members of the general public. The interview data were triangulated with RFA-related literature and media content to identify stakeholders' perceptions of the RFA process and its outcomes.

This study adopted a discourse-analytic approach that followed other work in public policy development (see, e.g., Fischer & Forester, 1993; Dryzek, 1997; Meppem, 2000). Interview data were analyzed via visual coding and analytic deduction in the search for discursive themes and patterns. The analysis was done on the sentence level with the aims (a) to minimize author intervention and the risk of selectiveness, (b) to enable participants to tell their stories, and (c) to transfer openness and transparency to the reader.

Chosen data fragments were partitioned into word maps, also called rhetorical landscapes (Butteriss et al., 2001) or environets (Myerson & Rydin, 1996), to identify emerging themes and to create more manageable data categories. Data partitioning provided the basis for further questioning and analysis and allowed for a parenthetical presentation of the interview data. We then complemented and compared case study data with information from relevant RFA-related literature and media content.

The discussion below is a digest and offers a selection of themes pertaining to the science of the RFA. The different perspectives going into the RFA are presented in the form of a coherent meta-narrative, a synthesis of individual accounts of this policy process. Due to confidentiality constraints, however, individual RFA stakeholders cannot be identified, and only broad indications are provided of the respondents' backgrounds and organizational affiliations.

Scientific Dogmatism in Forest Management

Forestry in Australia is defined as embracing the science, art, and practice of creating, managing, using, and conserving forests and associated resources to meet social goals, needs, and values (Institute of Foresters of Australia, 2002). This definition indicates that forestry is anthropocentric in orientation, meant to maintain perpetual human forest uses. Forestry is, at the same time, an applied natural science that invests confidence in the scientific management of forests. It is positivistic in nature with a strong adherence to quantifiable evidence. However, the profession's anthropocentric and positivistic character increasingly has come under attack

Over the last thirty years, conservationists and members of the non-government scientific community have raised doubts about the management of native forests in Western Australia by the State's Forest Department. Arguably, the forest debate intensified markedly in 1985, following the formation of the Department of Conservation and Land Management (CALM). Perceptions of a conflict of interest over its responsibility for both forest production and conservation made CALM's role in forest management controversial. Calls for more conservative management of public forestland came mostly from the environmental lobby, which saw forest management practices and the rate of timber extraction as unsustainable (e.g., Cameron & Penna, 1988; Conservation Council of WA, 1990). As forestry was perceived as serving primarily extractive forest uses, forest management became a symbol of commercial forest exploitation (Routley & Routley, 1975; Dargavel, 1995).

Both the Australian timber industry and professional foresters rejected these criticisms, arguing that forests were indeed being managed sustainably (Australian Conservation Foundation, 1987; Watson, 1990; National Association of Forest Industries, 2002). Conservationists' calls for more precautionary forest management regimes were largely viewed as emotive romanticism and countered with repeated demands for a more rational debate to overcome what were seen as ideological approaches to forestry (e.g., Spriggins, 1998; Tombaugh, 2000). Essentially, the forestry profession took the stance that the forest debate should be left to those who have the facts and the answers about how forests ought to be managed (Institute of Foresters of Australia, 2002). This attitude is also observable internationally (see Society of American Foresters, 2002).[1]

Foresters are wrong, however, to suggest that conservationist claims are devoid of scientific basis. The green movement has had longstanding ties with the scientific community, a relationship that Yearley (1992) considers to be doubly bound "by epistemological affinity and common descent." This suggests that grassroots movements, too, rely on the authority of science to legitimate their claims and to exert legal-rational authority in the political arena (Yearley, 1991, 1992). In other words, there is more to the demands for precaution in forestry than what some observers regard as utopianism.

In Western Australia, the philosophical differences between CALM and the conservation movement became more entrenched over the years, intensifying further during the 1990s over aspects of forest management, but also over allegations of departmental corruption and scientific censorship (see Lowe, 1993; Schultz, 1993; Schoombee, 1998; Churches, 2000).

[1] Some observers have begun to recognize a discernible change in the identity of the Australian forestry profession in response to community pressure and changing public attitudes (see Kentish & Fawns, 1995).

Concomitant to the widening rift between conservationists and foresters was a growing division within the scientific community, leading to what Paehlke (1989) has described as the emergence of an environmental counter-science. The schism within the scientific community involved CALM staff and independent scientists from research institutes and universities in Western Australia. CALM scientists defended their silviculture management prescriptions that allowed a high level of commercial timber extraction, while critics challenged longstanding beliefs about forest use and management.

A number of Western Australian scientists expressed concerns about forest management in light of what they perceived to be insufficient knowledge of complex forest ecosystem functions (e.g., Wardell-Johnson et al., 1989; Wardell-Johnson & Nichols, 1991; Calver et al., 1996, 1998; Horwitz & Calver, 1998).[2] A common critique centered on the lack of good data on forest management issues and the resultant inability of CALM to assess confidently the impacts of forestry in Western Australia. Moreover, critics deemed CALM's forest research agenda as too narrowly focused on commercial tree species, suggesting that the department paid insufficient attention to broader conservation perspectives. Critics also held that CALM's interpretations were too optimistic and overly supportive of the forestry status quo concerning the large-scale management of highly diverse, complex, and vulnerable forest ecosystems. Against this background, non-CALM scientists called for further applied research and the establishment of guidelines for the consistent and codified operationalization of the precautionary principle within forestry, as well as greater openness between Australia's forestry departments and the wider scientific community.

The staff of CALM's Science and Information Division responded aggressively to this criticism and attacked what they viewed to be "emotive and unscientific approaches" to forestry (Abbott & Christensen, 1994). CALM staff asserted strongly that current scientific knowledge is "most complete" (Abbott & Christensen, 1996) and thus adequate for forest management. They claimed that no scientific argument effectively challenged the Department's practices, which were proven sound by the "unalterable fact that Western Australia's forests are one of the very few major ecosystems in Australia still retaining almost all of the original pre-European species and ecological processes intact" (Abbott & Christensen, 1994). Overall, suggestions contrary to CALM's official stance were seen as ideological, and scientific counterarguments were labeled as the work of prejudiced, anti-logging greenies based on subjective relativism and extreme biocentrism (Abbott & Christensen, 1994,1996,1999).[3]

Non-CALM scientists, therefore, held a palpable sense of unease concerning the optimism conveyed by their government counterparts prior to the Western Australian RFA process. CALM's categorical dismissal of dissenting views within the wider scientific community added to the concern. As these scientific preludes were bound to have an impact on the science of the RFA process, the analysis below focuses on a range of aspects of the debate that illustrate the connections between administrative structures and institutions and the resultant divisions within forest science in Western Australia. Some of these elements relate to issues within the RFA process, while others are examples of substantive philosophical differences between departmental and non-departmental science.

Science and the Western Australian RFA

The Western Australian RFA process was coordinated by a Steering Committee comprised of government officials from the Commonwealth and the State and their respective departments and agencies, with CALM being the principal negotiator on behalf of Western Australia. The Steering Committee was entrusted with the scoping and commissioning of the scientific studies conducted for the Comprehensive Regional Assessment. In this context, CALM was also the key provider of research expertise and scientific data. This agency centrality, as is shown below, raised suspicion among conservationists and non-CALM scientists as to the RFA's independence and degree of politicization. In particular, there were concerns with respect to the scoping and timing of CRA reports and the quality and treatment of scientific research data.

Comprehensive Regional Assessment Reports

The government officials that headed up the CRA work in Western Australia intended to deliver the scientific basis on which the Commonwealth and the State governments could reach an RFA. Many of the constituent reports underlying this process were unique in that they represented the first attempt by the State to bring together the existing body of knowledge about forest ecosystems. The results were then assembled into a complete CRA document designed to aid public consultation and negotiations over forest use options (Commonwealth of Australia and Government of Western Australia, 1998a). Non-CALM scientists, however, criticized the assessment on the grounds of time committed, data quality, and independence.

Common to many of the CRA studies were comments by scientists about the timelines for individual research reports (including data collection and analysis) that on average were designed to last for only a period of six weeks. Critics considered this an "extremely brief contract time-frame" (Lamont et al., 1997), with substantially limited capacity to critically reflect upon, and digest, often complex data (Majer & Heterick, 1997). Non-CALM scientists felt that "not enough time was given" and that overall the time available to complete the reports was "utterly inadequate." It was widely held that additional time would have enhanced the quality of the CRA studies.

Many non-CALM scientists believed that this fast-paced schedule rushed the process and made it difficult "to … have a good look . . . [at] what needed to be done" and in turn made it "[im]possible to do anything new or . . .

[2] The papers by Wardell-Johnson et al. (1989) and Wardell-Johnson and Nichols (1991) involved CALM scientist.

[3] Similar debates relating to issues such as fire management, species conservation, and ecosystem heterogeneity still continue today (e.g. Wardell-Johnson & Horwitz, 1996, 2000; Abbott, 1998; Abbott & Burrows, 1998; Wardell-Johnson et al., 2004).

to do things properly." This last concern was raised in relation to the scoping of the reports that, together with the establishment of timeframes for the CRA studies, was "something the Steering Committee ran." In this regard, scientists queried "whether . . . [the] short-term desktop review[s]," upon which many of the studies were based, were "adequate for the topic[s]" being researched. In short, the non-government scientific community had questions about the adequacy of the data that underpinned the CRA. In the words of one respondent, "the data sets that were available are totally inappropriate really for the modeling process." To several dissenting scientists, the scoping of projects, which effectively prevented additional data collection, was deliberate and based on the attitude that, "We don't want a particular sort of information, we don't want good data sets on this, we don't want to know." It was alleged that, "there was a guiding fear that if there are good quality data and they are in the public domain then the nature of the debate would change enormously."

Non-CALM scientists involved in CRA research also took issue with the review of the scientific data, the treatment of research results, and their publication. In relation to peer review, many scientists involved in the CRA projects suggested "that there ha[d] been an inadequate review process." It was held that "all . . . reports went through some sort of haphazard review, an unclear process of incorporating the material found within them." Both researchers and reviewers expressed similar reservations. Research scientists suggested that the peer review was "a higgledy-piggledy mess in terms of . . . how [the] reports were going to be dealt with, how they were going to be reviewed, how they were going to be assessed and handled." One reviewer felt that the submitted reports had been compiled too hastily and that work submitted for "review was clearly incomplete." There was a sense that the "process itself seemed to leave too little time for the actual preparation of the reports and then for the proper assessment of those reports once they were submitted."

Another issue of concern was data handling and data publication. Scientists expressed misgivings about how their "reports were dealt with and how they were incorporated into the process." Respondents feared that "the people who were actually in control were not scientists" and "had no knowledge." It was felt that bureaucrats "took facts, or what they thought were facts and figures, out of the report[s]," which on occasion meant that certain "recommendations that were in . . . [the original] reports were not included" in the final CRA document. A number of CRA studies appeared to be highly selective (e.g., Lamont et al., 1997; Majer & Heterick, 1997). Horwitz & Calver (1998) also observed that many of the scientific debates on aspects of forest management were ignored. As many of the concerns raised in the constituent reports were not included in the final CRA document, many scientists felt that "the coverage [of different viewpoints] was inadequate" as "certain scientific views that have been expressed about the ecology of the south-west forests . . . did not find their way into any of the RFA documentation." Overall, the "process . . . was [perceived as] limited and controlled."

Finally, many RFA stakeholders complained that a number of reports did not reach the public sphere until close to the end of the formal review period, if at all. One respondent told me that "the working papers that were generated . . . some of those key reports were either never written or they were written very late." As such, not all CRA reports informed the public consultation period in a meaningful way and some reports were unavailable altogether during the consultation process (e.g. Joint Commonwealth and Western Australian Regional Forest Agreement Steering Committee, 1998). Among members of the scientific community, the mired publication process was considered a fundamental weakness of the RFA. They believed that "the public needed to know what the processes were, why those reports were commissioned, what was important about each of the reports; in other words, the rationale for each report, and the public needed to have time to review and adequately assess all of these reports to enable the logic trail, the reason trail, and the paper trail to be followed from the commencement of the RFA process to the final decision."

Directing attention away from the procedural aspects of the science component of the RFA, the section below focuses on a range of specific issues regarding forest management that were subject to scientific contention. The data will shed light on the philosophical positions within the forest debate and thus give a better understanding of the degree of polarization among the various protagonists.

Philosophical Differences on Forest Management and Conservation

Old growth forest logging was the single most contentious issue during the Western Australian RFA process.[4] The debate focused chiefly on the two dominant commercially exploited tree species in Western Australia, namely karri (*Eucalyptus diversicolor*) and jarrah (*Eucalyptus marginata*). Nationally, the significance of old growth forest was recognized for its "high aesthetic" and "cultural" values, but also for its "nature conservation values" (Commonwealth of Australia, 1992). CALM, however, was said to have held "an explicitly stated philosophical view that old growth forest was an anthropogenic construct." One respondent noted, "CALM fundamentally did not believe in a special value pertaining to old growth." Indeed, CALM staff confirmed, "there is nothing particular about [Western Australian] old growth forests which is absolutely indispensable for biodiversity conservation." Unsurprisingly, there were "a lot of arguments over the basis for the determining of negligible disturbance" between CALM and Commonwealth government negotiators who sought to determine the areas of jarrah old growth to be set aside for reservation purposes. For jarrah, "disturbance was used as a surrogate for old growth," but this definition "left open the meaning of negligible disturbance." Disturbance was largely seen in connection with human activities such as logging and mining, but also with the occurrence of disease (primarily *Phytophthora cinnamomi*). In this context, Commonwealth

[4] According to the nationally accepted definition, old growth forest is "forest that is ecologically mature and has been subjected to negligible unnatural disturbance such as logging, roading and clearing. The definition focuses on forest in which the upper stratum or overstorey is in the late-mature to overmature growth phases" (Commonwealth of Australia, 1992).

officials suggested that CALM appeared to have "used phytophthora mapping strategically to determine the areas that were not old growth" so as to minimize the amount of forest that could be classified as old growth. In the end, a total of 24,300 ha of old growth were excluded on the basis of disease (WA Parliamentary Debates-Hansard, 1999). This decision was seen to have come about because of CALM's stance on old growth forest.

Similar problems with CALM were encountered in connection with the accreditation of linear/informal reserves to be included in the protected forest management area. The National Forest Policy Statement made it clear that the use of "linear reserves should be avoided where possible except for riverine systems and corridors identified as having significant value for nature conservation" (Commonwealth of Australia, 1992). RFA scientists also suggested that "there is a very large body of literature available which all indicates that in terms of secure reservation systems linear reserves are not much good." This is why the inclusion of informal/linear reserves was intended to be a last resort where formal reservation was not achievable. Yet, "[CALM] wanted to accredit a large contribution from those linear informal reserves" because—as conservationists argued— "there [was] no logging potential" (see also Conservation Council of WA et al., 1999). The RFA, as signed in May 1999, delivered a forest reserve system of approximately 1.5 million ha that included 12,898 ha of informal reserves on Crown Land and 137,886 ha of informal reserves in State Forest (State of Western Australia and the Commonwealth of Australia, 1999). The inclusion of "road, river, and stream reserves," that were widely perceived to have "no real genuine environmental value," struck many RFA stakeholders as an attempt to effectively minimize the extent of new conservation reserves. Especially, this view was hardened as "[t]he RFA . . . [did] not recognize the Valley of the Giants" (a well known tourist destination in the south-west of Western Australia) "as old growth but [recognized as old growth] the scrub on the side of the highway south of it."

As a final point, the allowable cut for jarrah and karri has been the subject of heated debate in the state for many years, including during the RFA process (for a historical overview refer to Calver & Wardell-Johnson, 2004). In the early 1990s, acrimony arose in response to what some opponents described as an "aggressive philosophy to timber harvest within some high-level administrators of CALM" (McComb, 1994). Earlier timber availability forecasts predicted a long-term decline in the saw log yield for jarrah (see Forests Department, 1982; Department of Conservation and Land Management, 1987). In 1992, however, CALM proposed to amend past resource availability assessments with a temporary increase in the cut followed by a stabilization in the saw log yield (Department of Conservation and Land Management, 1992). "[I]n the jarrah forest ... they were proposing a massive increase in the rate of logging and a major change in the style of logging where they go from selective logging to almost clearfelling." Critics (conservationists and non-CALM scientists) viewed the proposals as a "prescription to raze the forests." Although the Environmental Protection Agency (1992) rejected CALM's initial proposal, "logging was maintained at its 1983 level rather than being scaled back as had originally been intended in the previous Forest Management Plan." In other words, "an accelerated rate of logging in the … forests" prior to the commencement of the RFA process caused considerable public agitation. During the RFA process, the cut levels proposed for jarrah and karri as part of the forest use/management options presented for public discussion were all above known sustainable levels. This proposition gave rise to the community perception that the Public Consultation Paper "seemed to exclusively look at the needs of the timber industry" (Commonwealth of Australia and Government of Western Australia, 1998b).

Despite public demands for a reduction in cut, the finalized RFA document, as signed by the State and the Commonwealth, endorsed a level that produced a consistent and stable yield of saw logs, with the admission that this volume was left above sustainable levels until the expiration of the then-current Forest Management Plan (Commonwealth of Australia and Government of Western Australia, 1999). The fact that the "allowable cut [was] in excess of what" was considered sustainable made it difficult for the Western Australian government, however, to convince most people that "the RFA [was] giving" them ecological sustainable forest management. Despite scientific support for the reduction of logging levels, the decision to decrease the cut was postponed until 2004 to protect contracts and employment in the timber industry. The controversy surrounding sustained logging levels and the reserve design fueled an already tense forest debate, one aggravated further by the state government's refusal to protect all remaining old growth forests under the RFA. The combination of factors ensured that the controversy intensified after the signing of the RFA, and this ultimately led to its amendment eight weeks later.

The interview responses presented above give the impression that the science of the RFA was tamed, meaning that dissent was ignored or vehemently rebutted, and that science overall was made compliant with a dominant scientific/political viewpoint. This imposition of CALM's scientific stance instilled the feeling in RFA stakeholders that "science was used as a weapon." According to a non-CALM scientist, a façade was constructed that "the process would be using science to provide [Western Australians] with . . . answers, and that was publicly acceptable, whereas in reality, the guidance, the levels of forest reservation and so on, were coming from elsewhere, and it was not coming from science." This blurring of science and politics led stakeholders to believe that the "RFA process ha[d] not been about science," and that "overall that the scientific arguments were rather unimportant." Indeed, many stakeholders felt that the "scientific outcomes [of the CRA work] were not necessarily reflected in the outcomes of the RFA" and that the "nexus between what the science has found out and what actually happened was not particularly strong."

This case study leads to the suggestion that CALM was defending more, or perhaps something other, than just a scientific argument. Members of Western Australia's scientific community interpreted CALM's position as being symptomatic of a profession/administration "in denial." The issue of denial was raised because some stakeholders believed that there was "no way in the world that they [CALM officials] would accept (a) that they have done things wrong in the past, that they have been over-exploiting the forest ecosystems for years, and (b) they can't seem to come to terms with the idea that community attitudes and values have changed and therefore there are different expectations placed on the forest in the way it is to be used." The term "denial" may also explain why CALM seemingly did "not want to know" about dissenting views, because it would have meant that "they might have [had] to change [their] current procedures" even though they "have been arguing that [they] do know and what [they] are doing is right." Some interviewees saw this sort of closed-shop behavior to be "endemic in a lot of those sorts of professions." In Australia, according to one respondent, forestry departments are staffed with graduates from "two universities," who generally are "all buddies."

Closed-shop professions, like any other tight-knit organization, are at risk of cultural cloning, breeding practitioners with systemic blind spots and myopias toward change around them (Emery & Trist, 1965; Emery, 1997). As a consequence, confrontation and fervent defense of culturally entrenched views can become the norm. Also, perceptions of crisis are rejected and ridiculed, and faults or errors of judgments are not admitted. This is akin to what Torgerson (2001) refers to as the limitations of the administrative mind. Administrations are also prone to strongly reject criticism, for they fear that any admission of errors or flaws would bring into question the raison d'être of the entire administrative complex. Thus, in the case of CALM, we can view the issue of denial as two-tiered. CALM exhibited features of a closed-shop mentality towards forestry and public relations during the 1990s and the RFA process, with its staff maintaining that "there is not really a problem" and that all that needs to be done is "to tweak the dials" and "to change the formula slightly." This professional stance also received administrative backing from, or indeed may have been driven by, the administration. As a result, the scientific disagreements with the Western Australia RFA (and earlier quarrels) need to be seen in connection with a profession and an administration in denial, with its practitioners and managers responding systematically and apprehensively to challenges to their professional pride, identities, and egos.

Discussion: Lessons from the Science of the Western Australian RFA

The case of the Western Australian RFA can aptly be couched within broader debates about the appropriate use of scientific expertise on matters such as the sustainable management of natural assets. Complexities arising out of ecological, social, and economic collisions render controversies such as these messy, trans-scientific affairs. In this context, social science studies agree that effective conflict management requires holistic approaches that seek to address socio-econo-ecological complexities via trans-disciplinary integration (Kates et al., 2000; Lowe, 2001). Indeed, the socialization of science, or the integration of traditionally perceived trans-scientific issues into science, is more likely to enrich science and to make it more relevant and robust than it is to render science obsolete, as some traditionalists fear. Yet, as the above data attest, these concerns are alive and well.

Fear and denial, combined with the economic and political ramifications of a new forest politic, resulted in a RFA process characterized by scientific exclusion and a sense of closure. CALM scientists made rigid distinctions between valid and invalid modes of understanding forest ecology. Reductionist departmental knowledge was elevated to the status of an accepted, scientifically-informed view. In contrast, alternative understandings outside the agency were seen as inferior. This division between acceptable and unacceptable modes of knowing within the RFA debate can be illustrated by what is known as the Möbius strip or topology (adopted from Booth, 2000). The strip, as shown in Figure 1, symbolizes the field of human knowledge that expands as the ribbon is stretched. Following this analogy, the outer side of the ribbon represents accepted modes of knowing (e.g., CALM science) distinct from the inner side of the ribbon that represents alternative modes of knowing (e.g., non-CALM science). Both sides are, and remain, separated by the outer edges of the ribbon, even if the ribbon's ends (AC and BD) are joined together.

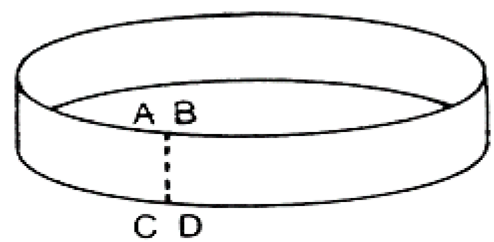

Figure 1. The Separation of Modes of Knowing
Source: Adapted from Booth (2000)

The RFA offered an opportunity for an open and exploratory debate on forestry based on a holistic and synthetic understanding of forest ecology. Metaphorically, there was a chance to make connections between the two sides of the ribbon, bringing together a plurality of perspectives of forestry as described by the scenario depicted in Figure 2. In this illustration, the ends (AC and DB) of the ribbon are connected with a twist, creating a singular surface, which brings together the inside and the outside. The duality between accepted and unaccepted modes of knowing is demolished, for they are now one. The dichotomies of objectivity and subjectivity, experts and non-experts, hard and soft science, become intertwined, rendering departmental reductionism only one of many modes of understanding the forest along a spectrum of different modes of knowing. Treating each of these different modes as valid enables a synthesis of knowledge and understanding, enhancing contextual sensitivity and thus improving adaptive capacity.

The RFA was intended to deliver an integration of knowledge, drawing from the best expertise available. In other words, this process could have made the connections between the different modes of knowing relevant to forest use and management. Yet, as occurred in the years prior to the RFA, this integration was restricted due to the domination of a single approach to forestry. As the entrenched hierarchy of knowledge was maintained during the RFA process, only a scientifically incomplete endorsement of the status quo could be attained. Instead of breaking down barriers within the scientific community, the RFA seemed to have hardened them. This also meant that the boundaries between science and politics could not be discerned and led to the discrediting of the science of the RFA. As one conservationist poignantly remarked, "there are not too many scientists who will say 'best science.' They will say 'RFA science' very disparagingly."

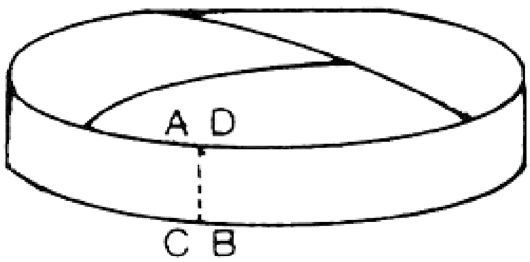

Figure 2. Connecting Different Modes of Knowing
Source: Adapted from Booth (2000)

Science is always at risk of being a mere reflection of social structures and dominant constructions of order and reality. This, in turn, jeopardizes its future relevance and trustworthiness in policy processes that are increasingly dependent on a mode of scientific practice that thinks outside rational squares. A new or more robust science, often called holistic, would therefore face a reduced risk of cooptation and corruption, as it would prevent the overly narrow political framing of complex policy issues. Realization of such an objective means the active involvement of an aware science in the political process.

The notion of an open science demands a widening of understanding and of the recognized expert realm. This could be understood as a broadening of Haas' (1992) "epistemic communities" or Funtowicz & Ravetz's (1991) "extended peer communities" to what might be seen as knowledge networks. Science's instrumental role in policy processes is that of reducing uncertainty. If science is to do so effectively, then uncertainty's underlying complexity ought to be matched with humanity's complete arsenal of tools of understanding the world. While "the path to action lies clearly in the best understanding of nature available" (Killingsworth & Palmer, 1992), incomplete approaches to seeing the world are unlikely to deliver such a comprehensive view. They are instead more likely to politicize science, as remaining uncertainty becomes a source of political power (Handmer et al., 2001). Therefore, the counterproductive barriers that exist among the sciences, as well as among scientists and non-scientists, need to be overcome. Single perspectives (modes of knowing) are inevitably segmented and incomplete, enabling only a limited understanding of the reality of the systems to which they are applied. In contrast, fused modes of knowing, or multiple perspectives, can lead to a broader, more complete understanding of a system's reality. These enriched perspectives can jointly form a more complete picture of reality, one that reduces uncertainty and the likelihood of unintentional consequences (see Cavaleri & Obloj, 1993). This ought to be a priority, especially in the context of our growing understanding of risk, precaution, and irreversibility.

The notion of knowledge networks also recognizes the possible value of contributions by non-experts to our understanding of nature based on local knowledge and venerable experience. The insights of such individuals have been shown to add value to the work done by so-called experts (Holman & Dutton, 1978; Krimsky, 1984; Funtowicz & Ravetz, 1991; Renn, 1992; Laird, 1993; Bailey et al., 1999). As noted by Funtowicz & Ravetz (1991), "knowledge of local conditions may not merely shape the policy problems, it can also determine which data are strong and relevant." This is not to suggest that lay-knowledge is necessarily scientific, but that it is another valid source of knowledge worthy of consideration. This is why the existence and validity of answers produced outside the traditionally recognized expert realm should not be denied or dismissed. Instead, their value and possible contribution to a given problem need to be acknowledged and considered.

Critical in this regard are questions as to when and how non-experts should, or may need to, become involved. Important also, echoing Yearley's (2000) concerns, is how the insights of non-experts, or "extended facts" (after Funtowicz & Ravetz, 1991), are to be treated, how their value can be determined, and how new or different knowledge should be incorporated into processes of political decision-making. In this context, Kleining & Witt (2001) propose a departure from the deductive-nomological, scientific protocol and advocate a path of 'discovering' data congruency (refer also to Wardell-Johnson et al., 2004). They suggest that, in the face of complexity and plural perspectives, the narrow scientific approach of deduction fails to deliver coherent prescriptions in science and much-needed input into political decision-making processes. In contrast, the discovery or exploration of common patterns among different perspectives, coupled with a requisite preparedness to change acculturated assumptions about the world, can lead to novel modes of understanding natural phenomena and thus aid the development of new, policy-relevant insights. This is what Anderson et al. (1998) describe as the expansion of the range of possibilities for viewing and managing the natural world, pointing toward the existence of numerous, if not infinite, scenarios. Many techniques exist for the political operationalization of pluralism, focusing, for instance, on transactive planning, collaborative learning, and various other forms of coordinated social action (for reviews of selected approaches refer to Babin & Bertrand, 1998; Ramírez, 1998; Vira et al., 1998). While these approaches offer potential solutions to different conflict situations, their effectiveness remains contingent on a genuine willingness of decision-makers to allow for an opening of perspective and the possibility for change. Such openings, in the case of the Western Australian RFA, were effectively prevented by systemic constraints on the scientific-cum-political alliances responsible for the RFA process.

The science of the RFA was necessarily limited by the imposed format under which it was conducted and by differential attention to scientific information depending on its acceptability to RFA management. Overall, RFA science was characterized by the exclusion and marginalization of views dissenting from the narrow scientific and administrative perspectives of forest management. While it must be recognized that Western Australian forest science itself faced problems because of its lack of ontological and epistemological openness, the interconnections between forest science and rigid political and bureaucratic apparatuses compounded this situation. Unsurprisingly, the institutionalized access of science to politics and vice versa meant that enduring calls for a widening of perspective (e.g., more precautionary approaches of forest management) have reverberated largely unheard.

Systems such as these do not facilitate learning and change. Key actors generally resist the modification of existing attitudes and behaviors, and instead seek to control information, usually by resorting to highly constrained discourses and problem definitions that only serve the prevailing political system. The final outcomes are often what Walker (2001) describes as "garbage-can policies." These bureaucratically-mediated ad hoc initiatives are threatened by the re-emergence and worsening of previously "solved" political problems, rapid changes in political direction, and external shocks. In this sense, more recognition needs to be given to the political nature of closed spheres of knowledge and the extent to which they add to the constrainedness of political processes.

Concluding Comments

This paper asserts that a great deal of work is required to make explicit the need to open up "closed bodies of knowledge" (Wynne, 1995). Despite progress in theoretical debates, more traditional scientists and policymakers maintain that such suggestions are direct attacks on scientific authority and robustness. In other words, variety and pluralism are still treated as impediments to the credibility of science, although they should be seen as lifelines that ensure its future relevance and trustworthiness.

The analysis presented here also points to systemic barriers affecting both science and environmental policymaking. In the case of the Western Australian RFA, these constraints, which resulted from scientifically sanctioned political and economic entanglements, were found to have limited the exploratory potential of the RFA process. The closed quality of this process draws attention to the positional weakness of any pluralistic model, especially as it relates to the relinquishment and sharing of power. To overcome these obstacles to the mobilization of multiple perspectives in science and policy, future research and praxis may therefore need to focus on identifying and making explicit the pervasive constraints that characterize natural resource conflicts.

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ARTICLE

Uncertainty, innovation, and dynamic sustainable development

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Sustainable development is a rich concept that has helped shape the discussion of human society's interaction with the biosphere. However, the term "sustainable development" is contentious, and some dismiss it outright as an oxymoron. The seemingly contradictory "sustainable" and "development" can be reconciled by accepting that due to two factors, the inherent complexity and uncertainty of human and natural systems, and the ability of human society to innovate, sustainable development must be dynamic. It must be an ongoing process, not a goal. A sustainable society must constantly evaluate its relationship with nature as it adopts new innovations and encounters unexpected events. The role of feedback and suitable application of the precautionary principle are key elements of a dynamic sustainable development process. The example of nuclear waste management in Canada demonstrates the beginning of such a process.

KEYWORDS: sustainable development, human-environment relationship, human impact, innovations, appropriate technology, human ecology, waste management, radioactive wastes

Introduction

Since being defined by the Brundtland Commission as behavior that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987), the concept of sustainable development has continued to evolve. There are now hundreds of definitions for "sustainable development" (Dale, 2001), a term that several observers contend is problematic. Certainly some of these definitions are no longer mutually compatible, yet this ongoing debate can be seen as an evolution rather than an argument.

William Rees, co-developer of ecological footprint analysis, argues that a prerequisite to formulating sustainable policies is to develop a satisfactory working definition of the concept (Rees, 1989). However when dealing with complex systems such as human societies and ecological regimes, meaningful global definitions are not always possible or useful. The Brundtland Commission's definition was left purposefully vague to allow various shareholders to work toward common ground. The resulting controversy, according to some observers, has created a constructive dialogue (see, e.g., Dale, 2001).

Though some protagonists argue that the very term is an oxymoron (Livingston, 1994), another possibility is that the perceived incompatibility in the terms "sustainable" and "development" is an artifact of a worldview based on equilibrium. However, from the perspective of complex adaptive systems theory, human societies are dynamic, open systems far from equilibrium and must evolve and adapt to survive. Development does not need to refer to mindless growth; it can also manifest itself as adaptation. Such adaptation can be sustainable over very long time scales, as is demonstrated by the biosphere, which has grown more diverse, extensive, and complex over the last several billion years.

Embracing dynamic sustainable development comes at a price, as the concept of a stable equilibrium state for human society disappears. This occurs for two reasons: complex adaptive systems are inherently unpredictable, and innovation constantly changes our impact upon the biosphere (Newman & Dale, 2005). Innovation and uncertainty ensure that a dynamically sustainable society must prepare for the unexpected.

From Goal to Process

Numerous recent publications support the shift from a goal-oriented to a process-oriented sustainable development. As C. S. Holling (2001) argues,

> Sustainability is the capacity to create, test, and maintain adaptive capability. Development is the process of creating, testing, and maintaining opportunity. The phrase that combines the two, "sustainable development" thus refers to the goal of

> fostering adaptive capabilities and creating opportunities. It is therefore not an oxymoron but a term that describes a logical partnership.

Such an approach is a shift from a command-and-control model to a self-organizational model of dynamic sustainable development. This type of model is more likely to succeed if it can emerge organically from unsustainable behavior in manageable steps. Norms cannot be imposed in advance (Robinson, 2003), but emerge as part of an adaptation process. Instead of being a final objective, sustainable development has to be understood as a continuous process of change (Jokinen et al., 1998); a potentially fruitful approach is to treat it as an evolution (Rammel & Van den Bergh, 2003).

Treating sustainable development as a process creates the need for an indefinite program of monitoring and adjustment, with every successful adaptation only a temporary "solution" to changing selective conditions (Rammel & Van den Bergh, 2003). In short, sustainable development is a moving target (Salwasser, 1993). In some cases, the time spans involved are long to the point of being indefinite. The two factors earlier mentioned - the inherent unpredictability of complex adaptive systems, and the changes brought about by human innovation - necessitate certain requirements of what I call dynamic sustainable development.

Uncertainty and Dynamic Sustainable Development

Complexity is the defining feature of our highly heterogeneous modern society. Human society is very non-ergodic. Ergodicity is the tendency of a system to move towards equilibrium, maximizing entropy and minimizing free energy. Human societies do not settle down into stable patterns for long. They constantly innovate, grow, and change, posing a challenge for those trying to adjust our interactions with the biosphere.

Though we might wish to design a perfect and stable society, history suggests such experiments end in failure. Sustainable development models must therefore be flexible enough to mitigate the ecological effects of a non-ergotic society. Theories based upon a complex systems approach are appropriate for the study of human society and its interaction with the biosphere for several reasons. First, complexity deals with the links between things. Second, it is neither reductionist nor holistic, but combines elements of both, necessary for multi-scale systems. Finally, the science of complexity deals with systems composed of varied elements connected in non-linear ways, a state that is certainly found within human societies.

Complex adaptive systems are far more than a collection of elements; they are bound together by the flow of energy, matter, and information. This flow is often two-way, forming feedback loops within the complex system. Achieving a sustainable society is fundamentally a question of observing and responding to feedback. Feedback loops form the nervous systems of complex adaptive systems, allowing the flow of information among elements and between the system and the environment. Feedback is a process in which a change in an element alters other elements, which in turn affect the original element (Jervis, 1997). Feedback is an iterative process, and is a fundamental part of what makes a system both complex and adaptive.

Complex systems generate both positive and negative feedback. Negative feedback loops are those which moderate a system, damping out change; this process, however, does not always lead to stability. Too much negative feedback can cause a system to become stagnant and unable to adapt to suddenly changing situations. A system composed only of negative feedbacks will become out of step with its surrounding environment and perish.

In order to thrive, systems must also contain positive feedback, defined as feedback which reinforces a change or trend. As environmentalists we tend to shrink from positive feedback, as it evokes thoughts of runaway growth. However, positive feedback is what allows our societies to respond quickly enough to adapt to changing conditions. Sadly, positive feedback introduces an insurmountable uncertainty into our system that is best described as a sensitive dependence on initial conditions. This phenomenon is also called the "butterfly effect," a term coined by Lorentz in a 1972 talk titled, *Predictability: Does the Flap of a Butterfly's Wings in Brazil Set Off a Tornado in Texas?* (Lorentz, 1993). Positive feedback can reinforce a small event again and again until it becomes a system-wide phenomenon.

Positive feedback loops allow accidents of history to get magnified in outcome (Waldrop, 1992). If negative feedback loops hold a system stable, positive feedback loops allow systems to explore their environment and follow new development paths. As they magnify random small variations, positive feedback loops add an element of surprise to the system's behavior. This leads to the results of many small actions being unintended and unpredictable from the initial conditions (Jervis, 1997).

The existence of positive feedback and sensitive dependence on initial conditions within society has profound consequences for sustainable development. As we can never trust our predictions of the future entirely, there can be no perfect model of a permanent sustainable society. Instead, we must monitor feedback loops carefully and continually adjust our models and our actions accordingly. Systems theorists sometimes refer to this inherent unpredictability as "strong uncertainty," in the sense that not only are we unable to predict the consequences of events, we are unable to determine which events will lead to future change (Spash, 2002).

The effects of feedback are well illustrated by the collapse of the cod fishery in Newfoundland. Once the largest cod stock in the world, the Newfoundland stock supported a viable commercial fishery for over three hundred years. However, the stock was destroyed in only two decades and has yet to recover (EEA, 2001). During the 1970s and 1980s, the Canadian Department of Fisheries and Oceans ignored negative feedback from two important sources: its own research scientists and the inshore fishers who were directly observing the cod's decline (EEA, 2001). The fishers, for instance, noticed that the fish were becoming fewer and smaller and tried to communicate this information to the scientists at the DFO. They were ignored and dismissed. This is negative feedback, as in a perfect world their knowledge would have led to a change in fish catch limits, stabilizing the stock. At the same time, a positive feedback mechanism was in play. The large offshore fishing fleet was upgrading its technology, and this contributed to the pattern of stock depletion. As fish become scarcer, fishers were encouraged to invest still larger sums to ensure that the quota was being caught. In effect, the fleet was working harder to achieve the same result, but the catches were remaining constant, presenting the illusion of a stable stock. This cycle of increasing pressure upon the stock continued right until the eventual collapse. Once it became clear the cod stocks were declining, corrective action occurred only slowly due to another set of negative feedbacks. The DFO feared the social and political effects of drastically reducing the fishery, and accordingly moderated their response (EEA, 2001). Positive feedback drove the stock's destruction and negative feedback inhibited the imposition of fishing curbs—a worst-case scenario for sustainable management.

Nuclear Waste Management and Complexity

The mismanagement of the Newfoundland cod stock is a good example of the problems that can result from incorrect actions. However, trouble can also arise when no action is taken and problems are allowed to accumulate. The lack of long-term management of nuclear waste is such a problem. This very complex issue involves both ecological and social systems on an unprecedented time frame.

In Canada, there are roughly 1.7 million used nuclear fuel rods from power generating stations in three provinces. To date, used fuel has been stored on-site, in cooling pools and in concrete bunkers. This waste will remain dangerous to human and ecosystem health for tens of thousands of years, posing a managerial problem on an immense scale. Many complex questions arise: Should waste be stored at reactor sites, or undergo the difficult process of being moved to locations far from population centers (where it might be neglected)? Should we place the waste beyond the reach of future generations, or do we include a level of accessibility in case a better method of disposal is developed? How can we communicate to future generations the danger this waste poses? These issues, combined with strong public feelings, make nuclear waste management a bellwether for dealing with complexity and uncertainty. Nuclear waste disposal presents vague and poorly defined social and ecological feedback loops.

Managing such a complex process successfully will require the development of new tools. First, plans must be ongoing and iterative, subject to adjustment. Ecological footprint analysis can provide a starting point for this purpose as it relies on quantitative data to provide a "snapshot" of how sustainable a society is at a particular time (Wackernagel & Rees, 1996). However, as this tool only provides an idea of present conditions, more work must be done to extend this process into the future. As an example of such a combination of visioning and measurement, the Natural Step process, developed by cancer researcher Karl-Henrick Robert to take advantage of the power of iterative analysis, has been widely used by both corporations and municipalities to map out a route to more sustainable behavior (Nattrass & Altomare, 1999). The application of the Natural Step involves four core processes that build on each other to provide a course of action that leads toward a state of higher sustainability. The procedure is therefore a creature of feedback—it can be applied again and again, taking the user group to higher and higher levels. The steps are outlined below:

Understand the principles of sustainability.
Locate unsustainable processes and determine the gain in changing them.
Form a vision of how to change them by "backcasting" from the final goal.
Identify a series of paths leading to that goal, and then *pick* a path.

The process of "backcasting" is one of the key innovations of the Natural Step. Selecting a goal and imagining how to get there works better than adapting to prediction when the problem is complex, when the changes needed are major, and when trends and externalities play a role in the problem (Nattrass & Altomare, 1999). In the case of nuclear waste, this process involves understanding the need to manage this waste, evaluating the sustainability of current practices, determining what the desirable goal of nuclear waste management might be, and identifying the steps necessary to reach that goal.

Innovation and Dynamic Sustainability

Humans must innovate to survive. The physical human is strangely and woefully unequipped to survive in the wild, and we rely extensively on technology to compensate for our lack of physical preparedness (Debray, 1997). Innovation, however, is not just technological; it can take several forms. Technical ingenuity creates new technology, but social ingenuity reforms old institutions and social arrangements into new ones (Homer-Dixon, 2000).

Innovation within a complex society occurs on many scales. At the smaller scale, we see incremental innovations, small refinements that occur relatively continuously. At a larger scale, there are radical innovations, very significant shifts in existent technologies and social structures. These are not predictable and may happen at any time. Lastly, there are systematic innovations that create entire new fields (Pereira, 1994). They cannot be predicted, and their occurrence radically reshapes society. These innovations can be thought of as "gateway events" and they can lead to rapid change (Rihani, 2000). Such sudden shifts can provide new technologies to protect ecosystems, can shift use from one resource base to another, and can also increase our impact on ecosystems in new and unexpected ways. We desperately need to sharpen our *a priori* understanding of what effect an innovation might have.

Detecting gateway events is difficult, as it is hard to identify signals of massive change early enough (Levin et al., 1998). While there is no real way to predict gateway events, we can increase the chance that we will be able to take advantage of them when they occur. In the case of nuclear waste management, we might consider making certain that the material remains accessible in case better disposal technologies arise in the future.

Incorporating innovation into a model of sustainable development is difficult. Though technology can be seen as an "adaptive answer" to problems (Rammel & Van den Bergh, 2003), there is a fundamental disconnect between the world of the information society and the groundings of sustainable development. These two systems of social organization are often presented as mutually exclusive due to differing values held by the actors involved (Jokinen et al., 1998). Even if we can surmount this chasm, there is inherent uncertainty in the process of innovation (Buenstorf, 2000). Innovations can give rise to new needs, but they introduce variation and learning that is essential to the exploration and development of new possibilities (Vollenbroek, 2002). Some of our problems require systems innovations that will enable the fulfillment of needs in an entirely new manner, yet planning is difficult when resources and concepts that are useful to us today might be of no use in the future, and resources and concepts that we do not presently value may be essential to humans living in the future (Gowdy, 1994).

Precaution in an Uncertain World

One method used to mitigate the uncertain effect of new innovations is to evaluate them according to the precautionary principle. However, the very complexity that makes the precautionary principle desirable also makes it contentious and hard to define. The origin of the precautionary principle concept is often credited to the German notion of *Vorsorgeprinzip*, or foresight planning, which began to receive attention in the 1970s (Morris, 2000). The concept has evolved over time, and what began as a "measure" shifted to an "approach" and finally to a "principle" (Adams, 2002).

The Rio Declaration urges the use of the precautionary principle. Principle 15 states that where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing cost-effective measures to prevent environmental degradation (Morris, 2000). A stronger definition, known as the "Wingspread definition," emerged from a 1998 conference. The Wingspread definition of the precautionary principle states that when an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause-and-effect relationships are not fully established (Raffensperger, 2002).

Intuitively, the precautionary principle is straightforward, (Adams, 2002; Saltelli & Funtowicz, 2005). The general idea is to avoid serious and irreversible damage (Som et al., 2004). As Raffensperger (2003) states, the precautionary principle can be used to prevent, not just redress, harm. What is simple to describe, however, is not necessarily simple to put into use. Critics say the precautionary principle is ill defined, unscientific, and ideological. Some commentators argue that universal application of the precautionary principle would rule out any action, including doing nothing (Sunstein, 2002). It is also argued that the precautionary principle inhibits innovation and the creation of better substitutes (Goldstein & Carruth, 2005). These concerns must be addressed before the precautionary principle can be applied practically. Innovation is critical to human health and welfare. The optimal balance between precautionary principle proponents and their critics would be to develop a method of screening inventive adaptations that does not cripple innovation, but does limit potential harm. Such an approach might proceed as follows:

- A brief application of the precautionary principle is needed for trivial innovation similar to other innovations with only local effect. As an example, imagine that someone develops a slightly better corkscrew. It is unlikely such a refinement will have serious consequences, and therefore the precautionary principle might consist simply of testing to ensure the product does not cause injury.
- A much more thorough application of the precautionary principle is needed when a clear risk can be imagined. For example, genetically modified organisms that contain genetic material from serious allergens such as peanuts and shellfish should be carefully studied before being used in food products.
- We must accept that some breakthrough technologies will have unpredictable effects, and develop our ability to cope reactively with problems accordingly. As an example, the development of chlorofluorocarbon-based refrigerants allowed a revolution in cooling and food storage that saved many lives and greatly improved human health. The technology to understand the risk that these compounds posed to the ozone layer did not exist until much later, and thus what mattered was not our ability to apply a precautionary principle, but our ability to react quickly and effectively to an unforeseen problem.

It is necessary to begin by asking, "to what sort of hazards does the precautionary principle apply?" What level of evidence should be required for its use, and what kinds of preventive measures should be invoked? In the first instance, there must be some evidence that a hazard exists if the precautionary principle is not to lead to efforts to rule out any action (Sandin et al., 2002). If the precautionary principle is not to stifle progress, it should be coherent, use known information and theories, have explanatory power, and possess simplicity (Resnik, 2003). Low complexity solutions should be preferred to high complexity solutions, if the precautionary principle is to avoid simply creating further problems (Som et al., 2004).

Tickner & Geiser (2004) point out that an important proviso is needed if the precautionary principle is to be practical and workable. Many framings of the precautionary principle call for preventative action and reversing the burden of proof. These measures need to be coupled with alternatives assessment in order to be proactive. This recommendation leads to a focus on solutions rather than problems and can stimulate innovation. Alternatives assessment can also allow an avenue for public participation, as we will see in the following discussion of nuclear waste management. To summarize:

- The strength of the precautionary principle applied should reflect the scale of the innovation in question.
- A discussion of alternatives should be a part of a precautionary principle process.
- The precautionary principle should focus on known risks, with the understanding that unknown risks might exist.
- It must be understood that no precautionary principle short of disallowing any action will be 100% effective in preventing problems, as our society and ecosystems are inherently unpredictable. We must therefore develop our ability to respond to such problems as they arise.

Uncertainty and Resilience

Complex systems are filled with uncertainty, and no amount of precaution will eliminate all risks. We therefore need to build system resilience, which Holling (1976) defines as the ability of a system to persist by absorbing change. Several factors influence a system's resilience. These include its latitude, or the maximum amount of stress that it can absorb without changing to a new state, its ability to resist change, and its precariousness or fragility (Walker et al., 2004). The more resilient an ecosystem or society is, the better it will be at responding and adapting to unpredictable changes.

There are several ways we can increase system resilience. In the first instance, we can increase resilience by ensuring that as we undertake a course of action we leave room for alternatives. Preventative measures should allow for more flexibility in the future (Gollier et al., 2000). Especially in cases of irreversibility, options should be kept open (Arrow & Fisher, 1974). We can expand resilience by increasing a system's buffering capacity, by managing for processes at multiple scales, and by nurturing sources of renewal (Gunderson, 2000). Allowing cross-scale communication can be particularly important, as information presented by the inshore Newfoundland fishers demonstrates (although it was ultimately ignored by the government). Moving information across scales is difficult, but it is critical to resilience (Peterson, 2000).

In his detailed study of historical social collapses, the geographer Jared Diamond (2005) highlights several points of failure: failure to anticipate problems, failure to perceive the problems once they exist, failure to act on problems, and finally failure of an action to solve a problem. The precautionary principle can mitigate the earlier stages of this progression, but how do we successfully manage the entire spectrum of proactive and reactive responses? Diamond argues that important components of resilience are a willingness to engage in long-term planning and an openness to reconsider core values.

Precaution, Uncertainty, Resilience, and Nuclear Waste

Nuclear waste management presents a poignant example of a case that mandates action despite extremely uncertain information and future scenarios. Canada is currently deciding how to manage its existing high-level nuclear waste. During the fall of 2004 and the spring of 2005 I participated in the organization of three electronic dialogues on nuclear waste disposal with the goal of engaging the Canadian public.[1] The dialogues were conducted for the Nuclear Waste Management Organization (NWMO) of Canada, an entity established under the Nuclear Fuel Waste Act to study various options for managing the country's used nuclear fuel. Three provinces (Ontario, Quebec, and New Brunswick) currently produce such waste, which poses a very long-term hazard to both human health and natural ecosystems. The organization has been charged to:

- Establish an Advisory Council that will make public its comments on the study by the waste management organization and other reports.
- Submit to the Minister of Natural Resources, within three years of the legislation coming into force, proposed approaches for the management of used nuclear fuel, along with Advisory Council comments and a recommended approach (NWMO, 2005).

The NWMO focus on public involvement stems in part from the failure of the earlier Canadian Nuclear Waste Management Program (CNWMP) to finalize a waste management process. Begun in 1978, the CNWMP concluded in its final report, released in 1998, that broad public support for the proposed disposal measures had not been demonstrated (CEAP, 1998).

The dialogues were held to engage the public in a discussion of the NWMO Assessment Framework, of the general risk and uncertainty of nuclear waste disposal and management, and of the decision-making processes most applicable under such conditions of risk and uncertainty. The goal was to provide a neutral space where discussion of a contentious and complicated public policy issue could take place. The dialogues were also designed with an educational role in mind, to further public engagement with sustainable development issues in which the science is often uncertain, the needed information is incomplete, and the time frames transcend successive generations (Newman & Dale, 2005).

The process was similar for each of the three dialogues. Before each session, we posted on the e-dialogue website illustrative background material that was chosen to be informative, fair, and balanced. All three dialogues are available at www.e-researchagenda.ca, and a summary report was prepared for the NWMO.

The three dialogues introduced several new points and reiterated others for political decision makers. There was widespread consensus among both the experts and the panelists that the worst decision would be to take no decision, despite the risk and uncertainty. In the spirit of alternatives assessment, participants discussed the merits and detractions of several proposed solutions. Many participants believed that adaptability should be strengthened to include ongoing improvement, innovation, and research and development, a result that reinforces the above discussion on resilience. The public wanted to ensure maintenance of capacity to adapt to and to benefit from changing cognition. The framework should provide flexibility to future generations to "support improved management options" and changes in decisions, and not place constraining burdens or obligations on future generations.

More importantly, although the federal government mandated the NWMO to focus exclusively on the management of used nuclear fuel, an ardent public desire emerged, especially among younger Canadians, to see this issue linked to nuclear waste production. From a systems perspective, it was viewed as problematic to separate the human demand for, and use of, energy from the management of spent fuel. This result mirrors the previously discussed need to connect across scales.

We feel the issues raised during these discussions represent a successful and diverse engagement with the audience that has enriched the NWMO decision process. It was particularly interesting to see how the dialogues encouraged participants to challenge the assessment framework and to suggest more holistic approaches for the management of used nuclear fuel. The preliminary report from the NWMO to the Canadian government reflects these concerns, and calls for the waste to be buried but left accessible for at least several hundred years (NWMO, 2005). The alternatives assessment undertaken here resembles the Natural Step process. The problem was acknowledged, a goal set, and a selection of paths considered. In this case, the process will be ongoing for thousands of years, and the progress to date is only the barest beginning of a very complex management problem.

The NWMO process has precedent in the Berger Inquiry into pipeline development in Canada's North. Parliament established this inquiry early in 1974 to review plans to build an oil and gas pipeline in the Mackenzie Valley. This wide-ranging process evaluated social, environmental, and economic impacts of the prospective facility. The inquiry had

[1] These electronic dialogues were created by Ann Dale of Royal Roads University in British Columbia.

great flexibility, with permission to gather testimony at hearings throughout the country. Hearings were held in all communities along the proposed route. The inquiry concluded that no pipelines should be built in the Northern Yukon, and that the building of a pipeline in the Mackenzie Valley should be delayed. Key issues included the great risk to the fragile Arctic environment, the smaller-than-promoted size of economic benefits, and the opposition of the local population (O'Malley, 1976).

The Berger Inquiry and the NWMO represent flexible, open, and responsive approaches to complex issues. The mismanagement of the Eastern Cod fishery, particularly the exclusion of the views of local fishers, stands in stark contrast, suggesting that inclusion of public knowledge is crucial to a dynamic approach to sustainable development.

Conclusion

One of the goals of any approach to pursuing sustainable development is to ensure that future generations have ample options (Tonn, 2004). A dynamic approach that manages uncertainty as an ongoing process could maintain our future options. Dynamic sustainable development is largely about balance; embracing precaution will be most effective when paired with alternatives assessment. Innovation needs to be coupled with resilience building.

The NWMO has begun a process designed to address a very complex, very long-term problem in a manner that respects many of the issues addressed in this paper. The organization recognized the problem and realized that the status quo was not sustainable, even if the results of any recommended action would be intrinsically uncertain. The NWMO embraced the precautionary principle in their decision making process (NWMO, 2005), but acknowledged the need for alternatives assessment. As part of this process, the organization engaged the public and this helped to bring together the issue's social and technical dimensions. In the subsequent report, the NWMO responded to calls for resilience by recommending a course of action that would leave room for future technical innovation and allow for monitoring, thus providing important feedback. However, it remains to be seen whether Canadian governments will progress to a multi-scale conversation that connects waste management with waste production, an important step in linking feedback loops.

Throughout the public consultations, members of the public have asked why Canada's nuclear waste exists in the first place and whether the current dilemma could have been prevented. If the founders of the Canadian civilian atomic power program had applied the precautionary principle to the development of nuclear energy, they might have determined that the waste from these facilities posed serious, but poorly understood, risks that were not technologically resolvable, and that alternative sources of electricity were available at the time. However, even the most diligent application of dynamic sustainable development will never create an entirely proactive society. The interaction between human societies and biological ecosystems will occasionally generate surprising threats to sustainability, and these situations must be managed reactively. Inherent uncertainty always exists, and innovation can act as a double-edged sword, both straining the biosphere and simultaneously creating new ways to achieve sustainability. A society with sufficient diversity and resilience will be able to adapt to such surprises. As the concept of sustainable development evolves, a combination of proactive and reactive management should prove central to sustaining societies in the face of change.

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COMMUNITY ESSAY

EPA's P3 - People, Prosperity, and Planet - Award

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Author's Personal Statement:

Challenges regarding population growth, global warming, resource scarcity, globalization, and environmental degradation have led to an increasing awareness that engineering design and policy strategies can more effectively advance sustainability. From a design perspective, this requires a fundamental conceptual shift from current "cradle to grave" industrial system designs toward more sustainable systems based on efficient use of benign materials and energy. One of the most powerful approaches to advancing sustainability is ensuring that the next generation of scientists, engineers, and policymakers has the intellectual tools necessary to design effective products, processes, and systems. I hope that EPA's P3 Award program remains central to this important and urgent effort.

The United States Environmental Protection Agency (USEPA) has launched a unique grant program called P3 (People, Prosperity and the Planet), to foster future generations of scientists, engineers, and technology workers who can advance the principles of sustainability through technology innovation. Unique in the federal government, this program awards grants to teams of undergraduate and graduate students, along with their faculty advisors, to design and develop sustainability projects and support the integration of sustainability into higher education curricula. The teams also compete for additional funding to move their ideas to the marketplace. In its first year, the P3 program involved over 65 teams and 400 students from colleges and universities across the country and has already resulted in three small businesses. The program was launched and implemented in less than eighteen months and has been such a great success that the USEPA hopes to fund it annually.

Planning for the future is a critical aspect of sustainability. For the body of creative technology solutions to advance, we need to train future generations. However, most of the academic curricula in science and engineering is structured along traditional lines and offers only a small number of disjointed courses that discuss sustainability. The P3 program addresses the need to rigorously train students in the fundamentals of science and engineering, while they gain an awareness of their work's impact on the economy, society, and the environment.

To launch the P3 program, the USEPA brought together over forty partners from the federal government, industry, and scientific and professional societies to provide support. Through their communication efforts, the USEPA received nearly 150 applications. Each applicant was required to articulate the challenge and detail its relationship to sustainability, to define the innovation and technical merit associated with the project, to demonstrate their ability to measure outcomes through an effective evaluation method and implementation strategy, and to discuss the use of the P3 competition as an educational tool.

Ultimately, the EPA awarded 65 grants of $10,000 to teams composed of students and faculty from diverse disciplines, such as engineering, chemistry, architecture, industrial design, business, economics, policy, social science, and others. The teams conducted their research and development over the course of the 2004-2005 academic year. In May 2005, the teams demonstrated their projects and competed for additional funding. The competition was held on the National Mall in Washington, DC and judged by a panel convened by the National Academies, advisors to the nation on science, engineering, and medicine.

Through the competition, seven teams won Phase II awards to further develop their innovations, in some cases commercializing them, and to continue learning about sustainability science and engineering. The seven teams and their projects follow:

- **Oberlin College** designed a system that monitors total energy and water use for individual dormitory floors or an entire college campus. This project was converted to a small business with clients including Duke University and Sidwell Friends School in Washington, DC.
http://www.oberlin.edu/dormenergy/main.html

- **Rochester Institute of Technology** looked at how solar ovens could be mass-produced at low cost in Latin America using local resources. These ovens reduce wood consumption and deforestation, while providing local jobs. This project has been successfully implemented and evaluated in Venezuela, with plans to expand to other communities in South America.
http://www.rit.edu/~633www/EPAsolarovens/index.html

- **University of North Carolina at Chapel Hill** measured the effectiveness of three drinking-water treatment technologies for the developing world. Their project is now quantifying the public health benefits of these technologies.

- **University of Colorado at Denver** looked at environmentally-friendly energy technologies, such as small wind turbines, composting methods (for solid waste management), and solar cookers to see if they could be adopted in a tribal village in India. This team has returned to the village to implement its design and continues discussing ideas for innovations that would improve the inhabitants' quality of life.
http://carbon.cudenver.edu/engineering/places/current_project/current_project.html

- **University of California at Berkeley** tested two designs to disinfect drinking water, and even conducted user-preference and willingness-to-pay surveys. This project has won several additional awards, including the Massachusetts Institute of Technology IDEAS International Technology Prize, for its innovative design that is serving communities in Mexico and Haiti.
http://ist-socrates.berkeley.edu/~rael/uvtube/uvtubeproject.htm

- **Massachusetts Institute of Technology** designed a management model for research labs to use less-toxic and less-polluting green chemical alternatives. MIT has now partnered with Los Alamos National Laboratory to perform a feasibility study of incorporating this software into their purchasing system.
http://web.mit.edu/environment/academic/green_chemicals.html

- **University of Michigan** developed a computer-based tool for homeowners to monitor their resource consumption. Real-time costs and environmental impacts show how conservation actions are reflected in dollars saved and emissions reduced.
http://www.engin.umich.edu/labs/EAST/@home/home.htm

Because one of the five key criteria used in evaluating proposals for funding was implementation as an educational tool, the P3 program already has exerted exponential influence on the next generation of students majoring in the winning schools' science and engineering departments.

The over 500 faculty and students from 52 colleges and universities that participated in P3 (see http://www.epa.gov/P3 for more information) used this opportunity to alter core required courses, evolve senior capstone design courses around sustainability and their particular P3 project, and initiate certificates and minors in sustainability science and engineering. They also established extracurricular organizations that use science and engineering to address sustainability challenges on their campuses, within their communities, across the nation, and throughout the developing world.

Several universities that did not secure competitive funding from the EPA nevertheless proceeded with plans from their proposals, using the award process as an educational tool that reached students beyond the P3 boundaries.

The P3 program has the goal and potential to reach out to the thousands of colleges and universities across the country to transform the way we prepare tomorrow's workforce to meet tomorrow's challenges.