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The inherent biases in environmental research and their effects on public policy

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Abstract

Three types of bias: personal, institutional, and socio-cultural, will be examined together with their effects on public policy. Personal bias exists whenever a scientist, instead of being solely motivated by the search for empirical truth, tries to gain a personal benefit or advantage from research results or is unduly influenced by ideological commitments. Institutional bias occurs because “every institution directs its activities to the perpetuation of its own power and to a narrow range of objectives and missions” (Barbour IG, Technology, environment, and human values. New York: Praeger, 1980). Socio-cultural bias in Western industrialized society is reflected by the fact that most research is narrowly focused only on the mechanistic understanding of natural phenomena, a bias which arose from the discovery that mechanistic knowledge enhances the ‘control’ and exploitation of nature.

Based on a detailed analysis of each kind of bias, it will be shown that self-interest, whether that of an individual scientist, a funding institution, or an entire society, is the primary cause of bias in environmental research. In general, the greater the stakes, the greater the distortion of objectivity, and the greater the likelihood that environmental policies are biased in favor of the entity that is afflicted by the excessive self-interest. Finally, a number of recommendations are given on how to minimize each type of bias and thereby maximize the effectiveness of environmental policies.

1. Introduction

Many people, including those involved in environmental research, believe that science can provide objective facts about environmental problems and that these problems can be successfully solved by policies that are based on sound, objective

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scientific data. If environmental policies fail to be effective, it is generally attributed to the undue influence of special interest groups (i.e. politics) rather than poor or biased science. In short, it is widely held that science provides objective and value-free information about environmental problems and that issues of subjectivity and values are outside the domain of science. Subjective opinions and values, by contrast, are thought to enter only into the picture during the political process when objective scientific data are interpreted, judged, and drafted into environmental policies [2,3]. This is, in the words of science historian Proctor, "the ideology of pure or value-free science, the belief that science in itself is pure, and that values or politics enter only as contamination" [4].

It is the purpose of this paper to show that it is intrinsically impossible to carry out objective and value-free scientific research and that, in fact, all environmental science is inherently biased by subjective opinions and values. Bias in this paper is defined as the systematic and consistent deviation from objective truth due to either self-interest or dogmatic belief systems. As in statistics, the true nature of reality can never be known in the presence of bias even if an infinite number of repeated attempts are made to search for it [5]. Bias is present at all stages of research, from the initial formulation of the hypothesis through the design and execution of experiments to the final interpretation of the results [6–8]. The fact that environmental research is inherently biased has significant consequences with respect to the effectiveness of environmental policies. It is clear that bias in scientific research readily translates into biased or one-sided environmental policies. This concern has been well expressed by Schnaiberg and Gould [7] who wrote: "…ultimately, the most significant problem resulting from the way science is used in environmental policy-making is the fundamental assumption that scientific data can, in most instances, be used to make some objective judgment as to the type of action that is most appropriate, or whether any action is required at all". In this paper, three types of bias, namely personal bias, institutional bias, and socio-cultural bias, and their effects on public policy, will be examined and discussed in more detail.

2. Personal biases

Personal bias exists when a scientist, instead of being solely motivated by the search for truth, tries to gain a personal benefit or advantage from the performance of scientific research. In some situations, for example, where desire for excessive profit is present, the self-interest motive and the resulting biases are blatantly obvious and therefore can be readily identified. However, in most cases the scientist's idiosyncrasies are less obvious making the detection of the resulting biases more difficult. Several typical self-interest problems and their related personal biases, in order of increasing subtlety, are discussed below.

We have heard of scandalous cases where greed for profit, fame, or promotion has prompted environmental scientists to omit, falsify, or misrepresent research findings. This problem is particularly prevalent where an individual has to play the role of both researcher and salesperson, as is often the case in small businesses that promote innovative products of questionable effectiveness and quality. However, personal bias can also occur in larger companies where researchers are given strong incentives (raises, bonuses, promotions, job security, etc.) to obtain ‘positive’ results, i.e. those that enhance the company’s financial bottom line. Thus, the greater the temptation of rewards, the greater the chances of biased research reports.

Another type of personal bias, probably more prevalent in academia, occurs when the researcher has a strong desire for recognition. Since the researcher has a strong need to attract attention to himself, he may overstate his research findings in order to make them appear more impressive. In the worst case, research data may actually be invented. However, more common are probably those cases where the researcher publishes marginal findings solely to enhance his publication record. In general, the greater the need for public recognition, the greater the temptation to bias research results to get this type of attention.

A more subtle but common bias may occur when the researcher is unwilling to accept viewpoints that are different from his own. As a result of this strong need to be right, the researcher is unable to develop a balanced and objective interpretation of all existing facts. Instead, he will consciously or subconsciously select only data that support his own preconceived ideas [9]. It is clear that as the tenacity to hold onto his own opinions increases, bias will become more severe.

Another personal bias that is also related to the problem of not considering all available facts occurs when a researcher is either unwilling or unable to completely comprehend the entire research field as a result of a less than optimal educational preparation. In these cases, the researcher is more interested in easy and fast credit for his work rather than obtaining high-quality, objective research findings. The frequency of this type of bias has increased in recent years as more papers of marginal quality have been published in journals that do not require rigorous peer review [10,11]. The author receives the credit while the reader has to be concerned about the validity of the findings.

When a scientist subscribes to a particular ideology or worldview it is possible that these strong personal values will bias the way the research is chosen and carried out [12–18]. For example, a researcher who does not want to recognize the seriousness of many environmental problems because this insight may threaten his present consumer lifestyle may actually design experiments to make environmental issues appear harmless and thereby avoid confronting potentially painful lifestyle changes. By contrast, a researcher committed to environmentalism may carry out research to show that all environmental impacts are harmful and serious. This subscription to different values and paradigms is often the reason why even experts disagree when interpreting the same set of data [19].

Since almost all research funding including the researchers’ salaries are provided by private companies or government agencies, it is virtually impossible to conduct truly independent objective research. Since the researcher’s livelihood depends on the degree to which he pleases the granting agent (government, corporations, or private clients) there is always the temptation to go along with the wishes of those who provide the funding. As many whistle-blowing cases have revealed [20], individuals who normally have high ethical standards may, under pressure from their employers, falsify or omit data in an effort to protect their positions. While these extreme cases are relatively rare, situations are probably much more common where researchers, in order to just keep their jobs, have a tendency to design and interpret experiments in a way that is favorable to their employer's or client's viewpoint. This type of subtle bias is related to the institutional bias that will be discussed in more detail below.

2.1. How do personal biases affect public policy?

Fortunately, compared to institutional and socio-cultural biases, personal biases have relatively little effect on public policy since this type of bias is significantly reduced through the process of consensus building within the scientific community [6,21]. Through peer review, publications, and discussions at conferences, the scientific community will weigh all given research results and will, over time, reach a more or less balanced conclusion. It is clear that the process of consensus building will be more complicated if research findings have been biased as a result of the individual researcher's self interests. Generally, personal bias will make the process of consensus building more time-consuming and inefficient.

Thus, the main effects of personal bias on public policy is twofold. First, formulation and implementation of environmental policies may be delayed since the process of arriving at balanced and objective information has been slowed by personal bias. Second, since additional research is often required to compensate for biased findings, personal bias will also make the process of gaining objective knowledge about environmental problems more costly.

2.2. How can personal biases be minimized?

It is clear that the process of gaining new scientific knowledge would be more effective, both in terms of time and money, if personal biases could be minimized. For this purpose, it is most important that researchers are made aware of the fact that their self-interests will almost always bias their research findings. It is unfortunate that despite years of rigorous science education at US universities and colleges, students only very rarely receive training in such topics as professional ethics or philosophy of science. Nevertheless, even if such training were to be common, it ultimately depends on the individual scientist to recognize his or her own selfish motives, some of which may be subconscious, and to constrain their influence as much as possible. Since the ability for introspection and self-restraint are part of the personality structure of the individual researcher, it is clear that objective science does not only depend on sound research methods but also on good character. Thus, a reduction in personal bias is partly a matter of awaking personal integrity which would translate into a growing commitment to search for truth rather than to gain personal advantage or cling to dogmatic beliefs.

3. Institutional biases

While scientists in the early years could pursue their own research with few constraints, this type of freedom no longer exists today. As a result of the high costs of conducting experimental research, almost all environmental research is currently funded by institutions such as governmental agencies or large corporations. Institutional bias occurs because, according to Barbour, "every institution directs its activities to the perpetuation of its own power and to a narrow range of objectives and missions" [1]. While institutions may bias research in their favor at any stage of the research process, it is particularly common that institutional values 'infiltrate' during the process of formulating hypotheses and objectives [22]. The resulting bias can be very subtle, albeit powerful. Again, according to Barbour: "The way the issues are defined in the context of the policy debate will determine what data are relevant. The time-scale employed may emphasize short-term or long-term effects. The boundaries of analysis in space and time, and the types of impacts considered, will affect one's conclusion…the most important decision may be the way a problem is conceptualized and bounded" [1].

Two examples from the field of bioremediation will be used to illustrate the subtle effects of institutional bias. After the enactment of numerous environmental regulations (e.g. Superfund, RCRA, etc.), a wide range of environmental cleanup technologies, ranging from incineration for contaminated soils to pump-and-treat for impacted groundwater, were developed and evaluated during the 1980s. Bioremediation — the removal of contaminants via microbial degradation — emerged as one of the most preferred cleanup technologies, primarily because of its relative cost-effectiveness and general public acceptance [23]. Despite these advantages, it was found that bioremediation had several serious limitations. First, it soon became evident that bioremediation could not meet some of the stringent cleanup criteria for soils that had been contaminated for long periods of time. In these aged soils, many of the strongly sorbed contaminants were found to be unavailable to degradative microorganism. It logically followed that, due to these bioavailability limitations, many aged soils cannot be treated successfully using cost-effective bioremediation. Instead, a more expensive treatment technology may be required to meet soil cleanup standards. Second, in the case of aquifers contaminated with soluble petroleum hydrocarbons such as carcinogenic benzene, it was found that active in situ bioremediation, i.e. the engineered addition of oxygen and nutrients to groundwater, would be highly effective but grossly cost-prohibitive in view of the several hundred thousand leaking underground storage tank sites in the US.

The corporations and government agencies that are liable for the cleanup of these contaminated soils and aquifers soon responded by reformulating the above two environmental problems in a way to make them appear less harmful and thereby enhance their chances for reduced future remediation costs. In the first case, the question "What technology can be used to remediate aged soils to meet cleanup targets?" was reformulated as "Can it be shown that the residual contaminant fraction that remains after (inexpensive) bioremediation is not bioavailable to environmental receptors and therefore does not cause any harm?" This newly formulated objective led to a number of bioremediation research programs — for example, the EPA/DOE/NSF/ONR Joint Program on Bioremediation [24] and the industrial initiative on Environmentally Acceptable Endpoints [25] — that were particularly tailored to investigate how bioremediation reduces the bioavailability and thus the risk of soil-bound contaminants. As a result, as verified by a literature search, the percentage of bioremediation publications dealing with issues of bioavailability and sorption have increased almost fourfold during 1994–1998 as compared to the 1980s and are likely to increase even further in the future. In the second case involving hydrocarbon contaminated aquifers, almost all bioremediation research was redirected to studying the phenomenon of natural or intrinsic bioremediation. In essence, the initial question of "Is it possible to remediate contaminant plumes using engineered bioremediation?" was reformulated to "Do contaminant plumes disappear naturally without human assistance?" As a result of this new research direction, numerous studies have been published to show that natural biodegradation, or bio-attenuation, is indeed occurring at certain sites [26].

While these reformulated research questions will no doubt prompt researchers to discover many new and interesting facts, the point here is that the resulting research findings will be biased in favor of the funding agent whose values were incorporated into the research questions and objectives. It is clear that the formulation of the question will affect the type of answers, i.e. the nature of the hypothesis to be tested influences how experiments are designed, what type of data are collected and selected to prove or disprove the original hypothesis.

As an example of how the formulation of research questions may lead to different viewpoints about the 'real' state of environmental problems, it is useful to consider different versions of research objectives in the above mentioned soil bioremediation case. The question of what technology can be used to successfully clean up aged contaminated soils would focus research on technology development and would ultimately lead to a number of innovative soil treatment technologies. The likely conclusion of this research would be that soil treatment by innovative technologies could be successfully carried out but would be expensive. Alternatively, the reformulated question of whether bioremediation can reduce the bioavailability and risk of contaminants in aged soils to such an extent that no additional treatment is necessary will spark research that will focus on the risk reduction aspect of bioremediation treatment. The probable outcome of this research would be that bioremediation is the most cost effective technology for reducing the overall risk related to aged soils although some residual risk is likely to remain. Finally, a third hypothetical research question such as "What are the long-term impacts of leaving soils with residual contamination in the environment?" would focus the research effort in yet another direction. For example, it may be found that these aged soils, even after bioremediation treatment, still cause very subtle, long-term chronic toxic effects that may be unacceptable to future generations.

In summary it is clear that perfectly acceptable (i.e. objective) research methods can be used to selectively reveal different aspects of potential environmental problems depending on the type of questions asked. If funding institutions bias the direction of research by focusing primarily or exclusively on aspects that may result in more favorable information and if this type of scientific data is used for drafting environmental policies, it is clear that institutional bias can have a significant effect on public policy.

3.1. How do institutional biases affect public policy?

The main effect of institutional bias is the corruption of democratic processes that are designed to assure justice and fairness in the formulation of environmental policy issues and options. This occurs because funding institutions often have large financial stakes in the outcome of environmental policies and therefore are tempted to direct research in an effort to obtain scientific information that may favorably influence the policy debate. The main problem is that many policy issues and options are indirectly — through a biased research focus — defined by the funding institutions before the 'real' policy debate has even begun. By the time environmental policy questions are introduced for public debate, the limited availability of research data will greatly affect the discussion of potential policy issues and options. Consequently, the public is never involved in some of the most important decisions and questions such as "What are the environmental problems of concern (to me)?" and "What are the potential solutions and options (that may appeal to me)?" Instead, the public is presented with predefined problems and solutions that most likely will result in environmental policies that benefit the liable parties but may cause harm to the public and the environment.

Another aspect of institutional bias is that it is very subtle which, in turn, makes it both more effective and dangerous. Institutional bias is not readily obvious because most people believe that scientific data form objective foundations for policy debates. As a result of this blind belief in scientific objectivity, the public, and even researchers, can be manipulated into agreeing to environmental policy options that are not necessarily in their or the environment's best interest. The use of science as a manipulative tool by dominant interests has been succinctly pointed out by Helen Longino who wrote: "For others, a value laden science is the more frightening prospect of a science continually at the mercy of dominant interests, a science that, under the guise of neutrality, helps create a world to serve those interests" [6].

3.2. How can institutional biases be minimized?

Institutional bias could be largely prevented if a diverse group of stakeholders that represent the public (e.g. corporations, regulators, environmental organizations, researchers, citizens groups, etc.) would be asked to formulate the research needs and objectives. This concept is not entirely new. In their pioneering work on post-normal science, Funtowicz and Ravetz [27–29] have proposed that the uncertainty of policy decisions related to the management of complex environmental systems be decreased by extending the peer community to include not only scientists, as has been traditionally the case in 'normal' science, but also a variety of stakeholders representing different viewpoints. Similarly, a recent report by the National Research Council strongly recommends the involvement of a wide spectrum of interested and affected parties in defining environmental risks [30]. In addition, the US Department of Energy (DOE) has successfully carried out stakeholder participation programs to evaluate innovative cleanup technologies that may be used at DOE sites [23,31]. Various stakeholders are asked to voice their opinion about potential technologies and their issues and concerns are considered during technology development and testing. As a result of this stakeholder involvement, the acceptance of innovative technologies has been greatly increased.

After the stakeholders have determined the research needs, an independent government agency could provide the funding to qualified researchers. It is important that funding decisions are not affected by special interests but are rather based on how well the proposed science will address the research questions. It should be noted, however, that even if all institutional bias could be eliminated, environmental research would still be affected by the values of society. The resulting socio-cultural biases will be discussed in the next section.

4. Socio-cultural biases

For more than 300 years, the western cultures of Europe and North America have placed heavy emphasis on the experimental sciences for gaining a deeper understanding of nature and the universe. It is important to recognize that the philosophers of the Enlightenment did not promote the sciences because it would expand knowledge for its own sake but because it had the potential for improving a culturally defined the quality of life. According to Eugene Schwartz, "the principal aim of knowledge for Francis Bacon, as for most of the other precursors of the school of scientific progress, was the utilitarian goal of improving man's condition by lessening his suffering and increasing his happiness. Casting aside the viewpoint of the Greek philosophers that knowledge affords its own intellectual satisfaction, Bacon defined the true goal of the sciences to be 'the endowment of human life with new inventions and riches'. He called on man 'to establish and extend the power and dominion of the human race itself over the universe'" [32].

It is clear, then, that modern science was from the very beginning never value-free and objective. By contrast, the pursuit of sciences was and still is strongly motivated by societal desires to improve living conditions and, according to the utilitarian dogma, to maximize the happiness of the greatest number of people [33]. It is not surprising that scientific knowledge was almost immediately converted, with the help of engineers, into useful technologies which promised to fulfill the wishes of society. The utilitarian emphasis also explains the heavy focus on mechanistic research [2]. According to Longino, "mechanistic research is favored because it enables the manipulation of nature…" and that "…this was in line with the needs of society" [6]. However, it must be recognized that "these mechanistic models are not necessarily true in the sense of being accurate representations of an underlying or fundamental reality" [6]. Consequently, mechanistic sciences are fundamentally biased by subjective cultural desires. Again, according to Longino: "Because the characterization of the object of inquiry depends not on what nature tells us but on what we wish to know about it, that description will link the inquiry to the needs and interests it satisfies. Mechanistic philosophy, which characterized the natural world in a particular way, made certain kinds of questions appropriate and others inappropriate… the kind of knowledge sought about these objects is a matter of decision, choice, and values as much as of discovery. It is important to acknowledge that these choices are not often, if ever, perceived as such and thus could as well be described as the unconscious projection of human needs onto nature" [6].

In summary, western sciences have never revealed objective facts about the 'reality of nature' but rather have focused on elucidating specific mechanisms that could be used to exploit nature for the 'benefit of mankind'. By focusing on isolated mechanisms and providing powerful information on how to exploit nature, western sciences have actually been a significant causative factor in the current environmental crisis. For the most part, environmental problems were difficult to predict since mechanistic environmental research, by its very nature, can never elucidate all the interconnected relationships that exist in the natural world.

There are many examples that can be used to demonstrate the limitations and one-sidedness of mechanistic environmental research. For example, it will never be possible to determine all the adverse effects that synthetic chemicals may have in the environment. Scientific research has only focused on a few selected chemicals and their detectable effects on a very small subset of target species or organs. The selection of chemicals and species/organs to be studied as well as the choice of research methodology for the measurement of adverse effects (e.g. such as acute or chronic toxicity) are all subjective and therefore intrinsically biased. In theory, objective information could only be obtained if *all* possible adverse effects of *all* synthetic chemicals, pure and in mixture, could be assessed for *all* species. In practice, this is impossible because:

1. the detection of adverse effects is limited by the state-of-the-art of current scientific knowledge and methodologies (e.g. the endocrine disruption potential of chlorinated synthetic chemicals could not have been predicted 50 years ago due to lack of biological assays for the measurement of endocrine disruption);
2. the testing of millions of different chemicals and chemical mixtures is cost-prohibitive;
3. there are millions of species, many of which have not been identified; and
4. the potential effects on future generations are impossible to measure or predict.

In conclusion, science can only provide a very limited view of reality, a view that is inherently biased by the values of the observer.

4.1. How do socio-cultural biases affect public policy?

Since mechanistic environmental research can only provide extremely incomplete information about the state of the environment, it is clear that public policies that are based on this limited information must also be inherently limited in their effectiveness. In fact, it is somewhat questionable whether Western science which is strongly biased towards the exploitation of nature can provide useful information that would result in policies that can effectively ameliorate the effects of such exploitation (e.g. environmental degradation). This concern was expressed by policy analyst Sarewitz who stated: “Because mainstream science is reductionist while the environment is an interconnected, complex system, much of modern science and technology may be intrinsically unsuited to successful confrontation of ecological crises [2].” Similarly, conservation biologist Ehrenfeld, who sees contemporary science and technology as an expression of an overly anthropocentric humanistic culture, is convinced that “ there is no true protection of Nature within the humanist system — the very idea is a contradiction of terms” [34].

Many environmental policies, while reducing obvious pollution, are in effect reducing or eliminating the constraints that pollution placed on the exploitation of natural resources. If environmental constraints (such as serious pollution or resource depletion) are removed, the exploitation of natural resources will accelerate and lead to even more serious, but delayed, environmental consequences [7]. For example, the introduction of catalytic converters on automobiles has reduced obvious air pollution in metropolitan areas. Assuming that, in the absence of a catalytic converter, air pollution would have increased at some point to intolerable levels that would have provoked some type of mandatory regulation on the total number of miles driven, it is clear that the introduction of the catalytic converter effectively removed this potential constraint on driving. Consequently, the catalytic converter has improved the air quality in the short term but may have indirectly, by removing a powerful environmental constraint, contributed to more driving, greater traffic densities, more gasoline consumption, and consequently more greenhouse gas emissions in the future. Thus, the net effect of this pollution abatement effort was to accelerate resource consumption and long-term environmental problems such as global warming. In conclusion, mechanistic research is intrinsically biased by socio-cultural desires (e.g. the exploitation of nature for the culturally perceived and defined ‘benefit of mankind’) and policies based on such research will therefore have only limited effectiveness in protecting the environment from further exploitation and degradation.

4.2. How can socio-cultural biases be minimized?

Socio-cultural bias may be reduced by stepping outside the dominant western exploitative worldview and learning from traditional cultures that are still or were recently based on a non-exploitative relationship with nature. Prior to the industrial age, most humans lived for thousands of years in a sustainable, harmonious manner in their respective bioregions and, with a few exceptions, did not cause significant environmental disruptions. It is time to learn again from these indigenous cultures how to relate to nature in a non-exploitative way and thereby reduce or hopefully eliminate the negative socio-cultural biases in our current worldview [35]. For example, it would be useful to include members of Native American nations as well as those environmentalists committed to ‘deep ecology’, a philosophy in which nature has a ‘right’ to exist independently of anthropocentric utilitarian considerations

[36], in a debate on what kind of relationship our western society should have with respect to the environment. A new paradigm might emerge in which the cultural consensus shifts away from crude exploitation towards a more balanced interaction with nature.

Since science is a social activity that is strongly influenced by the dominant values of society, it is clear that a cultural change in attitude towards nature will automatically result in a change in scientific objectives and methods. While science at present is largely reductionistic in order to generate knowledge useful mainly for exploitative enterprises, science in the future will have to become ‘holistic’, elucidating many of the complex relationships between humans and the environment in order to promote sustainable lifestyles. In a way, environmental science has already been leading the transition from reductionism to ‘holism’ by having pioneered research that reveals the complex interactions and feedback mechanisms which exist in natural ecosystems. As a result of this systems approach to environmental research, many previously unrecognized environmental problems (e.g. the widespread toxic effects of pesticides and industrial chemicals, the influence of economic development on species extinction, and the impacts of fossil fuel combustion on the global carbon cycle, etc.) have been detected and studied. The newly gained knowledge about these ecosystem disturbances will hopefully serve as a warning regarding the exploitative behavior of western societies and may lead to less environmental exploitation and underlying socio-cultural biases in the future.

5. Conclusions

Based on the above discussion, it is clear that self-interest, be it that of an individual researcher, a funding institution, or an entire society, is the dominant cause of bias in environmental research. In general, the greater the stakes, the greater the distortion of objectivity, and the greater the likelihood that environmental policies are biased in favor of the entity that is afflicted by excessive self-interest. The most effective way to minimize bias is to reduce the influence of self-interest by taking the views and concerns of the greater ‘community’ into account. For the individual researcher, this greater community consists of peers that review the research, for funding institutions it consists of the various stakeholders that are interested in the outcome of research, and for western society it consists of other cultures that do not have an exploitative but rather a cooperative and protective attitude toward nature.

Thus scientific objectivity increases in proportion to the number of viewpoints that are taken into account. In the words of Longino: “From all this follows again that the greater the number of different points of view included in a given community, the more likely it is that its scientific practice will be objective…these conditions reinforce the point that objectivity is a matter of degree” [6]. If objectivity is a matter of degree it follows that the effectiveness of environmental policies that are based on more or less biased research is also a matter of degree.

It can therefore be concluded that environmental policies will have the greatest effect in protecting against environmental problems and crises if they are based on rigorously peer-reviewed research that takes an (eco) systems approach and that is funded by institutions that have no stakes in the outcome. It is clear that current environmental research is far from this ideal. This may not only explain the limited success of past environmental policies [7,37] but should also prompt us to enact only the most conservative policies that result in the least environmental disturbance, i.e. “in practice, this implies a relative conservative approach to natural systems: presumptions in favor of natural, evolutionary changes rather than man-made changes, in favor of native plants and animals, in favor of slow rather than rapid change, in favor of biological rather than mechanical, artificial, and manufactured solutions to environmental problems” [33].

5.1. Disclaimer

The views expressed in this articles are solely those of the author and do not necessarily reflect the official position of Battelle Memorial Institute, Pacific Northwest National Laboratory, or the US Department of Energy.

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