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Ethics, Physics, and Public Policy

Tina Kaarsberg
U.S. Department of Energy

ETHICS, PHYSICS AND PUBLIC POLICY

Tina Kaarsberg
Senior Scientist, Vista Technologies, Inc.

Abstract: This paper discusses the ethical aspects of physicists', and the physics community's involvement in public policy. The work of individual physicists is often quite distant from any societal impact and thus public policy is not normally considered an important ethical consideration for individual physicists. However, in light of the great societal impact of physics-based technologies, the physics profession, by definition, has a major impact on public policy. In addition, most physicists in the U.S. benefited considerably from public funding in their physics education, and many continue to depend upon federal and state funding. Thus, there is a strong ethical argument for the physics community to support some physicists and institutions that work to improve public policy so that these technological impacts are beneficial. For example, sustainability problems due to unequal resource allocation and unsustainable consumption patterns are both caused by and can be solved with technological innovation. Physics training can be useful for understanding and developing solutions to these problems. However, public policy, not physics, will largely determine whether technology exacerbates or solves these problems in the future. Therefore, this paper presents a framework of four world-views (the general public, bureaucracies, activists and chiefs) that was developed by anthropologists. It then suggests how this framework can be used to guide the broadening of the physics profession's impact on public policy. It is intended to counter the view of many physicists that policy changes they would recommend (such as those that would promote the use of more sustainable technologies) are not "politically feasible." This paper argues that such changes would be more politically feasible if the physics community trained and supported more "translators" to work with the full set players that impact policy in our democratic society.

I Introduction: Ethics Arguments For and Against Physicists' Involvement in Policy

In the early 1990s the American Physical Society (APS) Panel on Public Affairs began work on an ethics policy. The resulting statement (see Appendix 1) focuses almost exclusively on internal quality control. In this view, ethics means ensuring that physicists don't lie, steal or fail to give proper credit for data. External issues need not be considered since societal benefits flow automatically from scientific research. However, from a societal point of view, the internal quality control in science is not much of a problem. For example, provable fraudulent or falsified data has, by one estimate (Holton 1996), been down at the astonishingly low level of around 0.0002 percent. From the public point of view, the enormous external societal impact of science in general and physics in particular is a much larger issue. The narrowly focused physicists ethics statement is in stark contrast to the broad ethics statements of the chemists and electrical engineers (see Appendix 2). Physics impact, as the history of physics shows, is not always beneficial. Furthermore, the many physicists that have been funded by taxpayers for part or all of their careers have a direct social responsibility to give something back to society. If ethics is viewed in this broader context beyond physics itself, there is a strong ethical argument for the physics community to work to improve public policy so that these technological impacts are beneficial. This responsibility means also more than just providing just the facts to policy makers. According to a recent analysis it would be very difficult to point to any major political controversy that has been resolved on the weight of authoritative scientific data. (Sarewitz 1996). Finally, besides looking to influence policy outside of physics, physicists must look at their own profession from a public policy point of view. Physics act as if the contribution of physics to society cannot be improved by any changes in the way that physics is carried out. According to a Sarewitz ìthe inescapable extension of such arguments is that it is appropriate for science to have a profound and irreversible impact on the course of society, but inappropriate for society to exercise jurisdiction over how science goes about creating this impact.

That is not to say that each physicist has an ethical responsibility to attempt to personally influence policy makers. Few physicists are called upon to provide advice to policy makers nor would most of them be good at it. Successful physics research is arduous enough without adding an extra requirement to learn to communicate successfully with policy makers. Furthermore, such communication skills are not easy for physicists to learn since physics training and culture foster a communications style (aggressive, skeptical, facts to be conveyed more important that status) very different from that required to convince policy makers.

But all physicists should understand and appreciate the important role of physics in society. They should also all understand that the physics community has an obligation to society and as explained in the next section, this obligation has expanded dramatically in the past generation. Promoting this understanding may have the serendipitous benefit of attracting a wider variety of students to physics. Given the great positive contributions of physics-based science and technology to our society, it is highly ironic that physics students seem far less likely (than those in fields with a far smaller societal impact) to cite a desire to "contribute to society" as their reason for studying physics..

Many physics leaders are beginning to understand the need to judge their work from a perspective beyond physics. Indeed a prominent physicist recently argued "concern for humanity is our central driving force" (Bromley 1996). But to do this, physicists must clarify both for themselves and for those they would influence, how their research can benefit humanity in areas such as sustainability.

II. The Ethical Argument for Expanding the Physics Community's Policy Impact

During and immediately after the Cold War, physicists' were preeminent in influencing policy. This was done by a small elite group communicating directly with policy makers. Because the societal impact of science-based technologies was not yet broadly felt, and the relatively small number of physicists, it was considered appropriate that only an elite worried about the scientific and technological aspects of policies and the polices for science and technology. But in the past generation, this picture has changed dramatically. From the societal point of view, there are looming challenges both caused by and solvable by physics and physics-based technologies. From a physics community point of view, it is impossible for all but a few of the next generation to be clones of their thesis advisors. Other possibilities must be made more available through deliberate policy changes. Thus the old model physics and public policy--where an elite group advised policy makers, is now too narrow and unfair to both society and the physics community. The elite physicists who sit on advisory committees do not necessarily have the same interests as the majority of the physics community -- especially its younger members. Nor do these elites even have the staff support, background and training to be very effective in many cases. Besides, many commentators have noted that physicists are no longer especially successful at using this method.

The spread of physics-based technologies (see Table 2) to impact most of the population means that the policy decisions involving these technologies cannot be made only by "experts." Furthermore, as demonstrated in the next two sections, physics can produce enormous benefits. U.S. policy makers now listen to a far wider spectrum of voices on scientific and technical issues. Decisions and policy involving science and technology must now go through the civic process that has evolved in this country. These processes have been studied extensively by political scientists (Bennett 1994), anthropologists (Douglas 1986, 1978) and recently, science policy analysts (Ausubel 1993). The physics community needs to have in its membership some who have also studied and understand these processes.

III. Physics and Sustainability

One policy issue especially well suited to physicists is sustainability. Unequal resource allocation and unsustainable consumption patterns are caused or exacerbated by technological innovation. Physics training is very useful in both understanding and solving these "sustainability" problems. But to date, only a small minority of physicists has been involved. There is no time to waste. The looming global, regional and local impacts of unequal and unsustainable patterns will be felt by most of the readers of this book within the next generation.

A) Physics Perspective and the IPAT equation

Physicists invented and first applied thermodynamics. They understand conservation of energy. For them, the following data is cause for alarm: Human energy consumption (now at about 10 TW) is approaching the TOTAL energy consumption of the world's ecosystems (Johansson 1992) . From a materials point of view, the situation is also dire: humans use 40 percent of all the plant matter produced on land. Or to put it mathematically, humans' global resource use is now growing at about 5.5 percent each year; at that rate, human demand on the earth's resources doubles every 13 years.

Physicists also understand chaos and the math behind "winner takes all" tendencies of our technological global market economy. There is now a difference of two orders of magnitude between the per capita gross domestic product (GDP) of rich and poor countries. Between 1960 and 1980, the gap between rich and poor nations increased from a factor of 20 to a factor of 46, and it's still widening. According to the World Bank, "Even if the growth rate of the poor countries doubled, only seven would close the gap with the rich nations in 100 years. Only another nine would reach our level in 1000 years." Industrialized countries, with 22 percent of the world's population, command about 85 percent of the world's wealth and income, use 88 percent of its natural resources, and generate most of its pollution and wastes. This inequity has already lead to instability and misery in some countries.

The following equation illustrates why science and technology are key to both causes and solutions of such problems. The Impact (I) of humans on the environment is represented qualitatively by the IPAT (Ehrlich 1971) equation:

*Impact = Population * Affluence(GWP/person) * Technology(Impact/GWP)*

where P is population, A is the per capita "affluence" factor measured by per capita rate of consumption (or Gross World Product (GWP) per person), and T is the measure of the impact per unit of GWP of the population.

From a global perspective, it appears that the impact of humans, already far greater than any other species, is likely to increase dramatically within the next generation. This is clear from an examination of the individual factors. The discussion will focus on the growth rates in these factors and thus the growth in the overall human impact.

P, the world population grew by 6 million per year around the beginning of the twentieth century. By 1950, it was growing at 18 million per year. By 1975, 60 million per year. Currently P grows at 100 million per year (Hawken 1993). By 2050--a time when most readers of this book are planning to be around, P is projected to double from today (12 billion people).

Factor A for affluence, as measured by output or GWP is expected to grow by a factor of 10 or more (IMF 1996) in the next generation. Barring manmade or natural disasters, this appears likely since most policy makers agree that it is desirable for the affluence factor to increase. Thus, the world average GWP per capita is expected to increase by a factor of five or more.

The Technology factor -- Impact/GWP, as shown in Table 1, has also historically increased. However, policy makers are now mainly in agreement that this factor can and should go down.

Activity	Energy Flux (GJ/ha/year)	Material Flux (kg/ha/year)
Hunter/gatherers	0	40
Intensive fish farm	200	200,000
Manhattan	20,000	---
Oil Refinery	1,000,000	1,500,000,000

Table 1: Impact of Increased Use of Technology on Energy and Product Densities of Some Human Activities (Sizman 1989).

This factor is known as the "technology " factor because the technological contribution to it is what is changing most rapidly (see Table 2). Thus, the technology contribution of the impact per unit of wealth is the only one of these three factors that seems likely to be turned around. Since the other two factors contributing to Impact are increasing by a factor or 5 or more, in order for overall impact to remain the same, the technology impact factor must decline by nearly an order or magnitude. The challenge is that this must occur more often and more quickly than it has in the past.

B) How Physics Can Help

Slowing and eventually stopping the unsustainable growth in pollution and resource depletion described in the previous section requires technologies that are orders of magnitude more efficient. For example, new knowledge in physics about the microscopic properties of matter must be rapidly translated by physicists and others into technologies such as the physics-based technologies described in Table 2. For example, materials physics led to the manufacture of single crystal turbine blades that will be a key component of highly efficient advanced turbines for power generation from non-fossil fuels such as gasified biomass. Chemists and physicists have made crucial contributions to the development of fuel cells that produce power many times more efficiently than combustion systems that are limited by the Carnot cycle. New electric power technologies that incorporate these two technologies now produce electric power with double or triple the efficiency of current systems.

The physics community also needs to be involved in promoting the use of such technologies once they have been developed. Leading edge researchers, including physicists, must be involved in the formulation of policy to address environmental and resource challenges because incremental advances will not suffice. The IPAT equation explains why.

Technology	Order of magnitude improvement within the past few decades
Energy	Efficiencies of thin film photovoltaic cells have increased 500% since 1978 More efficient motors and new lightweight materials for wind turbines have reduced costs by 90% since 1991
	Light bulbs made using plasma physics and microwave technology don't burn out, produce full spectrum light, and use 66% less electricity than regular bulbs
	Automotive emissions have been reduced by 70-90% in the US since the '70s
	Microwaves require 1/10 the energy of thermal processing in some industrial processes
Materials	Improved materials processing methods and a growing market have led to a 600% increase in the amount of recycled plastics from 1987 to 1993
	1995-plastic bags are 70% thinner and glass soda bottles with 31% less glass than in the 1970s as a result of technological advances
	The cost of 1 gram of nanocrystalline materials (used in sunscreens) decreases from $1000 to less than 10 cents
Computing	Silicon microprocessor performance is 25,000 times better than it was 25 years ago
	A 3.5 inch disk can now store more data than 1000 of the original hard disks could
Instrumentation	The accuracy of atomic clocks (the basis for Global Positioning Systems (GPS), etc.) has increased 1000% every decade since 1950
	The first GPS receiver for civilian use cost $150,000 in 1984 and required two people to carry it--In 1995, hand-held devices cost $200
Communication	the cost for a transatlantic phone channel has decreased from $60,000/year in 1956 to $60/year today

Table 2: Physics-based Technologies (AIP 1996)

However, to date, persons working directly on such problems have not been supported or recognized by the physics community. It is ethically problematic that the physics community is happy to claim credit (AIP 1996) for the energy, communications and other technologies which stem from physics work, but as a community it has not taken the responsibility for ensuring that these advances described in Table 2 benefit society. For while a physics degree provides the background, it does not provide the means to work in these areas. According to a physicists' (Kammen 1996) at Princeton's Energy and Environment center, "There is no clear path, no university, agency, or society, that consistently trains people in this area." Furthermore, "rejection, and skepticism are rampant in this field, where projects are chronically under funded and understaffed." Physicists have made some very important contributions to energy and the environment , but with very little support or recognition from the physics community.

C) Public Policy and Physics-based Technologies

Public policy, far more than physics, will determine whether these new technologies exacerbate or solve these problems. There are countless examples of technologies that were assisted or conversely suppressed by public policies -- including automobiles and highways, electricity and other energy technologies. STE&E policies have been of interest to only a handful of experts. But now technological progress and its economic impact (see Table 2) are much more in the public eye. For example, physics and physicists have been very important to the early development of many new forms of renewable energy. Because many of the new renewable energy sources are small and modular, markets for them can develop very quickly in the right policy environment. For example, the cost of wind power had been dropping exponentially since the 1970s, but it still accounted for only a fraction of electricity production even in high wind areas. Then Germany, both its national and state governments, decided to "level the playing field" to encourage wind and other renewable energy. Wind received a price incentive of 3.7 to 5 cents per kWh or one-time capital investment grants of up to 60 percent of the facility cost (OTA 1995). The results are dramatic: in 1991, Germany had no installed wind power -- now it has more installed wind power than any other country in the world. To understand why German governments or any other governments decide to make such policy changes, it is helpful to use a framework established by social scientists.

D) Sustainability of the Physics Community

The physics community needs to expand its connection to societal problems including sustainability for internal reasons as well. In the past decade, there has been a growing problem of the "oversupply" of physicists. A successful professor will produce 10-20 Ph.D. students over his career. Given that the number of U.S. university faculty positions is relatively flat, it is impossible for all but a few of the next generation to emulate their thesis advisors. Yet they are being trained as if they are. Expanding physicists' contributions to policy will also open more career opportunities for physicists. In addition to a small number of directly policy related jobs, there could be vastly expanded opportunities by expanding physicists' roles in more interdisciplinary research, in innovation and technology diffusion and many other areas that are needed to address looming sustainability problems. It is still true, as recently stated by a physics leader, that "more than any other major, physics gives a versatile foundation from which to shift into other fields. (Schmidt 1996) But there need to be more deliberate attempts to develop and sustain these new and varied opportunities for physicists. An important step in doing this is to develop a framework for understanding and working with the full set of players in the policy process.

IV. Four World Views and Their Impact on the ST&E Policy System

Those who study policy, anthropologists, political scientists and others, have studied how policy is formed based on different types of world view. Figure 1 shows one mapping of the various points of view. There are four types represented in four quadrants -- of course these types rarely appear in pure form, but they are useful heuristic devices. These correspond roughly to the four ways of life identified by the cultural theory developed by Mary Douglas (Douglas 1986, 1978) and others. The horizontal axis displays the "group" aspect of world-view. This ranges from the most individual orientation on the left to the most collective orientation on the right. The vertical axis displays the "rules" aspect of world-view. It ranges from the most creative (those who like to create their own rules) to the most management oriented (those who try to get everything to operate by the set rules). Each of these cultural biases implies different approaches to the solution of societal problems.

Such formal analysis is useful because it provides a vocabulary for describing the system and it shows where the holes are in the current way physicists provide input to public policy. For example, it is clear that the "independent" and "public" voices are almost entirely absent from the physics/policy interface. Physics input to policy is primarily through the "chiefs." The ethics aspect of this is that including all points of view is important. It is the most ethical way to make decisions. This is a fundamental tenet of a civil society. Viewed this way, physicists now work in science and technology policy. A group of elite physicist providing advice only to the "chiefs" seems somewhat unethical or at least not socially responsible.

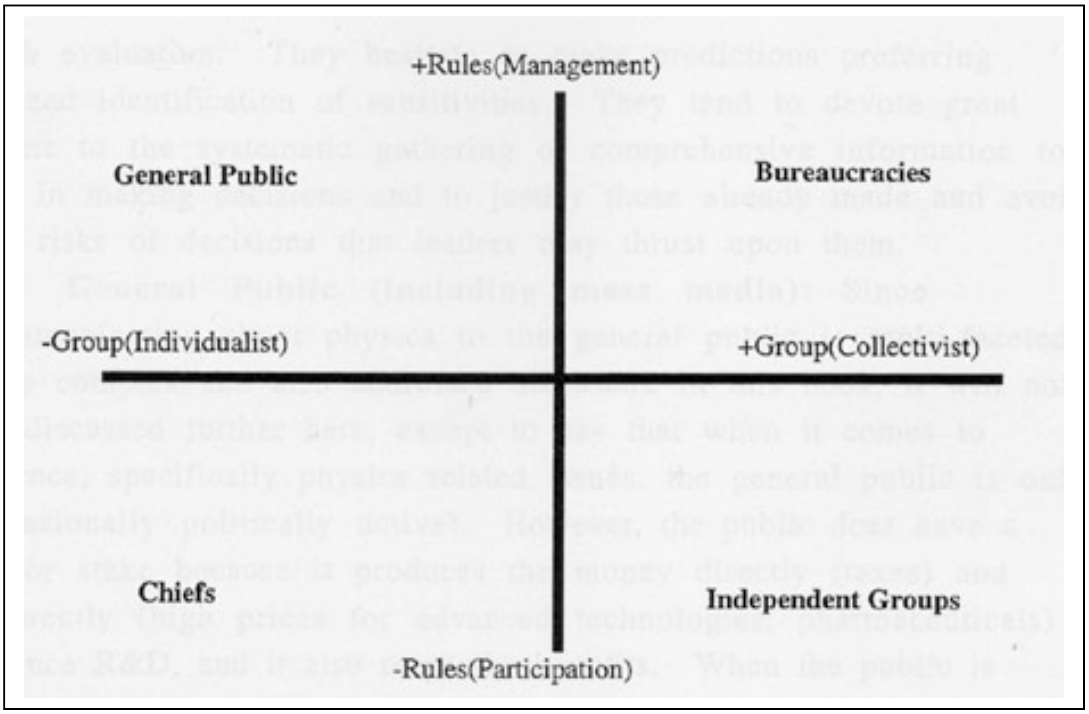

Figure 1: Four World Views [Located at the end of this paper]

Chiefs: These are the leaders and the "elites" whom they call upon for advice. Chiefs trade information and power and like to "do business" together privately, without rules and regulations. The chiefs' way of obtaining and prioritizing policy information is based more on their judgment of people, and whom they know and where they come from than on their training. Chiefs rarely receive information other than in face-to-face meetings. The average member of Congress reads only 15 minutes per day. Individual chiefs do not perceive communication failures, since they can pick up the phone and reach "anybody."

Bureaucracies: This is the set of stable organizations that supports the "chiefs." These exist both in government and in other large organizations. The bureaucrats attract those who prefer to work inside the system. Bureaucrats like to balance issues. Bureaucrats do not seek to change the system, just to optimize it through better-matched resources and tighter management. They seek to increase order and secure lines of authority. The organization chart is more important than the policy ideas. Thus, these ideas diffuse slowly. Since they are vulnerable to challenge by their bosses and the general public, bureaucracies protect themselves with evaluation. They hesitate to make predictions preferring instead identification of sensitivities. They tend to devote great effort to the systematic gathering of comprehensive information to aid in making decisions and to justify those already made and avoid the risks of decisions that leaders may thrust upon them.

General Public (including mass media): Since communicating about physics to the general public is multi-faceted, very complex and also addressed elsewhere in this book, it will not be discussed further here, except to say that when it comes to science, specifically physics related issues, the general public is only occasionally politically active . However, the public does have a major stake because it produces the money directly (taxes) and indirectly (high prices for advanced technologies, pharmaceuticals) to finance R&D, and it also reaps the benefits. When the public is activated, it can be a potent force in public policy.

Independent: These are persons or groups focused on a particular issue. The independents would tend to attract those who are skilled at communicating with the public and non-scientists. The groups are usually non-profit groups and are sometimes activists. Most "NGOs" (non-governmental organizations) fall into this category. According to "Independent Sector", an organization that assists and monitors NGOs in the United States, their number grows by over 5000 yearly -- but with high mortality. The Carnegie Commission (Carnegie 1993) has estimated that there may be four to five thousand scientific and technical NGOs in the US ranging from the APS to the Union of Concerned Scientists. Professional societies may act as independents but more often behave like bureaucracies. Activist NGOs are often in opposition to "chiefs" whom they view as part of exclusive clubs of the rich and powerful. They believe that scientists, whether chiefs or bureaucrats, in government or in industry will defer to their funding organization. Activists seek publicity and support for their causes. They are impatient and frustrated that others fail to see the urgency of their causes. Some see all compromise as the sign that serious matters are not fully addressed.

V. Discussion of Physicists and Sustainability According to World View

This section integrates the discussion of the sustainability problems that physics can help address with the four-group framework for understanding the differing world-views. Policy makers who try to solve problems must overcome the natural tendency of each of these groups to put great effort into identifying problems, but far less effort into developing solutions. Perversely, in many cases, the different world-views benefit from the continued existence of the problem. This section discusses the role of the physicists involved in "sustainability" issues from the four different world-views. In this area, world-views that are both pro-technology and pro-environment are rare. Independents dominate in the "environment" area while technology has been favored by chiefs and the bureaucrats. There are essentially no physics independents or bureaucrats that are recognized by the physics community. While the chief tradition is useful, there need to be additional and alternative ways for physicists to have input. At least two, and preferably three or four of the cultural perspectives need to be included in addressing any problem.

Independents: The leading voices on "sustainability" have been the independents. Activists in these areas, to their credit, often propose technology solutions to the problems they have identified. Their suggested solutions are sometimes poorly thought out from a physics point of view. For example, recycling is almost universally accepted as environmentally beneficial. However recycling can end up being negative if poorly thought out. A recent CMU study pointed out that poorly designed suburban curbside recycling programs result in increased emissions due to the additional recycling trucks. If paper mills recycle paper (rather than burning recovered paper as they have in the past), they end up producing more greenhouse gas emissions because they use carbon intensive coal rather than carbon-neutral paper to make the paper. Another stumbling block to cooperation is that Independents view themselves as by definition more ethical than others working on sustainability issues. But if they simply raise and do not work to solve problems they are in fact less socially responsible than the "chiefs" and "bureaucrats" they believe themselves to be ethically superior to.

Activists' institutional support tends to come from the non-profit sector, but "even if non-profits can attract technical people, it is very difficult to keep them for more than a short sabbatical. Most technically trained individuals view their tenure at non-profits as a diversion from their career path, which is generally seen as attaining an academic or research position. " Working on policy issues full time is considered much more respectable for social scientists or economists as compared with physicists, chemists or biologists. This is because in the social sciences, there is a long and respected tradition of "think tanks" where Ph.D.'s can make a career of using their training to develop real world policies. But there is no such tradition in the natural sciences. To be sure, a few of the larger non-profits, such as the Natural Resources Defense Council, the Union of Concerned Scientists and the Environmental Defense Fund, are large enough, well known enough, and can pay sufficiently high salaries to attract real scientists. Most non-profits, however, cannot. "As a result, they are heavily staffed by idealistic kids, often just out of school. Moreover, due in part to their youth and idealism, as well as their limited work experience, these individuals often feel inclined to weigh in on all issues, regardless of their expertise or experience. The result, needless to say, is a perception by both government and other established organizations, that these organizations are 'lightweights' in the policy arena."

Even sustainability-oriented non-profits that are founded on the basis of a technical area, such as renewable energy or energy conservation, have very few truly technical staff members. "To be credible players in the policy arena as well as credible players on the ground in implementing policy, non-profits need more technical people on staff." One result of this is that even the activists who strive for technologically oriented policy outcomes -- for example -- increasing energy efficiency and reducing pollution dramatically, do not appear to care (or even know) much about the most advanced technologies or the researchers working in areas that could have a major impact in the future (e.g. nanotechnology). Another problem is that while there is no shortage of studies, in-depth analysis is rare, and many rely heavily on anecdotal information. The same "facts" or "experts" are recycled frequently. Yet much relevant research is never referenced.

There appears to be a lower scientific standard for energy and environment work compared to disciplinary work. According to Dan Kammen (a physicist turned energy/environment person at Princeton), "It is remarkable how many people call up and say that they are interested in 'energy and development,' 'the environment,' or 'appropriate technology' and have read next to nothing in the field. You would never do this (I hope!) in a traditional field....Three-fourths of the people applying to our research group for postdoctoral positions are unable to articulate their interests beyond simple statements of interdisciplinarity."

Chiefs: The physics policy elites advise chiefs and are themselves most like the "chiefs" in world-view. But the elite physicists who participate in policy rarely have a supporting organization or staff for their policy efforts -- especially in interdisciplinary areas such as sustainability. Thus, most physicists in public policy related to sustainability are not true "chiefs" according to the previous definitions.

The current model of a socially conscious physicist is one who first works very hard at a research specialty, then achieves prominence, and then gets involved in societal issues, and is appointed to advisory panels and the like. This has been viewed as excellent preparation from a technical point of view, and there is no doubt that these elites are intelligent, hardworking persons. But on sustainability issues, there are even some technical problems with the current background of these elite physicists. Spending many years dedicated to physics research has not necessarily improved their ability to provide advice on issues outside of their specialties. Perhaps the legendary past eminent physicists were in a less competitive environment where they were free to explore other fields that were all less complex even a decade ago. Today's eminent physicists have no special grounding in ethics or social responsibility, no special qualifications for interdisciplinary work, especially with social sciences and economics. For advice on most aspects of sustainability, the expertise for which they have achieved eminence is not used. Of course they can be very important when advice is needed on funding for that field (determining relative priorities) or for a very small number of specific problems that physicists are considered to be experts on (arms control, nuclear power).

To be sure, the traditional physics advisory groups realize the problem of attacking problems with only physics expertise. Sustainability issues are so complex that no group comprised solely of physicists, however eminent, is qualified to address them. These problems and their solutions do not map neatly onto either academic disciplines or cabinet departments. For example, the policy advisory groups of the American Physical Society have in the past decade considered studying sustainability related topics such as global warming. But such topics were ultimately not studied as it became clear they were not appropriate for a group comprising only physicists. Thus, the current group of elite physicists seems resigned to remaining disconnected from sustainability problems. But this means that the physics community has not met its responsibility. Physicists' advice to policy makers has been reduced to telling government how it should give money to physics research, not advice involving the impact of physics and technology on nature and society.

From an ethical point of view, these physics "chiefs" have also become problematic. It has become clear that social benefits do not flow automatically from research. If contributing to society is a person's primary goal, then is it fair to ask young physicists to first compete in a very tight job market with those whose first motivation is research? Is it fair to advise someone to pursue something that he or she has a secondary interest in? Another ethical problem is the lack of diversity among elite physicists. The U.S. is more than half female and increasingly nonwhite. Among physicists, those employed in academia are now in the minority. Yet physicists appointed to advisory panels are still often older, white male academics. Finally, it does not help that many of these "objective" scientists on advisory panels have their way paid to the meetings by their own organization. With the lack of diversity and the cozy arrangements, it's not surprising that independents are suspicious of chiefs. This generation of elite physicists has now spent most of their careers dependent upon the federal government and/or major corporations for research funding.

Bureaucrats: From an ethical point of view, bureaucrats are in a potentially good position. They are not as dependent as "independents" on the continued existence of problems they have identified. Unlike the "chiefs" they are not dependent on maintaining a reputation in pure research. Since they are typically younger than the "chiefs" they are also more diverse. Unlike most chiefs and independents, bureaucrats have spent time in the trenches trying to solve societal problems. Even though their contributions have not been widely noticed, in many areas related to sustainability bureaucrats' contributions have been key. While they are rarely in positions to make major policy decisions, they often make the smaller decisions and carry out the actions that make the difference. Bureaucrats have the slow and patient style that is appropriate for well-thought out solutions -- but they tend not to be asked to do something that is proactive. They have the knowledge needed to implement policy. The Intergovernmental Panel on Climate Change or IPCC that has become the fundamental research document for the climate change negotiations is a preeminent example. But even this suffers from the typical problem of being an overwhelmingly long report.

Of course, many of the "bureaucrats" involved in sustainability issues are really idealists whom in other circumstances might have worked as independents. However, their ingrained sense of quality control, the lack of respectable institutions and the need to pay a mortgage and/or send their children to college led them away from the independent sector. Many examples of this type of bureaucrat are found among those who come to Washington as Congressional Science Fellows. Of more than one thousand former fellows (Congressional Executive and Diplomacy) surveyed by the AAAS, nearly 43% of those who answered indicated they had stayed on in Washington D.C. Physicists are especially likely to stay; of those with the word "physics" somewhere in their degree, 64% stayed in Washington D.C. after the fellowship. A handful went on to work for independent groups, but most ended up in or closely connected to a bureaucracy.

To be sure, physicists in bureaucracies are frustrated by the slow pace and the focus on the organization over the problem to be solved. Like the independents, they suffer from "stove-piping." For example, there is an almost complete separation between important aspects of sustainability such as technology and innovation policy, environment and energy policy. In addition, bureaucrat physics types rarely are treated as colleagues by the elites whom they serve. They are occasionally (more often if they are hard to find women and minorities) appointed to advisory panels but they are regarded as token.

VI. Future Roles for Physicists in Sustainability Policy

There is a need to broaden the representation and enhance the positive influence of physicists involved in sustainability issues. There need to be people and institutions whose job it is to make the connections between independents, chiefs and bureaucrats necessary to develop and deploy solutions. Technology and the environment must be integrated along with other public policies. Since each group described previously is self-perpetuating in its isolation, simply increasing communication between the groups will suffice.

There is a need for outside parties to better address sustainability. I proposed that the physics community recruit and train a small but diverse group of "translators" and develop institutions to support them. These translators should also have some training and/or experience in public policy, economics, politics, anthropology, social values ethics, and other policy relevant social areas. In addition to advising policy makers, these translators would work with activists, bureaucrats, and scientists in other disciplines including social scientists and economists.

The supporting institutions might resemble "think tanks" but they would be staffed by persons trained in the natural sciences as well as the more typical social sciences. These need to have a quality control process comparable to that of research universities, but more interdisciplinary and solution oriented. A more relevant and effective mechanism would also catalyze policies through project recommendations. Such an institution would be able to experiment where there are controversies and genuine unknowns.

There are many examples of sustainability-oriented institutions that have some of these properties. Physicists could contribute much to any of these. One example is the Pacific Institute, which brings together issues of water quality and economic self-sufficiency for the Latinos in California. Another example is the International Institute for Applied Systems Analysis (IIASA) that has developed acid rain precipitation models that are the basis for acid rain negotiations and policy in Europe. The Santa Fe Institute, although officially not a policy research institute, has pioneered the interdisciplinary study of complexity. The 20-year old Institute for Local Self Reliance has studied and implemented ideas about using local energy and materials sources.

The physics community should also take better advantage of current efforts of the APS and AIP such as the congressional fellowship program and perhaps expand it to executive, state and NGO fellowships. This fellowship is important because it recognizes, supports and rewards scientists whose skill is in translating science to policy makers. The physics community should also encourage universities, national laboratories, and industry to consider social values, community service and interdisciplinary work as part of their retention and promotion system. They should also be encouraged to provide ways for physicists to interact with outside researchers. University and college physics departments can become more integrated into their region and emphasize problem-solving skills related to sustainable economic development.

Practicing mid-career scientists should be encouraged to work with local NGOs, industry and governments for economic development.

The professional societies and others need not cut back on support for "chiefs" to support more independents and bureaucrats; the two efforts are complementary and mutually reinforcing. For example, as noted earlier, the physics "chiefs" need to have more policy-oriented staff to assist them. Such staff positions would be an excellent training area for the encouragement of the independents or bureaucrats in the previous section. The chiefs should also be encouraged to advise and collaborate with the mid-range and young scientists on policy issues and collaborate with and support interdisciplinary community and activist groups.

The physics community should actively recruit those whose first passion is not physics itself but service to society. It should better utilize and more reliably support those already so inclined. It must reinforce the idea in young physicists, from graduate school throughout their professional careers, that working on issues related to sustainability (as independents or bureaucrats) is an acceptable, indeed even an illustrious path to follow.

VII. Conclusion

Simply changing current institutions will not produce the transformations needed for the physics community to live up to its social responsibilities including providing responsible public policy input. There are too many incentives to maintain the status quo. The marketplace is NOT enough. The "winners" are doing well. Physics is contributing and will continue to contribute, but it could be so much more effective, and also more ethical. There needs to be a new intellectual framework to broaden and deepen the contribution of physics to society. The first step is to acknowledge that physicists can contribute to solving broad interdisciplinary problems such as sustainability. The specific suggestions of this paper may not be the optimal solution. It's the beginning of what should be a dialog in the community. We need to rapidly begin experiments on the various ways the physics community can increase and better direct its creative and intellectual energies to the benefit of society. Looming problems such as sustainability will need all of us, scientists in other disciplines, in applied fields, in industry, engineers, policy makers, and those most affected by the problems, to work together to improve public policy.

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Appendix 1

APS GUIDELINES FOR PROFESSIONAL CONDUCT

see http://www.aps.org/statement.html#91.8
[Updated address http://www.aps.org/conduct.html as of 8/29/02],
or more generally, the American Physical Society web site.

JOSEPH A. BURTON FORUM AWARD

Purpose: To recognize outstanding contributions to the public understanding or resolution of issues involving the interface of physics and society.

Establishment & Support:

The Joseph A. Burton Forum Award is named in recognition of the many contributions of Joseph Burton to the society and to the APS as its Treasurer from 1970 - 1985. The award was endowed in 1997 through a donation from Mrs. Leroy Apker. The award stems from the former Forum Award for Promoting Public Understanding of the relationship of Physics and Society, established by the Forum on Physics and Society in 1974.

Rules & Eligibility:

The award is for outstanding contributions to the public understanding or resolution of issues involving the interface of physics and society. Examples include issues of: public education, arms control, energy policy, protection of the environment, international cooperation among scientists, physics education, and the achievement of equity. Candidate nominations remain active for a maximum of three years.

LEO SZILARD AWARD FOR PHYSICS IN THE PUBLIC INTEREST

Purpose: To recognize outstanding accomplishments by physicists in promoting the use of physics for the benefit of society in such areas as the environment, arms control, and science policy.

Nature: The award consists of a certificate citing the contributions of the recipient, a sculpture to be held one year and passed on to the next recipient, and an allowance for travel to the meeting of the Society at which the award is presented. It will be presented annually

Establishment & Support: This award was established in 1974 by the Forum on Physics and Society as a memorial to Leo Szilard in recognition of his concern for the social consequences of science.

Rules & Eligibility: Any living physicist is eligible. Nominations are active for three years.

Year Recipient

Administered as a Forum on Physics and Society Award:

1974: David R. Inglis

1975: Bernard Feld

1976: Richard Garwin

1978: Matthew Meselson

1979: Sherwood Rowland

1980: Sidney Drell

1981: Henry Kendall and Hans Bethe

1982: W.K.H. Panofsky

1983: Andrei Sakharov

1984: Kosta Tsipis

Administered as an APS Award:

1985: James B. Pollack, O. Brian Toon, Thomas P. Ackerman , Richard P. Curco, Carl Sagan, John W. Birks, and Paul J. Crutzen

1986: Arthur Rosenfeld

1987: Thomas B. Cochran

1988: Robert H. Williams

1989: Anthony Nero

Appendix 2

The Chemist's Code of Conduct

see http://tungsten.acs.org:80/careers/empres/conduct.html [Updated address http://chemistry.org/portal/Chemistry?PID=acsdisplay.html&DOC=membership%5Cconduct.html as of 8/29/02] or more generally the American Chemical Society web site.

IEEE CODE OF ETHICS

see http://www.ieee.org/committee/ethics/

[Updated address http://www.ieee.org/portal/index.jsp?pageID=corp_level1&path=about/whatis&file=code.xml&xsl=generic.xsl as of 8/29/02]