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Physics & Society

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Editor's Comments

This edition of P&S contains a diversity of material. Global warming continues to attract attention as indicated by a brief announcement from the Forum Executive regarding APS Council action on the APS statement on this issue. Other material from the Executive includes a call for nominees for the Beller and Marshak Lectureships and background and statement information on candidates for open Executive Committee positions; elections should take place beginning in mid-October. Our four main articles cover a spectrum of issues: George Crabtree's paper on materials for Sustainable Energy, based on an invited talk at the March APS meeting in Pittsburgh, addresses some of the challenges and opportunities ahead of us in developing materials to help enable the transition to more sustainable forms of energy supply. Former APS President, NBS Director, and President's Science Advisory Committee member Lewis Branscomb writes on "Science as a Model for Rational, Legitimate Government Capable of Meeting Society's Grand Challenges," an article based on an invited presentation given in a session on science policy held during the April meeting in Denver. Tom Ruth of TRIUMF writes on the history and current situation of the medical isotope availability crisis, an issue of personal concern to this writer both as a native of Canada and having undergone a technicium-based bone scan a couple years ago. Continuing with our northern neighbors and also based on an April-meeting invited talk, Elizabeth Dowdeswell of the Canadian Nuclear Waste Management Office describes the efforts of that organization to solicit public input on the issue of that country's efforts to establish a nuclear waste repository, an exercise that contrasts strikingly with the United States' Yucca Mountain experience. Our three book reviews concern volumes that address the probabilities of various global catastrophes (natural disasters, wars, pandemics, and global warming) over the next few decades, possible routes to a "Green revolution" in energy supply, and the scientific aspects of major issues that future Presidents will have to face. As always, we invite your feedback and submissions.

—Cameron Reed

IN THIS ISSUE

FORUM NEWS

Ad-hoc Committee Examines APS Climate Change Statement

Don Prosnitz & Philip W. Hammer

At the May 2009 meeting of the APS Council, a member of Council moved that the Council reconsider the APS statement on Climate Change that was passed in November, 2007 (http://aps.org/policy/statements/07_1.cfm). In particular, this Councilor said that he and approximately 50 current and former APS members with whom he has contact feel that the statement is questionable by its inflexible declaration that the evidence for global warming is "incontrovertible." APS President Cherry Murray suggested, and it was approved by consensus, that the motion be tabled and that she appoint a high level ad hoc committee of respected senior scientists and charge them with reviewing the current APS Climate Change statement. The committee will make a recommendation as to whether or not the statement should be changed and suggest new wording if necessary. The committee will report its findings and recommendation to the APS President who will then convey these to the Council at its November 2009 meeting. After hearing the report from the ad hoc committee, Council will determine if any further action is required.

Call for Nominations: Beller and Marshak Endowed Lectureships

The APS Committee on International Scientific Affairs invites APS Divisions, Topical Groups, and Forums to submit nominations for the 2010 APS Beller and Marshak Endowed Lectureships. These Lectureships provide travel funds to support foreign physicists invited to speak during sessions at the annual March and April APS meetings. The Beller Lectureship was endowed by the estate of Esther Hoffman Beller for the purpose of bringing distinguished physicists from abroad as invited speakers at APS meetings. The Marshak Lectureship was endowed by the late Ruth Marshak in honor of her late husband and former APS president, Robert Marshak, and provides travel support for physicists from "developing nations or the Eastern Bloc" invited to speak at APS meetings. Four lectureships are awarded every year, with a $2,000 maximum for each lectureship. The lectureships support travel for distinguished speakers during sessions at the following APS meetings:

Beller Lectureship: For a distinguished physicist from outside of the United States. Two lectureships for the March Meeting (15-19 March 2010, Portland, OR), and one lectureship for the April Meeting (13-16 February 2010, Washington, DC). ***Marshak Lectureship***: For a physicist from a developing country or Eastern Europe. One lectureship for either the March or April Meeting. Along with the travel funds, recipients will be honored in the meeting program and/or other printed materials as recipients of the Beller or Marshak Lectureship. **The deadline for nominations for the 2010 Lectureships is Monday, 2 November 2009**; Lectureships will be announced in early December. You are welcome to nominate those physicists who have been or will be invited as speakers for your sessions to receive this distinction and the accompanying travel funds.

Nominations from FPS members should be forwarded to Philip Taylor, Nominating Committee Chair, taylor@case.edu.

Candidates for Forum Executive Committee Positions

Elections to fill open positions on the Forum's Executive Committee will soon be underway (Vice-Chair, Secretary-Treasurer, and two Members-at Large); Forum members should receive voting instructions around mid-October. The Nominating Committee [Philip Taylor (chair), Jessica Clark, David Harris, Beverly Hartline and Brian Schwartz] have put together a slate of excellent candidates, whose backgrounds and statements follow.

Vice Chair

(vote for no more than one candidate)

Pushpa Bhat

Background: Dr. Pushpa Bhat is a scientist at the Fermi National Accelerator Laboratory (Fermilab), which she joined in 1989. Her research career, which has taken her across three continents, has spanned applied physics, nuclear physics and experimental particle physics - from keV energies to the energy frontier. At Fermilab, she has worked on both fixed target and collider experiments, and was one of the leaders of the Fermilab Tevatron Luminosity upgrades project during the critical years 2003-2006. She has been an active member of the DZero collaboration for 20 years, making significant contributions to the discovery of the top quark, to the measurement of its mass and to new particle searches. Dr. Bhat is also a member of the CMS experimental collaboration at the Large Hadron Collider at CERN, and an adjunct professor and a member of the graduate faculty at Northern Illinois University. She has published over 250 papers including many review articles, has given many invited talks and public lectures, and has organized several international conferences. She has mentored dozens of students, at all academic levels, and is an active organizer and facilitator of public outreach programs. In 2008, Dr. Bhat was elected a Fellow of the American Association for the Advancement of Science for her "visionary leadership in new particle searches and her key role in the Tevatron upgrades program." She is currently serving her third and final year as the Secretary-Treasurer of the APS Forum on Physics & Society.

Statement: Scientists have an obligation and a duty to inform and interact with society at large in guiding how the ideas, and tools, of science are used. The renewal of a strong commitment to scientific research in this nation and the recent funding increases for research and education provide an extraordinary opportunity to enlist the help of scientists in setting humanity back on the path towards peace and prosperity. The APS Forum on Physics and Society (FPS) can and should play a role in this grand human endeavor. It has been my privilege to serve as the Secretary-Treasurer of the FPS for the past three years. The Forum supports a strong program on a variety of physics and society issues at the APS annual meetings and through its quarterly newsletters. Moreover, it provides an opportunity to lead a conversation between physicists, policy makers and the public. I therefore initiated, at last year's meeting, panel sessions and public town hall meetings to engage the broader community of physicists and the general public in such discussions. If I am afforded the opportunity to serve as vice-chair, I shall implement ideas aimed at improving the Forum's ability to fulfill its role as a facilitator of healthy dialogue about the most pressing issues of physics and society. I wish to make the FPS town hall meeting a regular feature at the annual meetings, and have them video-streamed as a live broadcast and archived so that anyone who wants to can access them through the FPS website. I believe we should also work towards holding such town halls at regional APS meetings with the help of member volunteers, whenever possible. FPS should also forge partnerships with similar forums abroad to engage in global issues. To encourage FPS members to drive the Forum's plans and activities, I propose to implement an ideas/feedback/volunteering "drop box" at the FPS website. The Forum is steadily improving and adapting to the times and the needs. My goal, should I be given the opportunity to serve, is to accelerate the process of improvement and rejuvenation so that the FPS remains a major participant in the important discussions about science and society that lie ahead.

William Fickinger

Background: Bill Fickinger is Professor Emeritus of Physics at Case Western Reserve University. He is a graduate of Manhattan College and earned a PhD in physics at Yale University in 1961. His research concentration was accelerator-based particle physics, moving from bubble chamber experiments to those with electronic detectors. His area of expertise was the associated software and data analysis, as he held various post-doctoral and junior positions at Brookhaven, Kentucky, Saclay, and Vanderbilt before joining the faculty at Case Western Reserve. He co-authored several dozen papers on the discovery and properties of hadronic states, contributing significantly to the Standard Model's building blocks. He has been for many years secretary of the CWRU AAUP Chapter and was recipient of the Ohio AAUP Kennedy Award for his service. During his last ten years at CWRU he was Director of Undergraduate Studies in the physics department, and while now in formal retirement, he continues to work at the university, writing and tending to physics archival materials. He recently published a history of 160 years of physics research at his home institution. He is currently writing a scientific biography "X-rays, Flutes and Aether, Dayton C. Miller's Physics". Bill has for the past several years been secretary of the Cleveland Chapter of National Peace Action, the descendent of Sane Freeze. He was co-founder in 2003 of "Case for Peace," a campus-based group. His particular interest is the control and speedy elimination of all nuclear weapons.

Statement: Every member of the APS should be a member of its Forum on Physics & Society. What are Society's most urgent concerns? Endless war, the abused environment, depleting energy sources, insufficient food, declining world health. What keeps Society from alleviating these concerns? Ignorance and greed. Where should Society turn for help?

Among other informed and well-intentioned citizens are many physicists who are concerned enough to complain, but not concerned enough to become part of the solution. It is time for them to counterbalance industrial and financial lobbyists by working with the nation's "decision makers" on such questions as arms control, nuclear energy, climate change, and renewable energy sources. Professional physicists must join with other scientists and engineers to make sure that people are educated and motivated and that politicians are challenged and informed. APS members should study up on one or more of these areas, talk about it in their classrooms, their workplace, their lab, their town hall, their tennis court. Then they should get on the phone and call their congressperson. In the long run, the Forum will prove to be the most important component of the APS.

Secretary-Treasurer

(vote for no more than one candidate)

Lee Schroeder

Background: Lee Schroeder is a retired senior physicist from the Lawrence Berkeley National Laboratory (LBNL) who is presently working part-time on connections between applied and basic research in the area of fuel cycle R&D at DOE. He received his PhD in physics from Indiana University in 1966 and was on the faculty at Iowa State University before joining LBNL in 1971, where he was involved in experiments in high-energy particle physics and relativistic nuclear collisions, co-authoring over 120 publications during his 36 years on the staff. At LBNL he served as group leader, Bevalac Scientific Director (1987-1991) and Nuclear Science Division Director from 1995-2001. In time away from Berkeley he was a program manager in DOE's Nuclear Physics Office (1987-1989) and its Nuclear Physics Advisor (2004-2005) and served as the Assistant Director for Physical Sciences and Engineering at the White House Science Office (1992-1993). He has served on national advisory committees for DOE and NSF, as well as the NRC's Committee on Biomedical Isotopes (1994-1995). He has been a member or chair of numerous international conferences on nuclear and particle physics. For DOE Nuclear Physics he co-chaired (2002) the Workshop on the Role of the Nuclear Physics Research Community in Combating Terrorism and in 2003 organized a nuclear training course for "first responders" for the city of Berkeley. He is a Fellow of the American Physical Society and the Institute of Physics (London, England). He was honored as an "outstanding alumnus" in the College of Arts and Sciences at Drexel University during its Centennial Anniversary as well as being one of the "Drexel 100" - honoring the top 100 Drexel graduates. In 1993 he was the recipient of Drexel's Science and Engineering Award for contributions in basic science in particle and nuclear physics and work in public science policy. He served as editor-in-chief of the Journal of Nuclear Physics (2003-2004) and presently serves on the editorial board for the Forum on Physics and Society.

Statement: Educating the public and political arenas on the challenges and rewards of supporting applied and basic research, particularly in this time of unprecedented challenges to our society, must continue as the principal focus of the Forum on Physics and Society. Education and outreach are the essential tools we need to continue to develop and refine at our public meetings, in our written articles and our visits at the local, state and congressional level. Science is one of the keys to enable the nation's future and, if elected, I look forward to working with the Forum's Executive Committee and its membership, in making the strongest case for its support.

Benn Tannenbaum

Background: Benn Tannenbaum is Associate Program Director at the Center for Science, Technology and Security Policy at the American Association for the Advancement of Science, where he works to connect policy makers with researchers studying science and security-related topics. He has testified before the House Homeland Security Committee on radiation portal monitors. Tannenbaum also serves on the Executive Committee of the APS Forum on Physics and Society, the Board of the Triple Helix and the Board of the Scoville Peace Fellowships. He has served on the APS Panel on Public Affairs. In addition to leading AAAS studies on the Reliable Replacement Warhead, nuclear forensics, and U.S. nuclear weapons policy, he was a member of the Council on Foreign Relations study "U.S. Nuclear Weapons Policy" and of the Henry Stimson Center study "Leveraging National Laboratory S&T Assets for 21st Century Security." Prior to joining AAAS, Tannenbaum worked as a Senior Research Analyst for the Federation of American Scientists. He is co-author of Flying Blind: The Rise, Fall, and Possible Resurrection of Science Policy Advice in the United States, a book detailing ways to increase the quality and consistency of science advising to the federal government. Before joining FAS, Tannenbaum served as the 2002-2003 American Physical Society Congressional Science Fellow. During his Fellowship, Tannenbaum worked for Representative Edward J. Markey (D-MA) on nuclear nonproliferation issues. Before his Fellowship, he worked as a Postdoctoral Fellow at the University of California, Los Angeles. At UCLA, he was involved in the Compact Muon Solenoid experiment at CERN, in Geneva, Switzerland, and the Collider Detector Facility at the Fermi National Accelerator Laboratory outside Chicago, Illinois. He served on the FNAL Users Executive Committee from 2000-2003 and was the UEC chair from 2001-2002. Tannenbaum also co-founded the Graduate Student Association at Fermilab while a student there. He received a Ph.D. in experimental particle physics from the University of New Mexico in 1997, a MS in physics from Michigan State University in 1993, and a BA in physics from Grinnell College in 1990.

Statement: The point where science and society - and especially science and security-intersect is a critical one. I have spent the past several years working to ensure that policy makers have access to the best possible science to help them formulate solid policy, and see a natural overlap between my work and the activities of the Forum on Physics and Society. While the last administration seemed to have no particular interest in using science in the formulation of public policy, the current administration has reversed that particular trend. Too often, however, the technical competence of the government has been allowed to atrophy, meaning that hard questions are even harder to answer. A vital gap in the ability of the government and the public to get high-quality analyses of important issues has been filled by the Panel on Public Affairs. The Forum on Physics and Society serves, in my mind, the opposite role: it provides a place in which physicists can discuss and reflect on how their work affects society, and how society affects their work. I have been involved with FPS for several years now and understand what the Forum can and cannot do. If elected, I will work to encourage an increase in this discussion within the APS and to encourage more members to engage those outside of the society. I will also work with the Chair, the Editor of Physics and Society and the members of the Executive Committee to find a way to give a voice to the membership of the Forum.

Member-at-Large

(vote for no more than two candidates)

Lea F. Santos

Background: Lea F. Santos is an Assistant Professor in the Department of Physics at Stern College for Women, Yeshiva University since 2007. She received a Ph.D. in theoretical physics from the University of Sao Paulo, Brazil, in 2000. Three postdoctoral positions followed: at Yale University (2000-2001) she worked on random matrix theory, at Michigan State University (2002-2004) she studied the interplay between interaction and disorder in quantum many-body systems, and at Dartmouth College (2004-2007) she developed new quantum control methods. She has been awarded two fellowships from the State of Sao Paulo Research Foundation (FAPESP), one from the New Zealand Official Development Assistance (NZODA), and one from the Brazilian National Council for Scientific and Technological Development (CNPq). She was selected as a KITP Scholar for 2009-2011 and as a member of the US delegation to 3rd IUPAP International Conference on Women in Physics in 2008. She is a member of the American Physical Society, the American Association of Physics Teachers, the ANACAPA Society, and the Committee of Concerned Scientists.

Statement: True democracy will never exist in a country where information and the knowledge of how to access it are privileges of few. When it comes to science related topics, such as energy, sustainable technology, the risks of nuclear weapons, climate change, public health, and education, the implementation of measures that benefit society as a whole requires citizens and representatives who are literate in science. The Forum of Physics and Society (FPS) has had a key role in sponsoring sessions and courses at APS meetings on topical science-and-society issues, many of which were published. A significant aspect of some of these symposia is to be co-sponsored by other APS forums and committees, such as the Committee on the Status of Women in Physics (CSWP). I would like to further reinforce these collaborative efforts. Having co-authored the U.S. delegation paper Women in Physics in the United States for the proceedings of the 3rd IUPAP International Conference on Women in Physics and written the article Science for All in a 2009 newsletter of the CSWP brought me awareness of how embarrassingly low keeps being the representation of women and minorities in physics and how crucial debates are to reverse this scenario. My other goal at the FPS would be to guarantee that the repercussions of the forum events are felt far beyond the physics community. This may be achieved by strengthening and establishing alliances with associations such as the American Association of Physics Teachers, the National Science Teachers Association, the American Association for the Advancement of Science and also with non-profit media organizations such as National Public Radio and the Public Broadcasting Service.

Oriol Valls

Background: Oriol T. Valls is currently a Professor of Physics at the School of Physics and Astronomy, University of Minnesota. He is also a Fellow of the Minnesota Supercomputer Institute. He has been a member of the American Physical Society since his student times, a member of the Forum on Physics and Society for over twenty years, and a Fellow of the American Physical Society since 1998, being nominated for his work on exotic Cooper pairing. He is a well-known theoretical Solid State physicist who has done extensive work on exotic forms of superconductivity as well as on nonequilibrium phenomena and on glasses. After obtaining his PhD in 1976 at Brown University, he was a postdoctoral research associate at the University of Chicago and a Miller Fellow at the University of California, Berkeley, before joining the University of Minnesota faculty. He has been a visiting Professor or visiting Scientist at NORDITA, the University of Paris, IBM, and Argonne National Laboratory, among other places. At the Forum on Physics and Society, he has recently served as member of the nominating committee for several years.

Statement: I joined our forum many years ago, and I have been active in it since, because I think that it is fundamental to the well-being of both the Physics profession and of Society at large that societal issues on which the physical sciences have something to say be discussed within the proper scientific context. Society's decision makers must be given the scientific input they need, while physicists must come down from their ivory tower, or out of their labs, and see what are the needs of society where they can help. If elected, I would endeavor to get the Forum to increase its outreach efforts. I would advocate to increase the size and circulation of our newsletter so that, while we continue our healthy debate on many issues amongst ourselves, more space can be devoted to articles directed not to other members, but to the educated public at large. We have to remember that most decision-makers in society at large did not take calculus in college. I would also attempt to increase the space devoted in Physics Today to Forum-related issues. The Forum should also continue to be active in its outreach efforts towards high school and undergraduate students, and the teachers who mentor them.

Herman White

Background: Dr. Herman White has been a particle physics scientist at Fermilab for the past 35 years. He completed undergraduate studies at Earlham College, graduate studies in Nuclear and Accelerator Physics at Michigan State, and Elementary Particle Physics at Florida State University and Yale. He was a Resident Research Associate in Nuclear Physics at Argonne National Laboratory for a period in 1971, an Alfred P. Sloan travel fellow at CERN in 1972, and University Fellow at Yale from 1976-78. His research has covered a range of topics in Particle and Nuclear Physics, as well as work with Accelerators and Particle Beams. In addition to his Scientist position on the Fermilab staff, for the past 15 years he has also served as an Illinois Research Corridor Fellow and Adjunct Professor of Physics at North Central College in Naperville, IL. Starting with a position as an elected member of the Fermilab Users Executive committee in 1999, he has maintained consistent involvement with many communication efforts to bring information, concerns, and focus about Physics and physical science research to many members of the US Congress and governmental agencies in Washington and elsewhere. He advises and currently serves on a number of panels and committees with the NSF, Department of Energy, and the National Academies. He has also been engaged in physics and science education for a number of years. He is a member of the APS Forum on Education, past member of the APS Committee on Minorities, and last year's US delegation to the ICWIP, and a member of DPF and past DPF and APS communication committees. He also contributes to his regional and national community as a member of a number of governing Boards of Directors, including Edward Hospital, Vice Chairman of the Board of North Central College, and civic commissions.

Statement: Perhaps now more than ever is a time to address important issues of science, technological progress and its impact on society. There is an active debate in our society and worldwide about the value of science and the use of science in education, economics, political leadership, global conflict, and many other topics. For some time the voice of scientists and the scientific community have been limited. There are many organizations increasing their voice in this important dialogue, and I believe the Forum on Physics and Society should continue to lead and be a vital component of this dialogue. Formulating a clear view of issues with an understanding of the scientific facts is most important in reaching effective and sustaining action that truly benefits society. I am grateful to be involved as a member of the Forum on Physics and Society and to help promote the vital aims and activities of the Forum and the APS.

Richard Wiener

Background: Richard Wiener is a program officer at Research Corporation for Science Advancement, a private foundation founded in 1912 by Frederick Gardner Cottrell that supports academic research in Astronomy, Physics, and Chemistry. He is directing RCSA's new funding program in Solar Energy Conversion. Until recently he was a physics professor at Pacific University in Oregon and Chair of the Division of Natural Sciences. His research interests are in the field of nonlinear pattern dynamics. He is also interested in environmental physics and modeling of resource depletion. He completed a BA in philosophy at the University of California, Berkeley and a Ph.D. in physics at the University of Oregon under the direction of London Prize recipient Russell Donnelly. He has been a National Corporation for Atmospheric Research Postdoctoral Fellow in Ocean Modeling at Oregon State University, a Visiting Professor at Lewis & Clark College, and a Visiting Professor at Cornell University, where he worked in the research group of Eberhard Bodenschatz.

Statement: The fundamental challenge for civilization in the

21st Century is providing food, water, and energy for humanity as population continues to grow nearly exponentially. We are facing dire consequences as access to nonrenewable resources for seven billion people becomes more problematic. Reliance on fossil fuels threatens global climate, just as resource shortages threaten global security. Physicists likely will play a critical role in the solution of these problems, if they are solved. I believe the purpose of the Forum on Physics & Society is to stimulate and foster rational debate on critical policy questions to which physicists can make an important contribution, both within the physics community and before the public at large. It is our responsibility to raise awareness of the magnitude of the difficulties facing humanity. One crucial contribution we can make is to communicate the physical constraints that bound these fundamental problems. For example, I wrote an article in the Forum July 2006 newsletter on the negligible effect drilling in ANWR would have on U.S. dependency on foreign oil. This is a microcosm of the much greater problem of supplying energy for an increasing world population while simultaneously limiting environmental degradation to an acceptable level. I also wrote book reviews of "The God Delusion" by Richard Dawkins in the Forum October 2007 newsletter and "Science, Evolution, and Creationism" by the National Academy of Sciences in the Forum July 2008 newsletter. These book reviews deal with the tension between science and religion that complicates solutions to worldwide problems. Please read these pieces in the Forum newsletters, if you wish to have a better idea of my thinking on these issues. I am committed to the Forum providing the highest level of ongoing discussion on what the constraints are, and what solutions fit the constraints, to the challenges we must overcome if civilization is to avoid global catastrophe.

ARTICLES

Materials for Sustainable Energy

George Crabtree

The Sustainable Energy Challenge

At every stage of human development, energy has shaped both our aspirations and our limitations. In agrarian times, we relied on energy from the sun to grow our food and energy from domestic animals to do our work. The industrial revolution brought a powerful new feature – harnessing the energy of coal in the steam engine and later oil in the internal combustion engine to do orders of magnitude more work than humans or animals could provide, on demand and without the maintenance costs of animals. The use of energy to do work, the hallmark of the industrial revolution, gave birth to other revolutions that use energy in subtler but equally significant ways, for observation, communication, information, and decision-making.

Energy is among the fastest growing commodities in the world. By 2050 we will need twice the energy we use today, driven by the rising expectations of the developing world. The question is, where will it come from? Our use of traditional sources of energy – coal, oil and gas – is reaching fundamental limits that we should not, and in some cases cannot, exceed. These sources of energy are not sustainable.

The first big problem is supply. Oil accounts for 40% of world energy use; its production in the US peaked in the 1970s, and world production outside the OPEC countries is peaking now. Eventually OPEC oil production will peak, most predictions say by mid-century or sooner. If we do not wean ourselves from oil, the transition through the OPEC production peak will be very difficult. But apart from world supply, the US faces a much more pressing problem. Last year we imported nearly 60% of our oil. Our consumption continues to rise, and our domestic production continues to fall - these trends are irreversible. The cost of imported oil is huge - \$700B/yr at the peak prices of summer 2008, and about \$300B/yr at today's prices. That money is drained from our shores, going to foreign producers where it cannot stimulate our economy or promote our recovery from the present recession. Furthermore, foreign oil supplies are uncertain, subject to interruption from terrorist acts, weather disasters, and internal political decisions in supplier countries. The flow of oil is vital to our economy and lifestyle – try to imagine our society without driving cars and trucks, which consume two thirds of the oil we use.

The second big problem — many say the more important one — is greenhouse gas emissions. Some effects of global warming, such as the decline in Arctic sea ice, are occurring at rates faster than we predicted just a decade ago. The 4th Intergovernmental Panel on Climate Change describes some of the consequences: a loss of Arctic sea ice and snow cover in the northern hemisphere, rising sea level, and the pole-ward migration of animal and plant species to maintain their preferred habitats. Once emitted, carbon dioxide takes 400 to 1000 years to settle in the deep ocean. That means that today's emissions will affect not only our children and grandchildren, but also many generations beyond. Left unchecked, the consequences of greenhouse gas emissions could be drastic: disruption of established agricultural patterns, of economic networks, and of population centers in coastal areas. The ultimate severity of global warming depends not only on still-unpredictable ocean-atmosphere dynamics, but also on human choices - the balance between pre-emission mitigation of greenhouse gas releases and post-emission adaptation to global warming. An early shift to low carbon energy technologies will have the greatest impact on reducing both the deleterious consequences of global warming and the degree of adaptation required to accommodate them.

To reduce our dependency on imported oil and our greenhouse gas emissions, we must find alternatives to fossil fuel that are more sustainable. The ultimate sustainable energy sources are solar (including solar electricity, solar fuel, and solar heat), wind, geothermal and other fully renewable resources. These technologies operate qualitatively differently from fossil fuels and most are not yet sufficiently cost competitive to replace them. Carbon emissions, one of the harmful effects of fossil fuels, can be reduced by capture and sequestration underground, and by greater use of nuclear energy, where a new generation of reactors could be twice as efficient (and therefore half as costly per unit of output) as the commercial reactors of the 1960s that we now rely on.

Materials and Chemical Change

Every alternative to conventional fossil energy, however, faces roadblocks that cannot be solved without basic research on materials and chemical change [1]. No one knows what will happen to enormous quantities of supercritical carbon dioxide placed deep underground as it reacts with porous rocks. Will the carbon dioxide migrate great distances, perhaps affecting water supplies? Will it react to form solid, stable compounds? Will it stay underground? If it leaks out at 1% per year, it will return to the atmosphere in a century, far too short a time to mitigate climate change. If it leaks, will the heavy carbon dioxide collect in low areas and displace the oxygen we need to breathe? These questions require significant basic research to predict the phenomena, effectiveness, and safety of carbon sequestration.

Doubling the efficiency of nuclear reactors and coal-fired power plants is a worthy sustainability goal. Higher efficiency requires operating at much higher temperatures, in turn requiring materials that withstand extreme environments, not only of temperature but also chemical corrosion and, for nuclear reactors, high radiation doses. Designing and fabricating these "extreme materials" is a significant basic research challenge.

Solar electricity needs higher efficiency, lower cost solar cells to compete with fossil electricity, and both wind and solar need long-distance electricity transmission to get power from renewable wind resources in the upper midwest or solar resources in the southwest to the population centers of the east and west coasts. Solar and wind are intermittent, requiring either companion conventional plants as backup or large-scale electrical energy storage to be effective. Long distance transmission lines require lower-loss cables, such as superconductors operating at DC and buried underground to minimize weather damage and the growing objection to unsightly infrastructure. Storing electricity at the utility scale is new territory - there is no conventional technology and all the potential options such as electrochemical flow batteries and fuel production are heavily dependent on new, complex functional materials and chemistry.

We would like to make chemical fuel from the sun, such as liquid fuel from the cellulose in the stalks and leaves of plants. Corn ethanol is now technologically ready for deployment, but its capacity is limited to a fraction of the gasoline needed for transportation, it displaces food, and at best produces only slightly more energy than it consumes. Cellulosic fuels are a potentially much bigger winner, but we lack the fundamental knowledge for the cost effective conversion of cellulose to fermentable sugars or directly to fuel. Fuel can also be made directly from carbon dioxide and water, without relying on plants or biological processes. An energy source is required for this uphill reaction, either heat from the sun to drive high temperature thermochemistry or photonic excitation of electrons at room temperature to drive photo-chemistry, an artificial version of biological photosynthesis. Both of these sustainable routes to fuel production require basic research in the materials and chemistry of splitting water and carbon dioxide and subsequent synthesis of fuels like methane, methanol, and hydrocarbon chains.

The roadblocks to deploying more sustainable next generation energy technologies are fundamental, not incremental. Refinement of existing technologies is not capable of delivering the alternative energy we need. Qualitatively new, more sustainable energy technologies are, however, within reach. There is no law of physics, chemistry, thermodynamics or economics that precludes their operation. We simply have to develop the materials and learn to control the physical and chemical phenomena that will enable them.

Interdisciplinary Science

Nearly every step in the energy chain involves the conversion of energy from one form to another: photons to electrons, heat to motion, chemical bonds to heat or to electrons. These conversions depend on physical and chemical phenomena, such as the photo-excitation of an electron in a semiconductor, the transfer of electrons and energy in chemical reactions, or the transmission of an electron without loss in a superconducting wire. The challenge in sustainable energy is to understand and control these physical phenomena to produce more efficient energy conversions. These phenomena are complex and often take place at nanometer or smaller length scales, and at pico- or femto-second time scales. We are beginning to probe these ultrasmall and ultrafast regimes, but to a large extent the atomic and molecular details of many energy conversion phenomena remain hidden. It takes the best science, including forefront experiments, theory, and computation, to understand how these conversion phenomena work.

Beyond complex phenomena, there is the equally difficult challenge of complex materials. The materials of sustainable energy applications are different from those of traditional energy usage based on combustion. The primary materials of combustion energy are the fuels, prized for their high energy content and the heat they release on burning. Fuels are commodities, used once and consumed in the combustion process. In contrast, sustainable energy materials direct the conversion of energy from one form to another and are not consumed in the process. They are expected to continue operating for many conversion cycles, with lifetimes as long as 30 years. These materials are much more complex than the commodity fuels of combustion. A solar cell, for example, must convert a photon to an excited electron and a hole, separate the electron and hole with a space charge at a p-n junction, and transport the electron and hole to external electrodes without allowing them to decay across the band gap. Each of these steps is a separate and specific function with stringent materials requirements, on the band gap for excitation, the impurity doping profile for charge separation, and the structural perfection for transport to the electrodes. The great progress in silicon solar cell efficiency, from 6% for the first prototypes in 1954 to over 20% in the best commercial cells today, is due to scientific advances in understanding the electronic structure and dynamics in semiconductors, and to enormous advances in perfecting silicon materials. Silicon is arguably the best-understood and most precisely controllable material in the world. A similar level of understanding of other sustainable energy conversion materials is needed to achieve the required technical performance and economic competitiveness.

The materials of sustainable energy are highly interdisciplinary. This is a great challenge and a great opportunity. Semiconductor solar cells can be adapted to split water from sunlight, using the electrons and holes to do chemistry at the electrode surfaces instead of tapping them off to an external circuit. A catalyst is needed to promote the water splitting reaction near ambient temperatures, combined with favorable nanoscale architecture creating high surface area and active catalytic sites. The interdisciplinary science of solar water splitting requires physicists and chemists working together, exposing new directions that neither could have found alone. Biology is needed as well: green plants split water at room temperature by an entirely different mechanism that we are now probing at sub-nanometer length scales and are beginning to imitate in the laboratory.

Meeting the Energy Challenge

Creating sustainable energy technologies is a monumental scientific challenge for basic materials and chemical research. Not only must we observe and understand atomic and nanoscale energy conversion phenomena, we must learn how to *control* these phenomena at the nanoscale to produce targeted functional outcomes that operate with high efficiency. These challenges are within reach using the rapidly developing tools of nanoscience, materials simulation on high performance computers, and characterization of structure and dynamics by scanning probes, scattering of electrons, neutrons and x-rays. Cracking the grand challenges of sustainable energy phenomena, however, requires dream teams of the best scientists, using the best equipment, focused on the most important problems. Such teams do not typically exist at a single institution or within a single discipline. They must be created deliberately to be multi-institutional and multi-disciplinary, and given sufficient resources for sufficient time to solve the basic science challenges. The Energy Frontier Research Centers established by the Office of Basic Energy Sciences are premier examples of this style of high risk-high payoff targeted basic science; we must insure that this new research paradigm remains an enduring and vital force for the decade or more required to bring sustainable energy to technical and economic viability.

In addition to dream teams of established scientists, we must recruit and train a whole new generation of interdisciplinary sustainable energy scientists. The time scale of sustainable energy is long, because the research problems are diverse and challenging, and because even potentially disruptive technologies in the energy arena, such as plug-in hybrid cars, can take decades to overcome market inertia. The knowledge and wisdom developed by today's dream teams must be passed on to the next generation through education and collaborative mentoring. Aggressive programs of fellowship and research awards for graduate students, postdocs and early career scientists must be established. The best and the brightest must be attracted and embraced by the sustainable energy enterprise.

The sustainable energy challenge is clear. The series of ten Basic Research Needs workshops and reports on the Basic Energy Sciences website outlines the current status of sustainable energy technologies, the scientific roadblocks to competitive viability and the promising research directions to overcome the roadblocks [2]. With this foundation in place, it remains to pursue the promising research directions with the best scientific talent working in interdisciplinary teams until the problems are solved. The prize is not only within reach and well worth the race, it is necessary if we are to create a secure and sustainable energy future.

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Science as a Model for Rational, Legitimate Government Capable of Meeting Society's Grand Challenges

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[The following is a slightly edited version of an address made by Dr. Branscomb at the April meeting of the APS held in Denver, Colorado, May 2-5, 2009 – Ed.]

Before World War II, science was largely dependent on support through teaching and a few foundations. A few government laboratories were well established even in the 19th century – the National Bureau of Standards and the Coast and Geological Surveys among them – but they were small efforts. The thousands of physicists who today attend the spring meeting of the American Physical Society would never fit in the room on the second floor of the Bureau of Standards East Building. But when I joined the Bureau staff in 1951, all 50 participating scientists fit easily in that room. In the last half century, thanks largely to the contribution of applied science to winning the Second World War, the vision of people like Vannevar Bush, and the threat posed after the war by the Soviet Union, our government became a deep-pockets source of support for science. At first, many academic science administrators were deeply suspicious of government as a sponsor, fearing constraints on their intellectual freedom and uncertain continuity of support. But the research universities, under leadership of people like Fred Terman at Stanford, soon saw the opportunity and took the risk to build their engineering and science programs around soft government research grant support. Government saw science as a means for sustaining its military primacy. In 1960, the U. S. Department of Defense funded fully one third of all R&D funded in the Western World.

Thus a marriage was consummated by two partners, science and politics, who needed each other, but for quite different and to some degree conflicting motives. In our democracy, the relationship between science and politics has never been easy, but in the minds of the drafters of the Constitution it was always important. The search for truth in science and for legitimacy in politics both require systems for generating trust, but these systems are not the same and indeed they are often incompatible. The most profound area of mismatch between science and politics is found, not in conflicts over how much research is deserving of public funding, but rather in conflicts over the advice government receives from scientific and technical experts on important but primarily non-technical matters of policy. Thus, as Harvey Brooks of Harvard University once famously said, it is not over "policy for science" that the conflicts arise but over "science for policy."

It is no accident that democratic America fostered progress in science and technology, perhaps more than any other nation. Democracy and science stand to benefit enormously when our political leaders understand that the traditions of science and the mechanics of democracy have common roots. Both

American democracy and modern science are products of the Enlightenment, with its emphasis on reason and openness rather than on religious and political authority [1]. American democracy has always benefited from a pragmatic willingness to learn from experience, very much as science relies on experiment. Progress in science is based on transparency, accountability, and trust; these are also basic principles of sustainable democratic government. Thus if science and democracy are both to flourish, government must be pragmatic, open, and viewed by the voters as legitimate and responsive to voter desires. If science is corrupted by government, government itself is in danger of becoming corrupt. And conversely, when government allows itself to become corrupt, science advice is sure to suffer as well.

In recent years, we seemed to have been going down that treacherous path. During the recent political campaign, presidential-candidate Barack Obama promised to reverse that trend. He, and many media commentators, spoke often of a "new pragmatism" as his guiding principle for governance. As President, Obama is off to a very good start, having appointed exceptionally well-qualified scientists to top posts in his government, and having initiated many of the changes he promised in his campaign.

But that leaves a major question unanswered. If government is to depend on science for practical advice on policy choices, it is not enough for the politicians to be pragmatic and be prepared to listen to the independent advice of the best experts. Having listened to science they must now find support from the public for the policies they put forward. But for the voting public to understand and support those choices, it must have some understanding of the technical basis for political decisions. If the voters are ignorant of technical matters, how can they evaluate the performance of government officials, and thus establish the legitimacy of their governance? Science must, therefore, not only give wise advice to government, but must also find a way to share their understanding of the factual basis for policy choices with the public. If we are to preserve the legitimate and accountable democracy envisioned by the authors of the Constitution and enjoy the fruits of an intelligent, informed society, government must be responsive to a well informed voting public, and science (and the media) must more effectively share what they know with the public.

But how well informed is that public? The Public Agenda, a non-profit research organization founded in 1975 by Daniel Yankelovich and Cyrus Vance, has been studying that question. They began by asking what the public knows and thinks about energy policy. The Public Agenda recently released a new study entitled "The Energy Learning Curve." Here are some of their findings, as summarized on the Public Agenda's website:

"There's significant common ground in public thinking on what the nation should do about energy. The public also thinks our energy challenge is here to stay. Three-quarters of the public believes we should move toward increased use of alternative energy, even if fuel prices go down."

The study identified ten proposals on alternative energy, energy efficiency and cutting gasoline use. These 10 have support from more than two-thirds of the public. A strong majority approve providing tax benefits to individuals and businesses who reduce energy consumption, 81 percent and 79 percent respectively. Seventy-eight percent approved increased gas-mileage requirements and would reward businesses that reduce carbon emissions and penalize those that do not. Some 86 percent agreed either "strongly" or "somewhat" that investing in alternative energy will create many new jobs. Nearly seven in ten (68 percent) want the nation to take steps to gain energy independence even if it raises costs.

But the report also found widespread agreement on some ideas that are off the table for the public, at least right now. "People don't want to be pushed," the report found, and they "don't want to do anything that increases the cost of driving." There was strong opposition to all such options: gas taxes to fund development of renewable energy sources (53 percent), taxes to help achieve energy independence (57 percent), setting minimum prices for gas (72 percent), or congestion pricing to force people to change their driving habits (61 percent).

Even so, the report continues, the cost of fuel and dependence on foreign oil remain the public's biggest concerns about energy. Nearly nine in ten (89 percent) say they worry about price increases, with 57 percent who worry "a lot." Concern about dependence on foreign oil is almost as high at 83 percent (47 percent worry "a lot") Climate change is lower on the public's priorities list. While 71 percent say they worry about global warming, only 32 percent say they worry about it "a lot." Public worry about global warming ranked 25 points less than those who worry about prices.

What is particularly interesting is the contrast between the large majorities in favor of policies that the technical community would also support, and the frailty of the public's scientific understanding on which these convictions rest. Thus the study goes on to say,

"But there are reasons to wonder how well this consensus would stand up under pressure. Our research shows that the public does not know critical facts about the problem. Half of all Americans (51 percent) could not correctly identify a renewable energy source such as solar or wind power, 39 percent could not name a fossil fuel, 65 percent overestimated U.S. dependence on Middle Eastern oil, and 52 percent thought that by reducing smog, the United States has come 'a long way' in addressing global warming."

Could it be, then, that lack of understanding of the most basic relevant technical facts is at least in part responsible for public unwillingness to accept any policy that increases the cost of driving, even though nearly seven in ten want the nation to "take steps to gain energy independence even if it raises costs?"

Dan Yankelovich concludes that the state of public education is such that science cannot rely on telling the public what we think they need to know. We cannot depend on well-intentioned programs of "public science literacy" or "public understanding of science." We must partner with government in a major effort to upgrade public education at all levels.

We must also face the fact that some people are nervous about direct democracy as the right principle of the public's role in Policy for Science, if not in Science for Policy. For example, Donna Gerardi Riordan express such reluctance in Issues in Science and Technology (Summer 2008) under the title "Research Funding via Direct Democracy: Is It Good for Science?" To be sure, the Founding Fathers had little problem with direct democracy since in their day the voters were landed, mostly well-educated white men, a small fraction of the population. Today we must carry out the basic ideas of the Enlightenment in a society that must link the entire voting public with both the elite (specialists and experts) and the empowered (government officials).

Sound policy and accountable democratic governance do not depend only on a good relationship between science and politics. In reality it depends on a triangle comprised of political institutions, the community of experts, and the voting public. When one examines the science policy literature, much of it is about science advice and scientific integrity in government. They are important, but the scientists' concern for the role of the voting public leg of that triangle is particularly weak. That role has been largely left to a fourth player, the media.

How well does the media help scientists to inform the public and help the public learn from science and use that knowledge to evaluate the quality of political governance? Dan Yankelovich parses the role of the media's role in public policy into three stages. For important emergent issues, such as energy policy, the first stage in the media's role is "consciousness-raising" about what the issues are. Yankelovich gives the media good marks for this role in public education. The second stage, "working through those issues," is where the media fall short. This is the stage where sorting out the facts and the evidence they rest on is most important. Here the media perform badly. The third stage Yankelovich calls "implementation." He thinks the media do OK here, since this is the phase of political consensus development, which rests on the public-to-politics link, where the media are more comfortable.

Thus there are weaknesses in all three legs of the triangle, and the media do not adequately compensate for the weakness in the relations between science and the public or between science and politics.

What is the prospect for building a stronger, more rational society, given the complexities and weaknesses in the current system of governance and the public participation that validates it? The task seems daunting but one can at least list four main challenges:

Through reform of the election process and lobbying rules, weaken the dependence of politics on moneyed interests and replace special interest politics with greater dependence on public evaluation and approval.

Include in the education of scientists, engineers and other experts the skills to communicate with the voting public, and enhance their sense of obligation to do so. The technical community must also take greater interest in the public issues to which their work is relevant, and the channels through which expert knowledge informs both political decisions and the public.

Reduce the concentration of ownership of the media, recognize the power of the internet to replace traditional channels and enhance the incentive of all media channels to do a better job of "working through the issues" – i.e., to help the public and the politicians to understand the facts and the unknowns on which sound public policy must rest.

As one component of government funding of research [in addition to pure science and applied research] establish funding for "Jeffersonian Science," long term, creative research that may be relevant to society's most difficult challenges. Government should identify these "grand challenges" and provide funding for unsolicited proposals to explore new ideas for increasing options for making those goals easier to understand and solve. A key requirement here is the availability of high levels of expertise and good judgment both in government and available to government.

Let me explain how what in 2001 I called "Jeffersonian science" might work. The top scientists in the executive branch agencies responsible for achieving a new energy economy, or advances in medicine that will reduce costs and improve public health, or reversing nuclear weapons proliferation would put in place the applied and engineering work that can be accelerated today. But they would also commission panels of experts for each goal who would identify the lively areas of basic science where new ideas might dramatically accelerate the applied and engineering progress. In these areas agencies such as DOE, NSF, and NIH would fund those unsolicited proposals in the identified. disciplinary areas. The funded scientists would not expect to become experts in the applied national goal, and if their work did not turn out to the relevant, no matter. Their work would be measured by the quality of the science, like the more traditional "Newtonian" basic science. My prediction, however, is that as these scientists came into contact with others who are funded by the same mechanism, they would quickly become knowledgeable about the possibilities of breakthrough discoveries that do accelerate achievement of the grand challenge goals.

How well is the Obama administration likely to address these issues? The Administration is committed to tackling item 1 – reforming politics. The intent to reform politics is there, but so far the bi-partisan cooperation in Congress has not emerged. There is not yet explicit commitment to item 2 – motivating scientists to take more seriously their obligation to inform the public, but Obama's "new pragmatism" approach surely implies the need to do this. In addition there is evidence that the technical professional societies, including the American Physical Society, are taking the issue more seriously. Indeed, the annual meeting of the AAAS in February 2010 in San Diego will be focused on this issue. As yet we have heard little about item 3 — media reform. Except for the government's authority to place legal constraints on anti-competitive concentrations of media channel ownership, this reform must be left to the media organizations themselves and the publics they serve. Media objectivity and independence are essential to a democracy, as is their capacity to work through complex technical issues.

The good news is that applying basic science to society's grand challenges, with energy, health and education policy at the top of the list, is a serious commitment. The President has set out the domestic grand challenge priorities, and he has said to the annual meeting of the National Academy Sciences that he is depending on science to help the nation make rapid progress on each. He has also made a dramatic commitment on the research resources: "…we will devote more than 3 percent of our GDP to research and development." Now John Holdren, Steve Chu, Jane Lubchenko and their colleagues will be able to design the process that I called Jeffersonian science 8 years ago, as they carry out the bottom-up research funding in support of the top-down, presidentially-defined grand challenges remains to be seen. If it all works out, perhaps this mode of applying the best and most long range scientific thinking to the nation's most urgent goals will be called "Obamian Science."

Given the high quality and leadership skills of the Obama scientific appointees, I am hopeful that they can also help energize the scientific community to seize the occasion to introduce a more rational, enlightened approach to solving our problems, both domestic and global.

While we have a terrific team of technical leaders named for key roles in government, it is rather as though we citizen-voters, watching from the bleachers, are just now seeing our players coming out of the tunnel into the field. How will our smarter, more energetic team, with a terrific new coach, fare against the traditional opposition of really big players – from entrenched interests, ideological foes of scientific knowledge, and those who want instant gratification? The outcome of the game is not certain, but our team has its eye on the fourth quarter, and deserves wholehearted support from its fans. If they win I am sure the Founding Fathers would be proud [2].

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This contribution has not been peer-refereed. It represents solely the view(s) of the author(s) and not necessarily the views of APS.

The Medical Isotope Shortage

Thomas J. Ruth

With the most recent shut down of the NRU reactor in Chalk River, Canada, the supply of medical isotopes has dwindled to the point that it is impacting medical diagnoses worldwide. How did we reach a situation with supply so fragile and prospects for solutions so bleak? As with most stories the answer is complex and convoluted. In some respects the medical isotopes community is a victim of its own success.

Technetium-99m is the most widely used radionuclide in diagnostic medicine. Its use for imaging human disease has its roots in the US Atomic Energy Commission, predecessor of today's Department of Energy. Research at Brookhaven National Laboratory in the early 1960s resulted in the development of the generator for producing Tc-99m.

The parent element, molybdenum-99, can be produced through a number of nuclear reactions, but the fission of ^{235}U with thermal neutrons provides for the most efficient, high-yield product with very high specific activity. Six per cent of the fission process results in the production of Mo-99.

After it is produced, Mo-99 is sequestered on an inert column matrix to which the decay product, Tc-99m, is loosely bound and can be washed off with saline. With half-lives of 66 hours and 6 hours, respectively, the ^{99}Mo/^{99m}Tc pair can be separated repeatedly over a week, with the Tc-99m fraction growing due to radioactive decay of the parent after each separation. Tc-99m is subsequently used for imaging studies such as bone scans or cardiac profusion. These scans are made possible by bonding the Tc-99m to an appropriate radiopharmaceutical that has the in vivo biological activity to be monitored. The gamma camera found in nearly every nuclear medicine department around the world has been designed for high efficiency for the 140 keV gamma ray emissions from the decay of Tc-99m to its ground state. Thus for more than 40 years Tc-99m has been the primary radionuclide used in nuclear medicine. Figure 1 shows a whole-body Tc-99m-based bone scan.

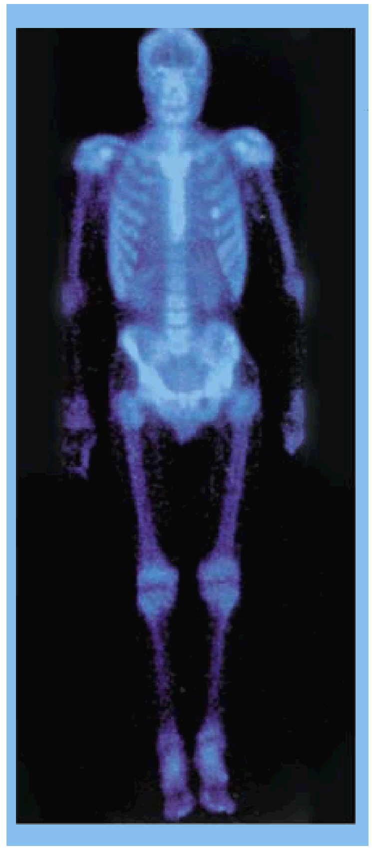

Figure 1. Whole body bone scan using Tc-99m.

Currently, the world depends on five ageing research reactors that are located in Canada, The Netherlands, Belgium, France and South Africa. The National Research Universal (NRU) reactor in Canada and the High Flux Reactor (HFR) in The Netherlands together supply approximately 80% of the world's Mo-99. The US uses approximately 50% of the world's Mo-99 and gets 60% from the NRU and the remainder from the HFR. The other 3 reactors supply Europe and parts of Asia. They also serve as backups for when one of the major producers are off-line for maintenance.

The worldwide sales of generators are on the order of $300 million per year. Since these generators account for multiple studies using Tc-99m radiopharmaceuticals costing a few hundred dollars each, the Tc-99m business accounts for hundreds of billions of dollars annually.

In the mid 1990's MDS Nordion (Ottawa, Canada) commissioned Atomic Energy of Canada Limited (AECL) to build two reactors, to be called Maple 1 and Maple 2, dedicated to the production of Mo-99. Each of these reactors was to have the capacity to meet the world's Mo-99 needs, so that each would serve as a backup for the other. With the prospect of the Maple reactors coming on line in early 2000, the community felt there was no need for additional supplies of Mo-99 and projects to have a US source through work at Los Alamos and then at Sandia National Labs never came to fruition. This has proven to be a serious mistake. After technical problems caused delay after delay and the Canadian Nuclear Safety Commission (CNSC) denied a license to operate the Maple reactors due to a positive reactivity coefficient, AECL suddenly cancelled the Maple Project in May 2008.

All of the today's existing production reactors are 40 or more years old, and while they can have extended lives, there will inevitably be problems due to age. In fact the problems that both the NRU and HFR reactors have had are not associated with the reactors themselves but in the infrastructure: leaking containment vessels and leaking pipes buried deep in shielding walls. Such problems are difficult to isolate and solve, resulting in prolonged shutdowns. These shutdowns cause major disruptions in the supply chain because the short half life of Mo-99 makes it impossible to stock for more than a few days. The smaller reactor operations can increase capacity somewhat but none of the other reactors has the capacity of the NRU or HFR.

The severity of this decision has become apparent through a series of unexpected shutdowns of the primary reactors producing Mo-99. The first was in the Fall of 2007 when the NRU was off line for maintenance and the regulator, CNSC, denied permission to restart due to a dispute over the installation of a backup emergency pump system. This shut down caused a shortage of Mo-99 that was felt world wide and the Canadian Government intervened to order the reactor restarted. Then in the Spring of 2008 a leak in one of the cooling systems was found in the HFR reactor in The Netherlands. This resulted in a two month shutdown for repairs, again causing a shortage. There were also a number of disruptions caused by a lack of coordination of the other producers having maintenance periods that overlapped. The next major problem occurred in May 2009 when a leak in the containment vessel of the NRU was discovered. At the time of the discovery the AECL stated that the NRU would be down for 3 months to access the extent of the leak and repair the vessel. Two months later the down time was revised to the end of the calendar year 2009. There are concerns within the community that it may never be put into operation again.

With the NRU shut down that left the remaining reactors to try and fill the gap; however the capacity is not there and thus the patient community has been severely affected by these shortages. Many procedures have been delayed or cancelled. While there are some alternatives such as using PET scanning or CT scanning with contrast agents, these measures cannot match the demand.

To compound the situation further, the HFR will be off line for at least a month during the August/September 2009 period. In addition, the HFR is due for a major maintenance period lasting six months in early 2010.

What alternatives exist?

There are two reactors proposed or being built in Europe. The Jules Horowitz multipurpose reactor (France) is due to come on line by 2015 and the replacement of the HFR, the PALLAS reactor, has yet to sited. The Missouri University Research Reactor (MURR) and the McMaster University reactor in Hamilton, Ontario, are probably the only reactors in North America that can be used to lessen the crisis. However, both are using highly enriched uranium (HEU) cores and have not been converted to use low enriched uranium (LEU) targets, compounding the problems associated with using them. Also, both are more than 40 years old. The problem with HEU is that it is weapons grade uranium and represents a major security issue. The US National Nuclear Safety Administration and the IAEA have been working for decades to remove HEU from civilian use.

There are plans to convert the MURR reactor to use LEU targets and build processing facilities to handle Mo-99 production, both of which will take approximately five years. Upgrades of MURR and the McMaster reactor have been proposed and each has received some funding to proceed. Does the push for LEU get put on the back burner until the crisis period is over, or do these reactors hold sufficient promise so that they should be converted to Mo-99 production in the process of upgrading them? This is a political question yet to be determined.

The Australian OPAL reactor is supposed to come on line later in 2009 and there is growing pressure to fast track the approval process for it. However it is not clear whether it can provide more than 10% of the US needs. Babcock and Wilcox is planning to build a reactor where fission of U-235 in solution will continuously produce Mo-99 which can be periodically extracted as needed during the production cycle. This approach represents an interesting concept but it is not clear how difficult it will be to engineer and how much can be expected to be promised in a single reactor. This proposed reactor being built in Lynchburg, Virginia probably will not be available for at least 5 years.

There have been discussions about operating the Maple reactors at lower power to mitigate the safety issues while still producing some Mo-99. While this may be worth considering, it does not address the HEU target problem. One possibility is that one could operate one reactor while the other is modified to deal with LEU targets.

The recent announcement in the Canadian press (CBC.CA) from the Canadian government that they were getting out of the "isotope" business caught the world by surprise. This statement basically indicated that the government would no long subsidize production of Mo-99. All of the present producers are located at government facilities. The infrastructure thus provided represents a significant subsidy. The Canadian government has assured the world that they will proceed with the repair of the NRU reactor and keep it in operation through the expected expiration of its safety license in 2016. However with the recent announcement that the NRU will not restart before the end of 2009 there is growing concern that it may never operate again.

Where do we go from here?

The alternatives are somewhat limited in the near term, while the mid- to long-term allows other options. But for these to have a chance of making an impact on the Mo-99 supply, decisions will have to be made very soon.

If there are no reactor-based solutions in the near term, can accelerators be used to help in this problem? While the idea of using high-energy accelerators to recreate neutrons through spallation has been proposed a number of times, such an approach can not compete with reactors for efficiency of neutron production. [Spallation involves the collision of high energy projectiles with the target nuclei with enough energy (>200 MeV, 1mA) to produce a very large array of products.] There has also been discussion of using a spallation device to generate neutrons for direct fission of U-235 in a blanket surrounding the spallation target.

What are the possibilities of using low energy cyclotrons? Takács et al (2002, 2003) explored the production of Mo-99 from the ^{100}Mo(p,pn)^{99}Mo reaction. However the production cross section for Mo-99 from proton reactions is too low to be of practical use. Their results indicated a thick target yield (40-45 MeV) of 3.8 mCi/μAh. The daily production for a cyclotron operating at 500 μA would be about 50 Ci; at this rate about 100 cyclotrons would be required to meet US demand for Mo-99. The other approach would be the direct spallation of a target to produce Mo-99. The production rate of Mo-99 from most reasonable target materials would be at best many orders of magnitude lower than the reactor methods and two orders of magnitude lower than the above accelerator reaction and thus not a viable approach.

The other reaction that has been explored is the direct production of Tc-99m from the $^{100}Mo(p,2n)^{99m}Tc$. The biggest disadvantage with this approach is that the final product (the one used in nuclear medicine procedures) is directly produced and has a short half life (6 hours). Thus, its usefulness will be greatly hampered if it needed to be shipped great distances to the end users. Even a network of suppliers would face a challenge. Takács, et al. report that the cross section for the direct production of Tc-99m from enriched Mo-100 would be approximately 17 mCi/μAh. At this level even with a very high beam-current facility (500μA protons) and irradiation periods of a day (i.e., 24 hours), the most that could be produced in a single facility would be < 200 Ci per day. Meeting US needs would require more than 25 cyclotrons dedicated to this process, not accounting for the losses associated with transport and chemical efficiencies for separating the Tc-99m from the target matrix. A single site might be able to become self sufficient but this would not help the larger community.

TRIUMF, Canada's National Laboratory for Nuclear and Particle Physics, has proposed the use of photo-fission of U-238 for the production of Mo-99. It turns out that the fission yield distribution for (γ,f) on U-238 is almost identical to that of (n,f) on U-235. However, the photon process is several orders of magnitude less efficient and would necessitate a very high photon flux. To generate such a high flux TRIUMF is proposing the use of a very high power (5 MW) electron linear accelerator. A workshop in the Fall of 2008 concluded that this approach held promise with the biggest outstanding issue being the converter required to produce the photons from the electron beam. With this approach, the product is identical to that produced in the present reactors and the HEU/ LEU issue is not a factor—both strong pluses. The downside is that even at 5 MW there would have to be several machines to meet US demand. TRIUMF is proposing to perform the demonstration experiment and to let market forces decide if this is a viable solution. With the recent announcement of funding for the e-linac (summer 2009) a demonstration is possible by 2012.

Concluding Remarks

This medical crisis is clearly a mix of technical and political issues. From this analysis, it appears that there are few viable alternative approaches to the supply of Mo-99 or Tc-99m for widespread distribution.

In the meantime, production of research radionuclides has been transferred within the DOE from the Nuclear Energy program to the Nuclear Physics (NP) program. As part of that process NP organized a workshop and assembled an Advisory committee to help them outline a path forward. Obviously the Mo-99 was the elephant in the room because of its overriding consequences to the field of Nuclear Medicine. While no part of the charge to the committee dealt with options for producing Mo-99, the discussions for producing research radionuclides often included possible solutions for Mo-99 including some of the approaches discussed here. The report from NSAC Isotopes report is due to be published during the summer of 2009.

With the termination of the Maple project, alternative approaches need to be explored in comparison to the cost of constructing and commissioning a new reactor facility, in particular the possibility of using photon-induced fission of U-238.

The interesting political situation here is that the US is considering supporting upgrading the MURR. Traditionally, the US has not been in favor of subsidizing industry while Canada has not shied away from this approach: the historical roles may be reversed. Nevertheless, the question is really an issue of supporting the public good in health care.

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A Contract Between Science and Society: The Canadian Experience with Nuclear Waste Management

Elizabeth Dowdeswell

[Editor's note: Professor Dowdeswell's article is based on an invited presentation she gave at a joint FIP-FPS sponsored session, "Managing Nuclear Fuels: An International Perspective," held during the April meeting of the APS held in Denver, May 2009.]

How to meet our ever-increasing energy needs in a responsible and environmentally sustainable way is one of the most vexing social and technological questions facing the world today. As energy demand grows, the prospect of climate change is forcing us to face the inevitability of a carbon-constrained world, a situation which has opened the door for discussion about a potential nuclear renaissance. While there are those who advocate that nuclear is at present the only safe large-scale energy source available for base load power, public acceptance of nuclear energy has not been fully embraced. Fears of human error (Chernobyl), technical failure (Three Mile Island), and terrorism are very real in the minds of many citizens. So are concerns about waste management and environmental impact of nuclear power. These citizens cannot be ignored: They have every right to feel secure from accidental radiation releases and proliferation. Perhaps the most challenging issues are the many social and ethical concerns, both real and perceived. Fundamentally, the future of nuclear energy raises questions about how we make good public policy decisions. Responsible management of nuclear energy is a quintessential complex public policy challenge that, if not done well, can instill inspire fear and insecurity in the public or possibly polarize them. This challenge is only magnified as public trust in governments and institutions erodes while citizens' expectations of being involved in decision-making have become more intense and sophisticated.

In this article I will use Canada's recent policy exercise about nuclear waste to make some observations about approaches to dealing with these social and ethical concerns. I present these thoughts not as a blueprint for other countries to follow but rather because they illustrate an approach that deliberately seeks to strike a bargain between science and society with the goals of benefitting from technology, reducing risk, and respecting the values of our citizens.

The Context

Canada has more than two million used fuel bundles currently stored on an interim basis at licensed facilities at reactor sites. The Nuclear Waste Management Organization (NWMO) was established in late 2002 in response to federal legislation requiring Canada's nuclear energy corporations (Ontario Power Generation, Inc., Hydro-Quebec, and New Brunswick Power Corporation) to create an organization to investigate and develop an approach for the long-term management of their used nuclear fuel. This followed a lengthy and extensive environmental assessment of geological disposal. That assessment concluded that the concept had been adequately demonstrated from a technical perspective, but that it had not been as well established from a social perspective, lacking the required level of public acceptability to be adopted.

We began by asking ourselves, "What would make this attempt different from those of the past?" We decided that the answer might lie in trying to understand the deeply held values of citizens and in reviewing our options through a multidimensional lens that would be in part shaped by citizens themselves. For three years the NWMO had the privilege of engaging with Canadians. I say "privilege" because there is an inherent wisdom among citizens that policymakers would be wise to tap.

Our mission statement was rooted in the concept of sustainable development: *To develop collaboratively with Canadians a management approach for the long-term care of Canada's used nuclear fuel that is socially acceptable, technically sound, environmentally responsible and economically feasible*. Our analytic framework was integrative and systemic, and featured eight objectives: fairness, public and worker health and safety, community well-being, security, environmental integrity, economic viability, and adaptability. One of our main goals was to gather and document the terms and conditions that would make such a project acceptable to society and to reflect a fundamental understanding and respect for these factors in the project's actual design and implementation.

During the course of our work we were often asked why we though it necessary to consider the ethical and social issues at all, the implication being that what we must do is simply seek the best technical approach. The answer is that members of the public have a right to be engaged in discussions about matters that affect their lives fundamentally. But it is not just a matter of recognizing rights. It is also about better decision-making. Astute decision-makers, whether in government or the private sector, have come to understand that people who are affected by policies bring special insights and expertise to the discussion. Just as importantly, policies and decisions that are developed in an environment of trust and confidence have a much greater likelihood of being supported by public consensus. Participants who feel as if they "own" the process are more likely to sustain its outcome. The answer also lies in how we as a society manage risk. The NWMO began its study with the understanding that technical and scientific specialists would articulate the nature of the risk and help us understand the technical adequacy of each of the management approaches available. They would also help us understand the impacts each approach might have on the environment and their economic feasibility. Experts could also propose mitigation measures. However, we also strongly believed that the analysis of scientific and technical evidence, while essential, could not be the sole determining factor.

We were also profoundly influenced by the time dimension of this issue. Effectively, we were being asked to develop public policy that would require implementation over a period longer than recorded history. Given the longevity of the hazard it was imperative that we consider explicitly how we might meet our obligations to future generations.

We concluded that values and ethics were absolutely central. Ethical questions rarely have unambiguous or definitive answers. We observed that past attempts to solve ethical questions through technical arguments alone have not been satisfactory. As with any complex issue, trade-offs among competing objectives were going to be inevitable. In order to best determine and then satisfy the primary objectives of a large socio-scientific project such as this, the process had to be transparent, open to input from any and all points of view, and rigorously discussed.

The underlying philosophy of NWMO was that ultimately it is society at large that must determine which risks it is prepared to accept. We needed to understand society's views of the benefits, risks and social implications if we were to develop a socially acceptable recommendation. In essence, if the general population concluded, after extensive and informed public dialogue, that there was sufficient assurance of safety, then we would have obtained a "social license" to proceed.

We listened and learned. Our study process was iterative. Through four phases, each with its own "milestone document" we sought to make transparent our deliberations, to elicit public feedback, to shape and direct subsequent steps in the study, and to test and validate NWMO's observations and conclusions as we developed them. Our analysis used the best science and technology, building on years of study in Canada and internationally. Furthermore, we integrated the input of citizens and specialists through continuous interaction between the analysis and the engagement components of our study.

Our approach was collaborative. We believed that progress in developing social acceptability would only come through genuine dialogue. Always we sought to bring multiple perspectives to the table to shape each major decision point. We experimented with a broad range of engagement and dialogue initiatives, including traditional and more innovative approaches. This was an issue that demanded engagement, not just participation; dialogue and not simply debate; and thoughtful deliberation as opposed to simple consultation. Some methods were used to elicit the concerns of stakeholders directly interested in the issue, and various techniques were adopted to hear from a statistically representative cross-section of citizens, including those who would not have otherwise involved themselves in the study.

Some of the specific methods we employed were

- *A Roundtable on Ethics* involving ethicists from fields as diverse as medicine, biotechnology, business and religion, who met over the course of the study to help identify the ethical issues associated with both the issue and the conduct of the study;
- *A National Citizens Dialogue on values* involving deliberative dialogue sessions with a representative cross-section of Canadians to learn about their deeply held beliefs and values;
- *A program of Aboriginal Dialogues* designed, conducted and reported on by Aboriginal Peoples themselves;
- *A Scenarios Exercise* involving a diverse group of 26 individuals who met over a period of 6 months to explore a range of plausible futures and conditions which might need to be faced in managing used nuclear fuel over the long term.

In parallel, the organization was conducting the necessary scientific and technical analysis of the management approaches. Our work was advanced through the contributions of a multidisciplinary Assessment Team. What differentiated this exercise from so many others was that it was grounded in the basic issues identified by Canadians. The development of a framework for analysis started with guidance from the Roundtable on Ethics about the social and ethical issues that needed to be central while industry experts provided technical information. The team assessed each of the technical methods against the objectives listed above. They brought rigor and discipline to the consideration of options and illustrated the wisdom of a holistic systems approach to analysis.

Public Response

We found that the public was both capable and pragmatic. While they may lack awareness and knowledge about the characteristics of used nuclear fuel and the technological choices for its management, our experience was that citizens could participate effectively in identifying a path forward. In fact, we found that common ground emerged among citizens and specialists:

- They felt a responsibility to deal with the waste we have created and for taking action now. They sought fairness to current and future generations and did not want a legacy to be left for their children;
- They saw safety and security as pre-eminent objectives;
- They wanted flexibility to accommodate advances in knowledge and the inevitable technological and societal changes over long timeframes.

The public demonstrated consistently that they are willing and capable of thinking through difficult trade-offs. They understood that decisions would have to be taken in a dynamic and adaptive rather than static manner.

The public instinctively gravitated towards a precautionary approach: they were humble about the state of our current knowledge and uncertainties over time, optimistic about the future and respectful of decisions made today for future generations. They did not shun risk; rather, they sought to manage it in the best way possible with decision-making processes that were phased, adaptive, inclusive and deliberative. We also observed that the public was not prepared to simply delegate responsibility to any one expert or specialist group, including the government: those individuals and organizations were not seen as capable of adequately considering the full breadth of objectives. Only a process which considered diverse views deliberately and transparently would be considered trustworthy of protecting the public interest. The Canadian public defined complementary and inextricable requirements of the socio-scientific contract: safety, fairness and flexibility.

Results and Recommendations

NWMO's response was to propose Adaptive Phased Management: a technical approach of isolation and containment in a centralized underground facility, using a system of multiple natural and engineered barriers married with a management approach that was phased, flexible and collaborative. The committee's report can be found at www.nwmo.ca.

The case we made to government was that Adaptive Phased Management was both responsible and responsive. Adaptive Phased Management commits this generation of Canadians to take the first steps now to manage the used nuclear fuel that we have created. It employs the best available science and technology in pursuit of safety and security, and it provides genuine choice and promotes continuous learning allowing for improvements in operations and designs that would enhance performance and reduce the uncertainties as the years pass. It includes sequential and collaborative decision-making and provides capacity to be transferred from one generation to another. Fundamentally, it is rooted in values and ethics.

Our journey from dialogue to decision reached an important milestone in June of 2007 when the Government accepted our recommended approach. The hard part has now begun. We know that the success of any management approach, no matter how well conceived, will depend on how well it is executed. Matters of implementation were uppermost in the minds of most people that we encountered: they wanted to talk about the decision-making process, what institutions and systems would have to be put in place, and how citizens would be involved on an ongoing basis. There were calls for strong governance and extensive oversight and clear accountability along with greater and continued opportunity for citizen engagement. We concluded that just as a considerable investment was made in examining and understanding the technical options, so too an investment in examining and developing a process of implementation would be essential.

Designing the process of site selection is now underway, building on the same collaborative approach we fostered in the study phase. The NWMO envisions that citizens will play a legitimate role in making decisions while at the same time creating conditions for productive movement forward. Sustained engagement with people and communities—whether they welcome, oppose, or seek modifications to our observations and conclusions—is vital.

During the study we became profoundly aware of the imperative to earn and retain the trust of Canadians. There is no reservoir of trust and confidence at this time. An industry or government mindset of exaggerated self-confidence or arrogance is no longer appropriate (if it ever was). History has shown that no public or private agency has adequately understood and considered the breadth of objectives important to citizens on this subject, from economic feasibility and environmental integrity to safety, security and fairness. Only a process that deliberately and transparently considers multiple perspectives will be considered trustworthy of protecting the public interest.

Finally, we humbly acknowledged that there would always be some uncertainties. It is sheer hubris to think that we can anticipate new knowledge and societal change over hundreds of thousands of years. The future will undoubtedly unfold in ways that may redirect the NWMO on its path. But that need not nor should not paralyze us. We are confident that we now know enough to take the first steps.

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Global Catastrophes and Trends — the Next 50 Years

Vaclav Smil, MIT Press, 320 pages, $29.95, ISBN-10: 0-262-19586-0-13; ISBN-13: 978-0-262-19586-7

This is largely a book on quantitative scientific analyses of probabilities for, and consequences of, potential events or developments that could have catastrophic or drastically altering effects on humankind. These are divided into three categories, each covered by a lengthy chapter:

(1) fatal discontinuities like encounters with extraterrestrial objects, volcanic mega-eruptions, and disease pandemics;

(2) unfolding trends like transitions in energy sources, changing seats of political and economic power and influence, and globalization;

(3) environmental problems like global warming, water supplies, and loss of biodiversity.

All of these problems and many more are analyzed at substantial length, presenting a wide spectrum of scientific viewpoints with each elaborately referenced. These references, about 750 in all, are perhaps the most valuable aspect of the book for research-oriented readers, and their abundance is truly impressive. Uncertainties in the analyses are constantly acknowledged, but these do not deter the author from arriving at what he describes as consensus conclusions.

Here are some samples of these conclusions:

• Over the next 50 years, there is a 1% chance that there will be as many as 40,000 deaths from incoming extraterrestrial objects, 3 million deaths from volcanoes and tsunamis, 40 million deaths from influenza pandemics, and 40 million deaths from a very large war. There is a 0.01% chance that over the same time period these numbers will be 1 million deaths, 10 million deaths, 100 million deaths, and 100 million deaths respectively.

• Except for inhabitants of the Near East, the average person's lifetime risk of dying in a terrorist attack is one chance in 50,000; his risk of dying in a car accident is 600 times larger.

• Following very extensive discussion and analysis, he concludes that a transition from fossil fuels to renewables will be extremely difficult and very slow to occur. For example, substituting corn ethanol for gasoline in U.S. would require twice the country's entire cultivated area; using cellulosic alcohol would require 75% of its farm land and would have drastic environmental consequences.

• A hydrogen economy could take shape only during the closing decades of this century, and he has little optimism about fuel cells. His best hope for the near future, a very uncertain one, is on methanol.

• Discussion of the new world order occupies one third of the book and presents many facts and references, but it is only superficially a scientific treatment. He concludes that China's rise and the U.S.'s retreat will continue, but slowly, with no other countries challenging them. He gives lengthy arguments for why they will not be challenged by Europe, Japan, India, the Muslim world, or Russia.

• There are serious problems arising from economic inequality both within nations and among nations. These inequalities have been getting worse, with little hope for them to improve.

• The best available evidence is that global warming will be 2.5 to 3 degrees Celsius by 2100; he even gives a curve of probability vs. temperature rise. The economic costs of this warming would be about 1% of the gross world product, with large uncertainty, but the effects vary greatly for different nations.

• He estimates a sea level rise of 15 cm by 2050.

• Water availability will be a severe problem in many areas. Contaminated water and water-borne diseases now kill 5 million people per year.

• Anthropogenic fixation of nitrogen is a serious problem which will be extremely difficult to overcome.

• For the past century, extinction of species has been 100 times faster than indicated by the fossil rate, and it may become 1000 times faster in the next 50 years.

• Antibiotic resistance is becoming a very serious problem; without new breakthroughs we will lose our ability to combat bacterial infections.

• Unpredictable consequences of our interference with biospheric functions could have catastrophic effects.

The final chapter is about how to deal with risks and uncertainty, keeping various risks in proper perspective and recognizing the large uncertainties in many of his previous analyses. He ends by reminding the reader that "demise" or "collapse" are categories of our making, and that catastrophes and endings are also opportunities and beginnings.

The author, Vaclav Smil, is a professor in the Faculty of Environment, Earth, and Resources at the University of Manitoba and author of several books and numerous research papers on related subjects. I found this to be a very valuable book, loaded with facts, figures, and above all references to wide varieties of analyses whose conclusions are summarized and commented upon. It is easy and interesting to read, although reading is slowed down by the ubiquity of numbers and the necessity for mentally digesting the concepts presented. I certainly plan to keep my copy close at hand as a reference for a long time to come.

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Physics for Future Presidents: The Science Behind the Headlines

Richard A. Muller, W.W. Norton & Company, Inc. (2008) ISBN 978-0-393-06627-2, 380 pages, $26.95

Based on his popular course at the University of California at Berkeley where he is a professor of physics, Richard Muller has prepared a primer on the major scientific aspects of four major issues that future presidents will have to face. Each section is followed by a two or three page summary in the tradition of issue briefs prepared by political staffers. Muller carefully avoids mathematics and complex jargon unless he defines his terms so that the book is accessible to a reader who is not a physicist. At the same time, he is careful to present multiple facets of the complex issues he writes about. While he avoids math, he does not duck complexity.

The first section, "Terrorism," treats the difficulty of screening passengers, the chance that terrorists will obtain nuclear weapons including dirty bombs, and other methods of mass destruction that terrorists might employ including bioweapons. The second section, "Energy," focuses on the economics of using different types of energy. Muller is careful to provide basic definitions of energy and power and does a nice job of relating energy stored, say in gasoline or liquid hydrogen, to energy stored in food. The next section, simply called "Nukes," begins with a nicely nuanced discussion of the dangers of radiation that is clearly designed to ameliorate the public's sometimes irrational fear. Although the material is accessible to a non-scientist, the discussion avoids simplifying complex issues and neither dismisses nor exaggerates the hazards of nuclear radiation. The remainder of the chapter contains a description of the operation of nuclear weapons and nuclear fission and fusion reactors. The discussion is clear and the author is careful to separate his personal political positions from his description of the science.

The final sections of the book are respectively titled "Space" and "Global Warming." "Space" presents the basics of spaceflight and then focuses on the uses of space, particularly for obtaining information both civilian and military. The section includes a tutorial on the various wavelengths of electromagnetic radiation and the way they are used as well as a discussion of the pros and cons of manned spaceflight. Muller uses the complexities of global warming to illustrate a solid discussion of the way in which presentation of data can distort science and force an erroneous conclusion. He separates the facts that the scientific community considers solid (that in the last 50 years, the average global temperature has risen and that the atmospheric concentration of carbon dioxide has increased) from the question of the degree to which both effects are anthropogenic. He attempts, quite successfully, to demonstrate how the complexities of the climate system such as clouds hamper our ability to predict regional effects of the changes in climate as well as details of global effects.

With *Physics for Future Presidents*, Richard Muller has produced a very readable and scientifically correct discussion of physics that both political leaders and concerned citizens need to understand. Physicists will find this book a quick read and an interesting introduction to applications of the physics they already know. However, its primary target is non-scientists who will make policy decisions based on this science. For this audience, it is excellent reading.

Any physicist who simplifies complex physics so that it is accessible to non-physicists necessarily neglects exceptions to general rules and subtleties that concern experts in the field. This book is no exception. In a few spots, for example in the introduction to the section on global warming, Muller is reduced to emphasizing his own excellent scientific credentials, and asking the reader to trust him. However, he has done an A-plus job of explaining where the physics ends and the policy discussion begins. It would make excellent supplementary reading for an introductory course in physics for students who are not majoring in science.

Lastly, the book would benefit by an annotated bibliography with a few major sources on each issue, aimed at the worried staffer who has been told to establish her principal's position on one of these issues. She would want to read more deeply about one of these issues and could use help in identifying accessible sources that are scientifically credible. In spite of these minor flaws, Muller has done one of the best jobs I have seen in making very complex physics both interesting and available to policy makers not trained in science who need to understand it.

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Hot, Flat and Crowded: Why We Need a Green Revolution—and How It Can Renew America

Thomas L. Friedman (Farrar, Straus and Giroux, New York, 2008) ISBN-13:978-0-374-16685-4, ISBN-10:0-374-16885-4, 438pp

The Green Era is upon us and America must lead the way in solving the world's global warming problems. This is Thomas Friedman's message. He is an award winning American journalist, columnist, and author. His op-ed column appears twice weekly in the New York Times. He has won the prestigious Pulitzer Prize three times, twice for international reporting and once for commentary. In his reporting he consults with a variety of people, adding vitality to his writing and making his reporting interesting and controversial. This book builds on his previous The World is Flat by adding hot and crowded. He attempts to integrate these into the mix necessary for the whole earth system. In the process he makes interesting suggestions on international affairs, including a chapter on China and its place in the green era.

The book's first half diagnoses the world's unique energy, climate, and biodiversity problems. The second half is about meeting those challenges.

Friedman sees five key problems: the demand for scarcer energy and natural resources; the massive transfer of wealth to oil-rich countries and petrodictators; disruptive climate change; energy poverty; and accelerating biodiversity loss. These are big problems accentuated by the flat, hot, and crowded convergence. They demand big solutions.

Friedman suggests four ways our oil addiction is changing the climate system and also the international system. First, our energy purchases are helping strengthen the most intolerant, anti-western, and anti-pluralistic strain of Islam—the major strain in Saudi Arabia. Many Saudis would prefer a more open Islamic State, but it is not their progressive outlook that is being exported to the madrasahs of Pakistan, London, Mosul and Jakarta. Second, energy purchases are helping to reverse democratic trends in Russia, Latin America and elsewhere. Friedman introduces his "first law of petropolitics": Whenever governments can raise most of their revenue by simply drilling a hole in the ground rather than tapping their people's energy, creativity and entrepreneurship, freedom is curtailed, education under-funded, and human development retarded. Third, our growing oil dependence fuels an ugly energy scramble that brings out the worst in nations. And fourth, our energy purchases fund both sides of the war on terror. So our refusal after 9/11 to do anything significant to reduce gasoline consumption funds the rope that will hang us.

Of the 23 nations that derive most of their export income from oil and gas, none are democracies! From this, Friedman derives his second law of petropolitics: Any American strategy for promoting democracy in an oil-rich country that does not include a plan for developing renewable energy alternatives to reduce the price of oil is doomed to failure.

Friedman does not go into a discussion of the finer details of global warming but refers to Joseph Romm's book Hell and High Water from which he quotes "the only holes left in the science of climate change is whether it will be serious or catastrophic." What we don't know are the positive and negative feedback systems yet to be encountered. Until these are fed into computer systems, there may be surprises. Despite this, climate will continue to change and with it the world as we know it.

Energy in the green era is not only a matter of soaring energy demand, climate change, and proliferating petro-dictators. A hot, flat, and crowded world is also a threat to biodiversity. Friedman suggests that it is our responsibility to follow Noah in creating metaphoric arks and not floods. Biodiversity, the total sum of life on earth, is directly linked to non-living components forming one great independent biosphere. Consequently, we must think of the problems facing us in integrated comprehensive ways. The remedies must start now. There is no "later" that we can postpone to.

Today, more than ever, economic growth comes via electricity. Developing countries suffer from energy poverty resulting from misgovernance or persistent civil war, leaving them no way to finance power plants and transmission lines. They need all the help they can get to protect their forests, coral reefs, and other natural habitat. They will also miss out on the education required to enjoy the benefits of electronic media serviced by a reliable green source of electricity. This is one reason we quickly need abundant, clean, and reliable power sources.

In the second half of the book, Friedman examines the solutions to the problems studied in the first half. In a flat world everyone can see what everyone is doing. There is no way of avoiding accountability, and this is one more reason why the effects of our American way of life must be recognized and remedied. "Green" can no longer be a fad or boutique statement. It must be a way of life. Friedman believes that America must lead the way in a green revolution that brings to the world's most disadvantaged the energy to improve their lives. One priority is to get rid of dirty fuel systems, and to Friedman this means producing "clean electrons"--Friedman's phrase for green electricity that solves problems and stimulates innovations.

Clean electrons must be accompanied by energy efficiency and conservation, which in turn involve attention to protecting our natural resources and educating people about their value. We need a new ethic of conservation that's not dictated by laws but rather by voluntary values and attitudes.

There are two avenues for pursuing clean electrons: the short term improvement of what we already have, and "eureka" breakthroughs from research and experimentation. Both are necessary but breakthroughs take about 25 years after commercialization to reach even 1% share of the global market. Clean energy that's cheaper than the true social cost of fossil fuels can be accomplished through government policies, regulations, research funding, and tax incentives.

Today there is a proliferation of "easy" ways to save Earth, ways that can lull the public into false confidence. But the easy way does not exist, and it is essential to learn the magnitude of the challenge. Friedman outlines the monumental nature of the task, but is convinced that there is hope based on the intelligent green energy technology which he believes can give us more growth, fewer power plants, and better energy. This by itself is not enough. In his view we must put in place a set of policies, tax incentives and disincentives, and regulations to mobilize the American market place. At the moment this is designed to keep fossil fuels cheap and renewables expensive. We need regulatory policies pushing on the boundaries of materials science, chemistry, physics and biology. Taxes must be applied to things we don't want and subsidies to the things we do. A renewable energy mandate should be imposed in which power companies in all states must generate a certain percentage of their power from renewable energy sources.

Friedman muses on how good it would be to have the Chinese system, but for one day only. With a top-down bureaucracy a country can do so much by fiat in one day that would take months in a democratic society.

We will know that the green movement has succeeded when energy inefficiency, carbon excesses and dependence on dirty fuels are the news and not the norm.

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This contribution has not been peer-refereed. It represents solely the view(s) of the author(s) and not necessarily the views of APS.

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