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PHYSICS & SOCIETY

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EDITOR'S COMMENTS

Our editorial comments in the July 2008 issue include the following statement: "There is a considerable presence within the scientific community of people who do not agree with the IPCC conclusion that anthropogenic CO2 emissions are very probably likely to be primarily responsible for the global warming that has occurred since the Industrial Revolution." In fact, we have not polled any scientific community (e.g., the climate research community, the physics community, or the general science community) as to the extent of its consensus regarding human-activity-caused global warming, and we apologize for making such a remark for which we do not have supporting data. We now do know that, in addition to the American Physical Society, the following scientific organizations have issued statements and/or reports in support of the IPCC's main conclusion concerning the role of anthropogenic CO2 emissions in global warming: The National Academy of Sciences, the American Meteorological Society, the American Geophysical Union, and the American Association for the Advancement of Science.

—JJM

The July issue brought forth a storm of email responses to the Editors and to officials at APS. The emails, from members and non-members of FPS, were primarily concerned with the article by Christopher Monckton, either lauding or condemning our decision to publish it. They ranged from polite rational discussions to very vituperative comments. We have chosen to publish just two of the calmer letters, one critical of, one supporting, the publishing decisions we made for the July issue. We also publish a very useful summary of the climate "debate" by an eminent historian of physics, Spencer R. Weart.

Also in this issue, in addition to the usual book reviews, we have a response letter from our Book Editor, two articles about people of great historical interest to physicists, and materials on the up-coming elections for officers of our Forum. We also strongly urge our readers to look at the recent APS energy study which is available on the Web at: http://www.aps.org/energyefficiencyreport.

—AMS

IN THIS ISSUE

FPS ELECTIONS

Please vote! You will be receiving the actual ballot via e-mail shortly.

CANDIDATES FOR VICE-CHAIR 2009 (one vacancy)

KATEPALLI R. SREENIVASAN

International Centre for Theoretical Physics, Trieste

Educated in India, Australia and the Johns Hopkins University, Katepalli R. Sreenivasan taught at Yale for twenty-two years from 1979, holding joint appointments in the Departments of Mechanical Engineering, Physics, Applied Physics and Mathematics. In 2002 he moved to the University of Maryland as Distinguished University Professor, Professor of Physics and Professor of Engineering, and served as the Director of the Institute for Physical Science and Technology for a year and a half. He is now concluding his term as Director of the International Centre for Theoretical Physics in Trieste, Italy, where he holds the Abdus Salam Research Professorship. He has held visiting positions at Caltech, Rockefeller, Cambridge, and the Institute for Advanced Study at Princeton.

Sreenivasan's research expertise is statistical and nonlinear physics, with strong focus on fluid dynamics and turbulence; it has also touched a few other areas of physics and applied physics (such as plasma physics and cosmology). He has authored some 240 research papers and supervised about 30 Ph.D. theses and mentored numerous students. He has served the scientific community in various capacities -- the APS community as the Chairman of the Division of Fluid Dynamics (1990), the founding Chairman of the Topical Group on Statistical and Nonlinear Physics (1996-97), Associate Editor of Phys. Rev. E (1994-97) and Divisional Editor of Phys. Rev. Lett. (1991-95).

Sreenivasan is a member of the US National Academy of Sciences and the US National Academy of Engineering, the American Academy of Arts and Sciences, the Indian Academy of Sciences, the Indian National Science Academy, the Academy of Sciences for the Developing World (TWAS), and the African Academy of Sciences. His honors include Guggenheim Fellowship, Otto Laporte Memorial Award of the APS, International Prize and Modesto Panetti and Carlo Ferrari Gold Medal of the Academia delle Scienze di Torino, Italy, National Order of Scientific Merit (the highest scientific honor) by the Brazilian Government and the Academy of Sciences, UNESCO Medal for Promoting International Scientific Cooperation and World Peace from the World Heritage Centre, Florence, Italy.

Statement: I grew up admiring great physicists who also had a strong social conscience. I have in mind especially those who mastered the enormous challenges of the Manhattan Project, yet devoted their time later, with equal zest, to nuclear non-proliferation. They understood physics very well, and its societal consequences at least as well.

Today's world has come to face a number of challenges such as global change, terrorism, energy crisis and environment, spread of infectious diseases, debilitating war machines, diminishing privacy, increasing imbalances between the rich and the poor, and an increasing litany of ills. Physics has much to offer in alleviating these complex challenges. It is the duty of physicists, and of the APS, to devote part of our energies to the task. The Forum is the instrument of APS that links physics and society.

Having spent many years in different parts of the world, I have a good sense of the uniting umbrella that physics can offer; I was involved in the International Freedom of Scientists from the late 70's; I served as a member of the Committee on Human Rights of the US National Academies. As Director of the International Centre for Theoretical Physics, whose role is to foster the highest possible level of scientific research and higher education in the needy parts of the world, I have come to understand international issues of science and science policies. Science, like most other human activities, requires leadership, and APS can provide it. Moreover, APS can, and should, be engaged with society far more than now, both within the US and without. Specifically, I would try to: (a) impress upon the APS the need for deeper involvement on societal issues at national and international levels; (b) bring more of the US physicists to work on such issues; (c) connect with the large network of international scientists for purposes of joining forces with APS. I readily recognize the public affairs and international initiatives being carried out by APS, as well as individual efforts of a number of APS Presidents, but these worthy goals must be widened by involving a larger cross-section of the membership through the Forum.

PETER ZIMMERMAN

King's College London, Professor Emeritus

I recently retired as Chair of Science & Security in the Department of War Studies at King's College, London and Director of the KCL Centre for Science & Security Studies but I'm still active with research and teaching in the UK as Professor Emeritus and I teach part-time in Washington. My work focuses on nuclear terrorism, nuclear proliferation, and studies of the effects of debris in space caused by the use of space weaponry. In 2004-2005 I was on the National Academies of Science panel on the Safety and Security of Spent Reactor Fuel.

Before moving to London I was chief scientist of the Senate Foreign Relations Committee until 15 January 2003 and Democratic Chief Scientist until 15 March 2004 - the problems with losing an election. I advised the chair of the committee, Senator Biden, on nuclear testing, nuclear arms control, cooperative threat reduction, and terrorism. I organized the Foreign Relations Committee's hearing on "Dirty Bombs" (radiological dispersion devices) in 2002 and the classified briefings the Committee received on nuclear terrorism.

Before the merger of the Arms Control and Disarmament Agency into the Department of State, I was the last chief scientist of ACDA, a nice closing of the circle since my first job in DC was as a visiting scholar at ACDA in 1984. After ACDA was merged into State I moved to the job of science adviser for arms control. I got to work on technical aspects of the Comprehensive Test Ban Treaty, biological arms control, missile defense, and strategic arms control.

In 2001 I was elected to a four year term as a member of the APS Council from the Forum on Education and re-elected in 2004. In 2006 I was elected to the executive board of APS, and in 2007 to POPA. I'm completing a term on the FPS ExCom.

I was honored to be the recipient of the 2004 Burton/Forum Award of the American Physical Society for work in arms control and national security and to be elected an APS fellow by the Forum.

I have B.S. and Ph.D. degrees from Stanford University and a Filosofie Licentiat degree from the University of Lund, Sweden, all in experimental nuclear and elementary particle physics.

Statement: I have been lucky to have had several opportunities to serve the Forum. When I became chairman in 1999 FPS was flat broke. If an organizer of a session needed money to bring an invited speaker, I had to say "no" because there was no money. When somebody suggested a project, I had to give the same answer: "we're broke." Almost all of the money we received from APS went to the same account, printing and mailing Physics & Society. The hardest choice I made was to suggest that we use e-delivery for two issues a year. As a result, nine years later the FPS budget is in surplus. That gives FPS the resources to increase its presence. If elected vice-chair, I will seek to expand the Forum's reach through establishing projects that involve self-selected volunteers from our membership, through bringing important non-physicist speakers to major APS meetings, and trying to sponsor Forum sessions at regional and section meetings of the APS.

FPS has long been the leading edge, the sensor, if you will for the APS's activities in societal aspects of physics - from energy studies to arms control, from the ozone hole to missile defense and nuclear nonproliferation, from smart weapons to homeland security. This is a role we are glad to play, for as physicists we have the education to sort through the arguments and the obligation to work to improve our world to make it more peaceful, less vulnerable, and more humane. Because we have the resources, we, The Forum, can plan programs that bring our members' efforts to bear on the problems of our country and planet. I would like to bring the academic physicists, the industrial physicists, and those physicists in non-traditional employment together on common efforts to identify areas of concern, and to recommend solutions to our national leaders. For the last seven years science advice has been ignored or politicized in the federal government. Either presidential candidate is likely to reverse that trend, and FPS should be on hand to educate its own members and the wider public. If I am fortunate to become your vice chair those are the areas on which I will focus my efforts

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CANDIDATES FOR EXECUTIVE COMMITTEE 2009-2011 (two vacancies)

JESSICA CLARK

Vanderbilt University Medical Center

Jessica Clark is currently a research fellow in the Radiology and Radiation Therapy departments at Vanderbilt University Medical Center in Nashville, TN. Until recently, she served as the first Head of Public Outreach for the American Physical Society, a position she held since 2000. During her tenure at APS Dr. Clark established a vibrant portfolio of programs aimed at communicating the excitement and relevance of physics to people of all ages, from "Pre-K to Grey". She created PhysicsCentral.com, the APS website for the public, and then helped lead the APS component of the World Year of Physics 2005. Dr. Clark received her BS, MS and PhD all from the College of William and Mary. Her graduate work was supported by the Henry Luce Foundation through the Clare Boothe Luce Fellowship program. She has served as an advisor for the television show NOVA and as a member of the Outreach Advisory Board for NOVA's "Absolute Zero: The Conquest of Cold."

Statement: It is an honor to be a candidate for Member-at-Large on the FPS executive board. While I can still be considered to be in my early career, the focus of my career thus far has been service to both physics and the society. In my eight years working for APS my objective was to develop activities that offer the public an opportunity to experience the excitement of physics. With our programs for children, my goal was to inspire kids with science, in much the same way that many of us were inspired by physics. In transitioning my career to medical physics, I will now be using physics to improve the diagnosis and treatment of cancer, a definite service to society. For many reasons, scientists are no longer as valued as we once were. However, I believe as physicists we still have an obligation to show our communities how science can improve the lives of all people. I believe that FPS should work to create a more locally active membership, either through encouraging grassroots outreach or service in local politics. Our society is facing huge problems, from climate change to a pending energy crisis (issues that have already produced enormous consequences in my home state of Alaska). As physicists we know that we can contribute to the solutions to these problems; we just need FPS to help the world listen to us. And, as the great bumper sticker says, "Think globally. Act Locally."

DAVID HARRIS

Stanford Linear Accelerator Center

David Harris is currently Deputy Communications Director for Stanford Linear Accelerator Center and Editor-in-Chief of Symmetry magazine, published jointly by SLAC and Fermi National Accelerator Laboratory. He obtained a first class honours degree and the University Medal from Australian National University, a Graduate Diploma in Science Communication from ANU, and then studied for a theoretical physics PhD at the University of Queensland. While a graduate student, he started his career as a science communicator and journalist, presenting a weekly science program on Australia's public radio broadcaster. He was the head writer and co-producer for 65 half-hour episodes of a science television program "Y?" for 8-12 year olds, broadcast nationally in Australia and then sold to overseas markets. After some years as a freelance science journalist, university public information officer, and science communication consultant, he moved to the United States to take up a position as APS Head of Media Relations from 2002-2004. At APS he was involved in the planning for the APS World Year of Physics effort. He then moved to Stanford Linear Accelerator Center to establish Symmetry magazine, which has won numerous awards for editorial content and design. He served on the advisory board to the AIP Media and Government Relations from 2004-2007. As a journalist, he has written news and features for a wide range of international science publications from *Nature* to *New Scientist* to *Wired* magazine. He is a Life Member of the American Physical Society and the Forum on Physics and Society.

Statement: Physics plays as significant a role as ever in ensuring a healthy, innovative, wealthy society. However, at times of economic insecurity, basic research is at serious risk of being marginalized in the policy-making process. The physics community has a responsibility to ensure that policy makers and the constituents they represent have sufficient information to engage in the policy process to make decisions for the benefit of society. Through the experience over the past five years of producing *Symmetry* magazine, which is aimed at non-scientist policy makers and opinion leaders, the value in bridging gaps between physics, the non-science-trained portions of society, and policy makers has become extremely clear to me. Finding ways to bring all three of these communities together is vital in making well-informed decisions that have a chance of influencing the formation of policy, not only for the benefit of the physics community but for society as a whole. As physicists, we must engage with these communities on a sustained basis, forming strong relationships with other stakeholders so that when external pressures become most acute, an already-existing shared understanding can allow us to make strategic decisions in forming plans for the future. Reaping the benefit of the research done by the physics community, and ensuring an adequate funding environment to allow physicists to do their research is critically dependent on the relationships between the physics community and other segments of society. My interest in offering my experience to the Forum on Physics and Society is to promote the building of relationships between the physics community and others (particularly in policy circles) and to use these relationships to better inform strategic planning for a healthy future for physics and the many areas of society to which physics can contribute.

CHARLES TAHAN

Booz Allen Hamilton, Inc.

Charles Tahan is currently lead technical consultant to DARPA's Microsystems Technology Office on programs in quantum information science and technology. Previously he was a National Science Foundation Distinguished International Postdoctoral Research Fellow at the Cavendish Laboratory of the University of Cambridge, UK (with research also conducted at the University of Melbourne in Australia and the University of Tokyo, Japan). While working in England, he was invited to be a founding member of both the United Kingdom's Nanotechnology Task Force chaired by Dr Ian Gibson, MP, and the Nanoethics Network of Aarhus University, Denmark. He also sits on the advisory board of the Nanoethics Group (Santa Barbara, CA). He received a B.Sci. in physics and computer science with highest honors from the College of William and Mary (2000) and a Ph.D. in condensed matter theory from the University of Wisconsin-Madison (2005), where his work focused on silicon quantum computing and spin-based devices. At Wisconsin he worked with professors in the sociology, public affairs, history of science, engineering physics, bioethics, and materials science departments to co-develop a new course on nanotechnology and its societal implications dubbed "Nanotechnology and Society," which he taught to undergraduates in the spring term of 2005. He has authored several guest articles on nanotechnology and its societal interactions and implications. Recently he has become interested in the social implications of quantum information science and technology. In addition to semiconductor nanodevices, his research interests have included quantum optics and the quantum many-body theory of photons and polaritonic "solid light" systems, which he helped introduce, and solid-state architectures for quantum technology such as silicon, diamond, superconducting electronics, and plasmonics.

Statement: A society that brings forth advances in technology will itself be changed by it. We few who are trained in and devoted to science have a responsibility to guide these transformations, both with our technical work and also with our interactions with the greater world. I believe the latter goes beyond calling for "more children interested in science and math." Science is awesome; we need for it to be a better career option for the brightest students. In the realm of physics and society, there is a greater need for scientists to engage with the science and technology studies and public policy communities earlier in their careers, without fear of stigma. Earmarked funding in the National Nanotechnology Initiative specifically for societal and environmental implications studies has created a unique opportunity where physicists can work directly with sociologists, ethicists, and science historians before speculation becomes accepted fact. Here, expertise in the actual science and the limits of technology can be vital. If I can add anything to the already excellent Forum on Physics and Society, it is the perspective of these new developments of physics in society - in fields, like nanotechnology and quantum information technology, that did not exist 20 years ago.

ORIOL VALLS

University of Minnesota

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 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 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. 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. 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 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 the mentor them.

CANDIDATES FOR REPRESENTATIVE TO POPA: 2009-2011 (one vacancy)

ANTHONY FAINBERG

Institute for Defense Analyses

Dr. Fainberg is a staff member at the Institute for Defense Analyses, having transitioned there following his retirement from federal service. He received his A.B. from New York University in 1964 and his Ph.D. from the University of California, Berkeley, in 1969 in experimental particle physics. He worked in basic and applied research for a decade at CERN, Syracuse University, and Brookhaven National Laboratory. Dr. Fainberg came to Washington, DC, in 1983 as an APS Congressional Science Fellow, working in the Office of Senator Jeff Bingaman (D-NM). He then spent a decade at the Congressional Office of Technology Assessment, before it was closed by the 104th Congress. While there, Dr. Fainberg participated in an analysis of the Strategic Defense Initiative, which had a major impact on congressional perceptions of this program. He also helped initiate and then directed studies on the role of technology in countering terrorism in 1990-1992, well before this topic had developed its high profile. Later, he spent a decade in various federal agencies within the Executive Branch, dealing primarily with scientific issues related to national security affairs. He oversaw research and development programs for the Federal Aviation Administration and the Department of Homeland Security. He also directed policy studies in the Advanced Systems and Concepts Office of the Defense Threat Reduction Agency. Most recently, he has focused on countering the threat of nuclear terrorism. Dr. Fainberg has been active in the Forum on Physics and Society in the past, having served as its Chair in 1993-4. He was also Vice-Chair of the APS Panel on Public Affairs in 1996. He has participated in several Forum sessions at APS meetings and co-edited (with Ruth Howes as editor) The Energy Sourcebook, published by the American Institute of Physics in 1991. He is a Fellow of the APS.

Statement: The current bad relations between the federal government and the scientific community are nearly without precedent. This situation has hurt the U.S. science community but has damaged the Nation even more. The disconnect is not uniquely a Republican-creationist-climate change-denial matter, either: last December's disaster in science funding was caused by an infantile game of chicken between the administration and a Democratic Congress, in which science was a severely injured bystander. Fortunately, there is an opportunity to reverse this trend in January. The APS can and should play a leading role in opening new and innovative channels of communication between the scientific community and the incoming leadership of both the Executive and Legislative Branches. The APS also should expand its past, highly successful efforts to perform serious scientific studies on matters with public policy relevance. The Forum, given its history of sessions, studies, and publications, plus its corporate knowledge, is well-positioned to suggest strategies and paths forward to the Panel on Public Affairs (POPA) in these endeavors. As well as addressing usual topics of concern -climate change, energy policy, national security, etc.--a couple of meta-topics could also be put forth, such as how to improve a) prospects that major political decisions with technical content not be made in a data-free environment and b) general scientific literacy--which would help with a). My career path has allowed me to spend many years both in the research world and in the government. Further, I have experience at both the Forum and POPA, dropping participation only when my oversight over some federal research funding would have led to perceptions of a conflict of interest. Given my background, I think I could be useful in presenting Forum-developed initiatives to POPA. I would aim for major improvements in government-scientific community relations, as part of a long-term effort to increase the ability of the nation's scientists and engineers to affect policy issues in which they have expertise and interest.

LAWRENCE KRAUSS

Arizona State University

Lawrence M. Krauss is Foundation Professor and Director of the Origins Initiative at Arizona State University. He moved to ASU from Case Western Reserve University, where he was Ambrose Swasey Professor of Physics, Professor of Astronomy, and Director of the Center for Education and Research in Cosmology and Astrophysics. He received his Ph.D. in Physics from MIT in 1982 then joined the Harvard Society of Fellows. In 1985 he joined the faculty of Physics at Yale University, and moved to CWRU in 1993. From 1993 to 2005 he also served as Chairman of the Physics Department.

He is a Fellow of the APS and of the AAAS and the author of over 250 scientific articles, as well as numerous popular articles on physics and astronomy. In addition, he is the author of six popular books, including the international bestseller, The Physics of Star Trek., and the award winning Atom: An Odyssey from the Big Bang to Life on Earth and Beyond. In addition to his newspaper commentaries, he appears frequently on radio and television around the world and is a commentator for Marketplace and Morning Exchange on NPR and writes a regular column for New Scientist Magazine. He has testified before Congress on issues ranging from Space Exploration to support of science research in general. Prof. Krauss is the recipient of numerous awards including the AAAS 1999-2000 Award for the Public Understanding of Science and Technology, the 2001 Julius Edgar Lilienfeld Prize of the APS, the 2002 Andrew Gemant Award from the AIP, the 2002 AIP Science Writing Award, the Oersted Medal of the AAPT, and in 2005, the APS's Joseph P. Burton Forum Award for his work on Science and Society.

He has been particularly active in issues of science and society. He serves on the steering committee of Science Debate 2008 and is outgoing Chair of the Forum on Physics and Society for the APS, and outgoing Chair of the Physics Division of the AAAS.

Krauss has also performed with the Cleveland Orchestra, narrating Gustav Holst's The Planets, and he was nominated for a Grammy award for his liner notes for a CD of music from Star Trek. In 2005 he also served as a jury member at the Sundance Film Festival.

Statement: Having served on both POPA in the past, and as Chair of the Forum on Physics and Society I believe I am in particularly good position to serve as the FPS representative on POPA. I am fully aware of not only the ongoing issues that have governed activities in the Forum over the past few years, and my longstanding interest and activities associated with physics and society should help me provide valuable perspective as POPA determines its agenda for the coming year. As the main body that helps determine public policy statements for the APS, POPA is an extremely important body, and I am excited about the possibility of being able to contribute to its activities.

ARTICLES

Simple Question, Simple Answer... Not

Spencer R. Weart

The following article appeared originally in slightly different form on September 8, 2008 on the RealClimate.org blog (see http://www.realclimate.org/index.php/archives/2008/09/simple-question-simple-answer-no/). It is being reproduced here, with the permission of RealClimate.org. The author has added a postscript.

I often get emails from scientifically trained people who are looking for a straightforward calculation of the global warming that greenhouse gas emissions will bring. What are the physics equations and data on gases that predict just how far the temperature will rise? A natural question, when public expositions of the greenhouse effect usually present it as a matter of elementary physics. These people get suspicious when experts seem to evade their question. Some try to work out the answer themselves (Lord Monckton for example) and complain that the experts dismiss their beautiful logic

The demand that the case for dangerous global warming be proved with a page or so of equations does sound reasonable, and it has a long history. The history reveals how the nature of the climate system inevitably betrays a lover of straightforward answers.

The simplest approach to calculating the Earth's surface temperature would be to treat the atmosphere as a single uniform slab, like a pane of glass suspended above the surface (much as we see in elementary explanations of the "greenhouse" effect). But the equations do not yield a number for global warming that is even remotely plausible. You can't work with an average, squashing together the way heat radiation goes through the dense, warm, humid lower atmosphere with the way it goes through the thin, cold, dry upper atmosphere. Already in the 19th century, physicists moved on to a "one-dimensional" model. That is, they pretended that the atmosphere was the same everywhere around the planet, and studied how radiation was transmitted or absorbed as it went up or down through a column of air stretching from ground level to the top of the atmosphere. This is the study of "radiative transfer," an elegant and difficult branch of theory. You would figure how sunlight passed through each layer of the atmosphere to the surface, and how the heat energy that was radiated back up from the surface heated up each layer, and was shuttled back and forth among the layers, or escaped into space.

When students learn physics, they are taught about many simple systems that bow to the power of a few laws, yielding wonderfully precise answers: a page or so of equations and you're done. Teachers rarely point out that these systems are plucked from a far larger set of systems that are mostly nowhere near so tractable. The one-dimensional atmosphere model can't be solved with a page of mathematics. You have to divide the column of air into a set of levels, get out your pencil or computer, and calculate what happens at each level. Worse, carbon dioxide and water vapor (the two main greenhouse gases) absorb and scatter differently at different wavelengths. So you have to make the same long set of calculations repeatedly, once for each section of the radiation spectrum.

It was not until the 1950s that scientists had both good data on the absorption of infrared radiation, and digital computers that could speed through the multitudinous calculations. Gilbert N. Plass used the data and computers to demonstrate that adding carbon dioxide to a column of air would raise the surface temperature. But nobody believed the precise number he calculated (2.5°C of warming if the level of CO_2 doubled). Critics pointed out that he had ignored a number of crucial effects. First of all, if global temperature started to rise, the atmosphere would contain more water vapor. Its own greenhouse effect would make for more warming. On the other hand, with more water vapor wouldn't there be more clouds? And wouldn't those shade the planet and make for less warming? Neither Plass nor anyone before him had tried to calculate changes in cloudiness.

Fritz Möller followed up with a pioneering computation that took into account the increase of absolute humidity with temperature. Oops... his results showed a monstrous feedback. As the humidity rose, the water vapor would add its greenhouse effect, and the temperature might soar. The model could give an almost arbitrarily high temperature! This weird result stimulated Syukuro Manabe to develop a more realistic one-dimensional model. He included in his column of air the way convective updrafts carry heat up from the surface, a basic process that nearly every earlier calculation had failed to take into account. It was no wonder Möller's surface had heated up without limit: his model had not noticed that hot air would rise. Manabe also worked up a rough calculation for the effects of clouds. By 1967, in collaboration with Richard Wetherald, he was ready to see what might result from raising the level of CO_2. Their model predicted that if the amount of CO_2 doubled, global temperature would rise roughly two degrees C. This was probably the first paper to convince many scientists that they needed to think seriously about greenhouse warming. The computation was, so to speak, a "proof of principle."

But it would do little good to present a copy of the Manabe-Wetherald paper to a technically trained person who demands proof that global warming is a problem. The paper gives only a sketch of complex and lengthy computations that take place, so to speak, offstage. And nobody at the time or since would trust the paper's numbers as a precise prediction. There were still too many important factors that the model did not include. For example, it was only in the 1970s that scientists realized they had to take into account how smoke, dust and other aerosols from human activity interact with radiation, and how the aerosols affect cloudiness as well. And so on and so forth.

The greenhouse problem was not the first time climatologists hit this wall. Consider, for example, attempts to calculate the trade winds, a simple and important feature of the atmosphere. For generations, theorists wrote down the basic equations for fluid flow and heat transfer on the surface of a rotating sphere, aiming to produce a precise description of our planet's structure of convective cells and winds in a few lines of equations... or a few pages... or a few dozen pages. They always failed. It was only with the advent of powerful digital computers in the 1960s that people were able to solve the problem through millions of numerical computations. If someone asks for an "explanation" of the trade winds, we can wave our hands and talk about tropical heating, the rotation of the earth and baroclinic instability. But if we are pressed for details with actual numbers, we can do no more than dump a truckload of printouts showing all the arithmetic computations.

I'm not saying we don't understand the greenhouse effect. We understand the basic physics just fine, and can explain it in a minute to a curious non-scientist. (Like this: greenhouse gases let sunlight through to the Earth's surface, which gets warm; the surface sends infrared radiation back up, which is absorbed by the gases at various levels and warms up the air; the air radiates some of this energy back to the surface, keeping it warmer than it would be without the gases.) For a scientist, you can give a technical explanation in a few paragraphs. But if you want to get reliable numbers—if you want to know whether raising the level of greenhouse gases will bring a trivial warming or a catastrophe—you have to figure in humidity, convection, aerosol pollution, and a pile of other features of the climate system, all fitted together in lengthy computer runs.

Physics is rich in phenomena that are simple in appearance but cannot be calculated in simple terms. Global warming is like that. People may yearn for a short, clear way to predict how much warming we are likely to face. Alas, no such simple calculation exists. The actual temperature rise is an emergent property resulting from interactions among hundreds of factors. People who refuse to acknowledge that complexity should not be surprised when their demands for an easy calculation go unanswered.

Postscript: Some bloggers have quoted from this essay to support their view that computer models can give no "proof" of global warming. That is true enough as they mean the term. So long as people disagree on what kind of "proof" is needed before we take action, we will never reach agreement on what to do, although we can hope to converge on where the disagreement is located. If we require a level of certainty equivalent to what governments use in deciding to intervene in markets or go to war, it is obvious that climate science has exceeded that level for a decade or more.

For history details and references see http://www.aip.org/history/climate/Radmath.htm

On Monckton see http://www.realclimate.org/index.php/archives/2008/07/once-more-unto-the-bray/

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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.

Feynman and Me

Paul Craig

This note is in the spirit of David Hafemeister's comment in the April, 2008 issue on bribing his way out of collapsing Soviet Union. I encourage you to run more reminiscences. To help this process along, here's one of mine.

The year was 1957. I was completing my Ph.D. dissertation at Caltech. Feynman had recently moved to Caltech from Cornell. All eyes were on him. Feynman was working on his theory of quantization in superfluid helium II. He had developed the idea that quantization could occur in macroscopic samples of superfluid. Feynman got together with my thesis advisor, John Pellam. Pellam had me working on what later became known as the "fly wing" experiment.

Pellam's idea was to test the concept of identically zero viscosity in superfluid helium II by looking at the lift on airfoil. Absent viscosity the circulation around an airfoil is indeterminate. In a viscous fluid, even the tiniest amount of viscosity establishes circulation around the wing of just the right amount so that the fluid velocity at the trailing edge of the wing vanishes. This is known as the Kutta boundary condition. Feynman realized that the circulation around my airfoil might be quantized.

I immediately began to search for the effect. My apparatus consisted of a superfluid wind tunnel in which was suspended a propeller – initially wings torn from dead flies -- hanging from a torsion fiber. To everyone's amazement, I found the effect. My world turned upside down. Feynman was in my laboratory for what seemed like half the time. Virtually every visitor to the Physics department or to the Aeronautics Department came to watch the wing jump. I spent my time giving demonstrations.

In short order a paper was prepared for *Physical Review Letters*. A Physics colloquium was scheduled, to be given jointly by Feynman and John Pellam.

At this stage Feynman began to review the experiment in great detail. He said the only way to confirm the experiment was to take it apart and rebuild it with different parameters. This I did. The effect went away. It turned out to be an artifact of my design. The only reason it was seen at all was graduate student error. I figured my career in physics had come to an end.

Feynman and Pellam decided to go ahead with the colloquium. Rather than presenting an exciting new result, they'd describe a proposed experiment. While everyone knew that a graduate student had screwed up, that question was never asked during the colloquium. They covered for me.

Feynman took the position that was his job to cross check everything, and that one should never expect very much of a graduate student unless or until they'd proved themselves. I never discovered what he thought about my advisor's inadequate quality control.

In due course the "fly wing" paper was published in Physical Review. It demonstrated experimentally that when the viscosity term is removed from the Stokes-Navier fluid flow equations, the order of the differential equations drops and the viscosity boundary condition is lost. Interesting, but not nearly as exciting.

Feynman continued to come to our graduate student parties, and he approved my dissertation. To my complete amazement I was offered several jobs, and took one at Los Alamos.

As I was cleaning out my laboratory I chanced upon a pile of handwritten papers. These turned out to be Feynman's draft manuscript of his classic paper on superfluid helium II. I didn't realize what a treasure I was holding, and discarded them. Bummer. Years later John Pellam died. A day of memorial speeches in his honor was scheduled at UC Irvine. In the morning I gave a talk about my experiences with Pellam. Mostly I concentrated on Pellam's research. Toward the end, however, I focused on his humanity. I told the story.

In the afternoon Feynman showed up and talked on his current research. At the reception Feynman came up to me, looked directly at me, and without preface said "Did you tell them?" Fortunately I had learned well the lesson of intellectual honesty Feynman had taught me. I replied "Yes". That was the totality of our conversation, and the last time I saw him.

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Rudolf Peierls' 1939 Analysis of Critical Conditions in Neutron Multiplication

B. Cameron Reed

December 2008 marks the 70th anniversary of the discovery of fission by Hahn and Strassmann, one of the most pivotal scientific discoveries of the twentieth century. The story of the subsequent elucidation of the fission process and the development and use of nuclear weapons continues to hold a strong fascination for physicists, historians, and laypersons alike. In this article I briefly examine a side story to this history that is now often overlooked: the first detailed analysis of the physics involved in estimating critical mass, an analysis published by Rudolf Peierls in late 1939.

Peierls' paper [1] was received by the *Proceedings of the Cambridge Philosophical Society* on June 14, 1939 and published in October of that year. The now relative obscurity of this paper is likely attributable to a combination of reasons: fission had been observed only with slow neutrons at the time and so any prospect of a weapon must have seemed remote if not impossible, it was published just after the appearance of Bohr & Wheeler's extensive analysis of fission in the September 1, 1939 *Physical Review*, and the fact that Peierls did not apply the formulae he developed to any situation as he lacked reliable estimates for cross-sections and secondary neutron numbers. By July 1941 the British MAUD report [2] used his formulae to estimate a critical mass for U-235 of about 9 kg. While this is an underestimate compared to the currently-accepted value of ~ 45 kg (a consequence of optimistic parameters; see [3]) one cannot help but wonder if he would have published in the open literature had he a sense of the numbers in the summer of 1939.

Discussions of the technicalities of computing critical mass now typically refer to the diffusion-theory approach presented in Robert Serber's *Los Alamos Primer* [4]. Peierls' name did not appear in the original *Primer* but does in Serber's book by virtue of the fact that it includes a reprint of the Frisch-Peierls memorandum of March 1940. It is of interest, then, to examine how the predictions of Peierls' formulae compare to those of diffusion theory upon adopting modern values for the fission parameters.

Peierls parameterized fissility with a dimensionless variable he designated as ξ and defined as

$$\xi^2 = \frac{\sigma_f(\nu-1)}{\sigma_s+\nu\sigma_f}, \tag{1}$$

where σ_f and σ_s are the fission and scattering cross-sections and where ν is the number of secondary neutrons emitted per fission; non-fission neutron absorption is ignored here. Note that if the neutron multiplicity is low ($\nu \sim 1$) then $\xi \to 0$ whereas if $\nu >> 1$ then $\xi \to 1$, that is, $0 \le \xi \le 1$ in general. He then developed formulae for the critical radius R of the form $(\beta R)^{-1} = f(\xi)$ that apply in these two extremes, where $\beta = n(\sigma_s + \nu\sigma_f)$ and where n is the nuclear number density. Explicitly, $f(\xi)$ is given by

$$f(\xi) = \begin{cases} 0.552\xi + 0.216\xi^2 & (\xi \to 0) \\ 0.78 - 1.02(1-\xi) & (\xi \to 1). \end{cases} \tag{2}$$

As nature would have it, the situation in reality for U-235 falls into neither of these extremes but rather takes $\nu \sim 2.6$ and $\xi \sim 0.51$.

The solution to the diffusion equation for the critical radius can only be carried out numerically as described in references [3] and [4]. In terms of a reduced critical radius $x = R/d$ where

$$d = \sqrt{\frac{\lambda_f\lambda_t}{3(\nu-1)}} \tag{3}$$

the diffusion equation leads to the condition

$$x(\cot x) + x/\eta - 1 = 0 \tag{4}$$

where

$$\eta = \frac{2\lambda_t}{3d}. \tag{5}$$

Here λ_f and λ_t are respectively the neutron mean free paths for fission and transport, defined as $(\lambda_f)^{-1} = n\sigma_f$ and $(\lambda_t)^{-1} = n(\sigma_f + \sigma_s)$; σ_s is here taken to be the cross-section for elastic scattering only, as effects of inelastic scattering are ignored in Serber's treatment.

It is straightforward to show that in terms of Peierls' $(\beta R)^{-1}$ quantity, the solution of Eq. (4) corresponds to

$$\frac{1}{\beta R} = \frac{6\eta}{x(4+3\eta^2)}. \tag{6}$$

The accompanying graph shows runs of $(\beta R)^{-1}$ (in meter^{-3}) for the physically interesting range of ξ. The dashed curves are Peierls' expressions for $\xi \to 1$ and $\xi \to 0$; the solid line is the diffusion theory prediction. Peierls' curves actually converge at $\xi \to 1$ although only one of them is valid there. Notice that the diffusion-theory curve tracks closely to Peierls' $\xi \to 0$ curve; this is because the diffusion theory is in fact only strictly valid when the size of the bomb core is large in comparison with the neutron mean free paths involved, which is the case when $\nu \sim 1$. (Even for relatively large values of ξ, however, the diffusion-theory prediction tracks reasonably closely to Peierls' $\xi \rightarrow 1$ curve.) As explained by Serber, a more exact treatment (which he does not detail) gives results in close accord with those of diffusion theory.

Adopting average fission parameters for U-235 as given in reference [3], $(\sigma_f, \sigma_s, \nu) = (1.235$ bn, 4.566 bn, $2.637)$ gives $\xi = 0.5083$. Solving the diffusion equation gives $\beta R \sim 3.1378$ whereas Peierls' solutions give ~ 2.9726 and 3.5907 for $\xi \rightarrow 0$ and $\xi \rightarrow 1$. The mean of Peierls' solutions lies only about 4.6% higher than the diffusion-theory solution; this would correspond to overestimating the critical mass by about 14% in comparison with the diffusion solution. The diffusion solution corresponds to a critical radius of about 8.26 cm, or a critical mass of ~ 45 kg. For Pu-239 ($\xi = 0.6221$) the various solutions are in even closer accord with the mean of Peierls' solutions giving a critical radius only about 3.2% lower than that from diffusion theory.

Clearly, Peierls developed an accurate and quite general model for predicting critical masses within a few months of the discovery of fission. But does this imply that fission weapons might have been available earlier had his work in some sense been better appreciated at the time? In the opinion of this author this is not likely: he had no experimental values available for the fissility parameters and apparently did not consider the idea of a fast-fission pure U-235 bomb until approached about it by Otto Frisch in early 1940. Even then they had to base their estimate of critical mass (about one pound) on an estimate of the fission cross-section derived from scattering theory. Experimental uncertainties aside, one has to admire Peierls' treatment of the problem. The availability of his work in the open literature at the outbreak of World War II makes all the more remarkable Werner Heisenberg's famous misunderstanding of the issue.

References

1. *R. Peierls, "Critical Conditions in Neutron Multiplication,"* Proceedings of the Cambridge Philosophical Society **35***, 610-615 (1939).*

2. *The MAUD report can be found in its entirety in M. M. Gowing,* Britain and Atomic Energy 1939-1945 *(St. Martins Press, London, 1964); see pp. 402-405 for the report's discussion of fission parameters and estimated critical masses.*

3. *B. C. Reed, "Arthur Compton's 1941 Report on explosive fission of U-235: A look at the physics,"* Am. J. Phys. **75** *(12), 1065-1072 (2007).*

4. *R. Serber,* The Los Alamos Primer: The First Lectures on How To Build An Atomic Bomb *(Univ. of California, Berkeley, CA, 1992).*

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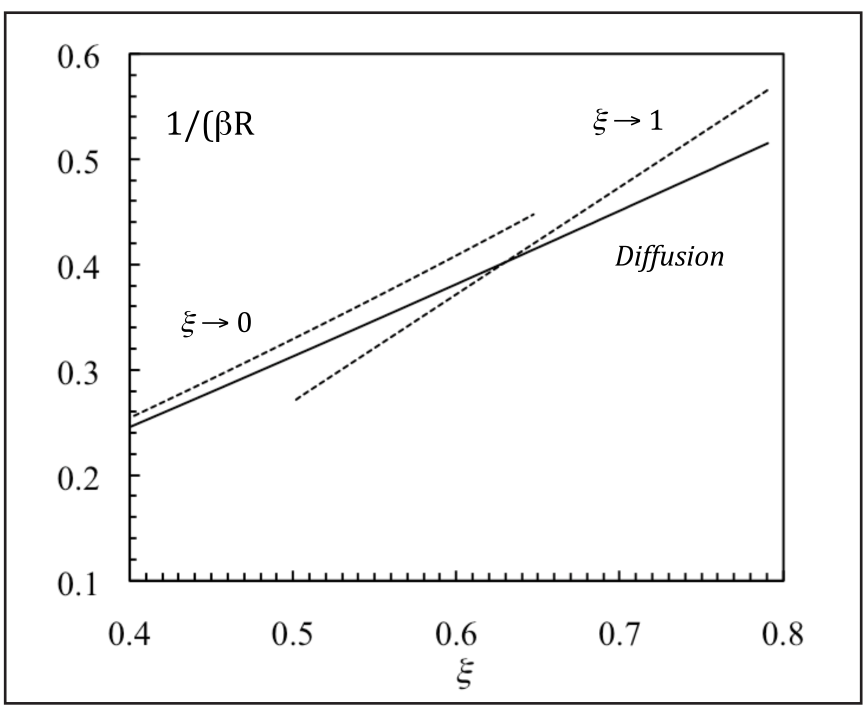

LETTERS

To the editor:

David Williams (April 2008) takes issue with my commentary (January 2008) "Winning the climate race." His main concern is that the commentary contains "not a single mention of the role nuclear power can and must play if the climate change problem is to be addressed--a truly remarkable omission."

But it happens that Williams and I nearly agree on this. It's clear from my commentary that the stated recommendations are not mine but instead come from George Monbiot's book *Heat: How to Stop the Planet from Burning*. Monbiot's aim is to take on the quite daunting task of explaining how industrialized nations can reduce greenhouse gas (GHG) emissions by 90 percent by 2030. Halfway through the book he discusses nuclear power briefly, puts it at the bottom of his list of preferred solutions, and never mentions it again. Since I was offering Monbiot's recommendations, rather than my own, as one way to get to 90 percent reductions, I didn't list nuclear power as part of the solution.

The task of getting to large reductions rapidly is lightened by adding nuclear power to Monbiot's list of recommendations and I, unlike Monbiot, agree that we should do this. I also agree with Williams that nuclear waste disposal is not a reasonable argument against nuclear power today, and I'd add that the same goes for the catastrophic accident argument against nuclear power. I do think that nuclear weapons proliferation concerns are an important drawback of nuclear power, and am happy to see that Williams is also concerned about this. Mainly because of proliferation issues, I greatly prefer efficiency and renewables to nuclear power, but nuclear will be part of the mix that solves the global warming problem. Indeed, this is already happening in China and India.

I do disagree with Williams' two other points. He suggests that Monbiot's recommended measures are "draconian and grossly unrealistic," and lists restrictions on automobile travel and long-distance air travel as examples. But these travel modes are already shrinking, and people are changing their living habits by moving from suburbs to central cities, due just to the increase in oil prices that we've seen recently. There's plenty of reason to think that such increases will keep coming, and that gasoline will before long reach $5 per gallon or more, with corresponding increases in jet fuel prices and thus airline prices. If you add that to the legislated carbon prices that are surely only a few years away, it becomes obvious that car and airplane travel are due for big reductions. It's neither draconian nor unrealistic to suggest that by 2030 we'll see a big shift to reduced travel and alternative transportation modes. In fact, it seems unrealistic to expect that there will not be such a shift.

Williams dismisses what's commonly referred to as "contraction and convergence" (C&C) as the fair long-term apportionment of the planet's limited future GHG emissions rights. C&C was developed in response to the U.N. Framework Convention on Climate Change's 1992 call for an equitable distribution of carbon emission rights among nations. It calls for a contraction of global emissions that, by 2050, converges on equal per-capita emission rights globally. Those rights would be about 1.5 tons/person-y, some 13 times less than Americans emit today but 50 percent more than Indians emit. This would presumably be accomplished by a cap-and-trade emissions agreement under which high-emission nations would buy their needed emissions permits from low-emission nations, thus helping to finance new technologies in the developing nations. During this process, the developing nations should also receive the developed world's technological assistance, as Williams properly suggests. C&C is supported not only by China, India, and most African nations, but also by the European Commission and the European Parliament, which endorsed it in 1998. I can't imagine that the developing nations would accept any plan that did not eventually converge on equal per-capita emission rights. Although C&C is the fair solution, it is not, as Williams puts it, "ideological." It is dictated not only by fairness but also by practicality and realism: The nations of the world will agree on nothing less.

Art Hobson
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Author, Physics: Concepts & Connections (Prentice Hall, 4th ed 2007)

Dear Dr. Marque:

As a longtime APS member and an (admittedly not very active) member of the Forum on Physics and Society, I am writing to express my concern about the article in the July 2008 newsletter by Christopher Monckton. While one can have differing views on whether the newsletter is an appropriate forum for contributions with different perspectives debating the science of climate change, this is not my primary concern. My concern is that now that Monckton's piece has appeared, an organization that Monckton serves as "chief policy advisor" on has issued a press release, http://scienceandpublicpolicy.org/press/proved_no_climate_crisis.html, that describes his paper as "a major, peer-reviewed paper" in "a learned journal". Do you consider your newsletter to be a peer-reviewed learned journal?. (As you are no doubt aware, there have also been other misrepresentations of this paper that have appeared in the media and prompted a response on the APS homepage.)

Frankly, I think that we, in the Forum, have basically been "used" in what is not really a scientific debate but rather a propaganda war. I would ask you, in the strongest possible way, to prevent future misrepresentations of Monckton's paper and its appearance in our newsletter.

Thank you for your time.

Joel D. Shore
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[affiliation withheld upon author's request]

Editor's response: The newsletter of the Forum on Physics & Society is not, and never has been, peer-reviewed.

Dear Jeffrey,

I want to thank you for promoting a discussion of climate change. It is the most politicized scientific topic I have seen, and, at the same time, by far the most consequential. The best science will come from open discussion and adherence to the scientific method. Perhaps you have taken some flak for publishing this issue, especially given the way in which it was misinterpreted on various blogs as a general APS position. I strongly support your decision and agree with your introduction to the newsletter. I am sorry the APS statement on its homepage did not, in addition to restating its (in my opinion very poorly worded) climate position, also forthrightly support your intellectual right and obligation to function as an editor as you see fit.

Yours,
Jonathan

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REVIEWS

Earth: The Sequel

By Fred Krupp and Miriam Horn (Norton 2008) 252pp ISBN 978-0-393-06690-6

There have been several good books published recently at the semi-popular level covering a variety of views on Global Warming. For example Al Gore's "An Inconvenient Truth" sounds the alarm by looking at what is happening all around us. Joseph Romm's "Hell and High Water," written by a physicist and reviewed in P&S, April, 2008, gives the scientific basis of global warming and makes alarming predictions. To avoid catastrophe worldwide nations must cut emissions of greenhouse gases in half over 50 years, implying that the United States must cut emissions by 80%! Krupp and Horn are well aware of the situation but nevertheless take an optimistic view that, bad as the situation looks, the US can overcome the problems through the dynamism of innovators and entrepreneurs, coupled with the adoption of the appropriate method of charging polluters for the carbon they produce.

Fred Krupp might be best described as an eco-lawyer. He graduated from Yale University, has a law degree from University of Michigan, and has taught Environmental Law at both schools. In 1984 he became the president of Environmental Defense Fund (EDF), a national non profit organization that links science, economics, law, and innovative private sector partnerships. Krupp and the EDF believe that environmentalists by themselves will not solve the global warming situation. It is vital that there be a strong connection to industry, its financial means, and the market place. Hence they are prepared to talk with industry and together work to obtain solutions to environmental problems.

Miriam Horn is now on the staff of the Environmental Defense Fund. She has worked for the U.S. Forest Service and written for numerous newspapers and magazines including Vanity Fair and the New York Times.

One of the problems needing urgent solution in the 1980s concerned acid rain. Krupp worked with the administration that eventually embraced a proposal suggested by EDF, and submitted it to Congress. The result was the Clean Air Act of 1990. Perhaps the most significant aspect of the EDF proposal was the world's first emission cap-and-trade system. Krupp and Horn use the success of the Clean Air Act to support adoption of a cap-and trade-system as a prime step in solving global warming. In this system the U.S. Congress determines an overall limit on allowable pollution. Each industry is allotted a cap on the pollution they are allowed to produce. Industries themselves determine how they achieve those limits. Heavy polluters with allowances below their current pollution production can trade pollution allowances with those whose pollution is lower than their allowed amount. The cap is ratcheted down over time so that the amount of pollution falls. The system rewards light polluters who profit from the trade, whereas heavy polluters must pay for allowances purchased from light polluters. This maintains market competition by encouraging entrepreneurs to invent new ways of decreasing acid rain pollutants or new ways of producing energy with lower carbon emissions. Krupp and Horn consider this the most appropriate way to benefit from America's boundless capacity for invention and from its equally important venture capitalists who provide the essential financial support.

The first part of the book describes the cap-and-trade process in some detail and explains why it is superior to carbon taxes and subsidies in producing a level playing field in which renewable energies can effectively compete with carbon producing energy sources of the past. The cap-and-trade mechanism has the remarkable property that it works for all energy sources.

Next, Krupp and Horn devote many chapters to a wealth of information on many projects gleaned from their personal interaction with entrepreneurs and venture capitalists. They describe the basic ideas of the entrepreneur and where and how they find the very large sum of money necessary for their commercial development. They systematically investigate each of the prospective green energy sources, dividing the book into chapters on energy from the sun, energy from living matter, ocean energy, geophysical energy, reconsidering coal, and a short section on nuclear energy. Some of these projects are well known and well along their developmental path. Others are "way out" with no guarantee that they will survive their infancy, but with great possibilities if they do. Indeed in chapter 9 they admit that up to this stage the book has focused on possibilities for reducing global warming pollution that are still just out of reach and in this chapter they consider solutions which can be applied relatively quickly to forestall the immediate crisis. These include schemes for protecting the remaining Brazilian and Indonesian rainforests (because of their rate of deforestation Indonesia and Brazil rank third and fourth in greenhouse gas emissions); elimination of other greenhouse gases, especially methane; energy efficiency (emulating California); energy intelligence (the energy equivalent of the internet, to distribute energy to where it is needed); the replacement of greenhouse-gas-intensive industrial materials (e.g. drywall and cement) with "greener" materials; electric cars, which still need great improvements in storage capacity, recharge time, lifespan and affordability of batteries; and reducing driving including smarter real estate development.

The final chapter, "The World of Possibility", maps the extraordinary flights of invention possible, outlining even more futuristic possibilities and efforts to remove the excess CO2 that has already been dumped in the atmosphere. They reiterate that to save the planet, rapid innovation and deployment of known technologies is essential. Cap and trading is the necessary catalyst, eventually world wide. They believe that whether the latter happens or not is largely determined by the USA which is now the only developed country not under a carbon cap. The starting point must be the U.S. Congress. Mobilization on the necessary scale will only occur when U.S. leaders pass laws allowing alternative energy sources to compete fairly with oil and coal. To Krupp and Horn this means accepting a hard cap on greenhouse gases.

In one sense the book is a great pep talk. This is probably necessary in a world which could easily succumb to hopelessness in the light of the enormous task ahead.

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Energy in Nature and Society: General Energetics of Complex Systems.

Vaclav Smil, The MIT Press, 2008, 480 pp., ISBN 978-0-262-69356-9, $70.00 (cloth), $32.00 (paper).

Vaclav Smil, a prolific author of science-based books about energy, has updated some of his previous work, presenting here an encyclopedic study of energy as a unifying theme in the development of human society. He considers two eras: the pre-modern, in which agricultural technology provided the basis of increased human productivity beyond that of hunter-gatherer societies, and the modern, where access to fossil and other fuels vastly expanded human populations and individual potential. For those of us engaged in the study of energy use in developed and developing nations worldwide, some of which are in transit between these eras, this is a superbly documented (over a thousand references) and valuable resource for understanding the complexities of the human use of nature's energy resources.

The first half of this book is concerned with the role of human and animal energy in producing the food and services that support human communities. The theme is agriculture as a component of net primary production in plant systems that support all life in the biosphere. Starting with the biochemical process of photosynthesis, he traces the energy paths that support heterotrophic ecoclimes which humans now manage rather than simply dwell in, sometimes destructively so. This biochemical energy cycle, powered by only a tiny fraction of the solar flux, is the prime mover of all biospheric life. Its agricultural component was the principal engine of economic growth prior to the onset of the industrial revolution.

Smil emphasizes that energy balance is only one factor in the human food cycle, and that other factors affecting nutrition are tightly linked to the minor cycles of nitrogen, sulfur, phosphorus, and other essential elements in the biosphere that is otherwise dominated by the carbon, oxygen, and water. Nevertheless, energy has great explanatory value in elucidating the basic fabric of life in all its forms.

Smil's later chapters trace the new paths of industrial energies, embodied in fossil and nuclear fuels and renewable energy technologies. These energy fluxes are an order of magnitude larger than food energy, and their introduction has changed the latter as much as it has changed human societies. Industrial agriculture has quintupled the human population that can be fed per hectare of arable land. This has been possible through use of only a small fraction of the industrial energy supply and the efforts of the human population. Nevertheless, the global food supply cannot be much expanded by throwing more energy at it; it is limited by the supply of productive arable land, water, and ecological resources.

The industrial energy analysis proceeds along conventional paths. World demand and supply of industrial energy is summarized and energy fluxes are characterized. The ratio of embedded energy output to input, which the author calls the "energy return on invested energy" (not at all the energy equivalent of return on investment that interests Wall St. investors), is very high for fossil and nuclear fuels, but low for agricultural crops. This explains in part why fossil/nuclear resources are more economical to exploit than agricultural resources. Renewable energy is comparable to fossil fuels on an output/input basis, but is more capital intensive, which adversely affects its economic cost.

Smil also reviews the land area requirements for renewable energy systems. These are on the order of one square meter per watt of annual average electrical power output. Even so, this is a more energy intensive use for land than energy crops, and less environmentally intrusive.

Producing needed energy, while limiting climate change through reductions in greenhouse gas emissions, is now a global goal for both developed and developing nations. Finding the path forward towards this desirable future involves much more than a scientific and technological understanding of nature's limitations on possible alternatives, which Smil's volume lays out for the reader's edification with economy and some elegance. It presents at least a good beginning for addressing this thorny problem.

Smil's book appears at an opportune time. The current debate and controversy over the diversion of agricultural crops from food to vehicle fuel production has highlighted the need for agricultural scientists, energy scientists, and technologists to plumb the depths of scientific understanding of these essential industries and their connectedness to the future of both ecological and human communities. Smil provides a fine starting point for the needed dialog.

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The Bridge at the Edge of the World: Capitalism, the Environment, and Crossing from Crisis to Sustainability

James Gustave Speth, Yale University Press, New Haven (2008), 295 pp. ISBN 978-0-300-13611-1 (hardcover).

One measure of our destruction of our natural habitat is the abundance of good books devoted to stopping that destruction. Humankind is deeply pondering its relations with the rest of nature.

Now comes a new entry into the field, one destined to change the terms of the discussion.

James Gustave (Gus) Speth is a long-time environmental leader. A Rhodes scholar at Oxford and graduate of Yale Law School, he co-founded the Natural Resources Defense Council and served as its senior attorney from 1970 to 1977, chaired the U.S. Office of Environmental Quality under President Carter, founded the World Resources Institute, and is now dean of the Yale School of Forestry and Environmental Studies.

Speth's 2004 book *Red Sky at Morning* argued that the environmental movement is losing the battle to preserve the planet, outlined the essential pathways to sustainability, and broadened environmentalism's traditional concern for nature to include connections with society. In his new book *The Bridge at the Edge of the World*, Speth goes much further in this direction, noting again that the planet's destruction continues without letup and finding the roots of the problem in several of our culture's sacred cows including corporate capitalism, the growth ethic, and the environmental movement itself.

The book is partly a compendium of environmental thinking, a sort of anthology of environmentalism. For example, Chapter 5, subtitled "moving to a post-growth society," quotes twentieth-century economist John Maynard Keynes at length. Keynes foresaw an eventual end to humankind's struggle for subsistence and thus an end to the need for growth. Speth declares that the developed nations are reaching that point and hence it's time to question the priority of economic growth.

Speth notes that, although scientists have long known that humans are causing the wholesale collapse of the natural world, the environmental movement's efforts to prevent that collapse have failed. Declaring modern capitalism "out of control," he calls economic growth "the secular religion of the advancing industrial societies." Historian J. R. McNeil is quoted at length, including this: "The overarching priority of economic growth was easily the most important idea of the twentieth century." In the United States this has led, says Speth, to growth at any cost, to a "ruthless economy," to ignoring laid-off workers, bankrupt firms, and crumbling cities.

The book provides many examples of the incrementalist and compromising nature of environmentalism over the past four decades. Environmentalists have dealt with effects rather than underlying causes. It has focused too much on environmental destruction and too little on the political, social, and economic causes of that destruction. He quotes from Michael Shellenberger and Ted Nordhaus' famous essay "The Death of Environmentalism," that mainstream environmentalists are not "articulating a vision of the future commensurate with the magnitude of the crisis. Instead they are promoting technical policy fixes …that provide neither the popular inspiration nor the political alliances the community needs to deal with the problem."

Much of the book discusses the nature of modern capitalism, and the corporation in particular. Speth believes we cannot prevent the collapse of nature without an overhaul of corporate structure. He's not proposing to overthrow capitalism, but rather to radically humanize the way it works. Current corporate operating principles such as separation of ownership from management, limited liability, the maximization of stockholder wealth, externalization of social and environmental costs, and excessive corporate political power, need changing.

Modern capitalism faces those who hope for a better world with a disheartening quandary: economic growth is declared the primary virtue, and profit-maximizing corporations dominate our economy. The only obvious counterweight is government, yet government is dominated by these same corporations.

The solution to this quandary turns out to be similar to the solution proposed by Bill McKibben in *Deep Economy*, another good recent book. Act locally. Political consciousness must begin in the neighborhood. It must be highly participatory, favoring national citizen initiatives and referendums. Beginning locally, citizens must organize at regional, national, and global levels.

A program to get there from here should involve transformation in three major dimensions: First, environmentalism must be broadened to the full range of relevant issues, including politics and "the democratization of wealth." Second, environmentalists must embrace a program to address the nation's social problems directly and generously. America's crisis of high poverty rates and concentrated wealth for a tiny minority poses a threat to our democracy and the environment alike. Third, campaign finance, elections, lobbying, and other aspects of the political process must be reformed, including revitalization of unions and other large membership organizations that give citizens more leverage in the political process.

If the first watchword of the new environmental politics is "broaden the agenda," says Speth, the second is "get political." American politics today is failing not only the environment but also the American people and the world. The transition to sustainability demands a broad and unified political movement that will come to be seen as the Environmental Revolution of the twenty-first century. According to Speth, "only such a response is likely to avert huge and even catastrophic environmental losses."

This call for an environmental revolution will seem quixotic to many. "The impossible," notes Speth, "takes a little longer." He quotes Mahatma Gandhi: "First they laugh at you, then they ignore you, then they fight you, then you win." And he quotes writer Arundhati Roy:

> Another world is not only possible.
> She is on her way.
> On a quiet day, I can hear her breathing.

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Physics and Society is the non-peer-reviewed quarterly newsletter of the Forum on Physics and Society, a division of the American Physical Society. It presents letters, commentary, book reviews and articles on the relations of physics and the physics community to government and society. It also carries news of the Forum and provides a medium for Forum members to exchange ideas. ***Opinions expressed are those of the authors alone and do not necessarily reflect the views of the APS or of the Forum.*** Contributed articles (up to 2500 words, technicalities are encouraged), letters (500 words), commentary (1000 words), reviews (1000 words) and brief news articles are welcome. Send them to the relevant editor by e-mail (preferred) or regular mail.