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Cameron Reed Is New Editor of P&S

Physics and Society has a new editor, who is making his debut with this issue: Cameron Reed of Alma College in Michigan. A native of Toronto, Canada, Reed got a B.Sc. in physics from the University of Waterloo in 1977 and a master's in theoretical astrophysics from Queen's University in Ontario in 1979. A desire to learn how astronomers acquire and analyze their data motivated Reed to return to Waterloo for a Ph.D., which he earned in 1984. Because he had developed an early interest in galactic structure, his thesis involved using optical-wavelength photometry and spectroscopy to analyze the line-of-sight distribution of stars in a certain region of the sky.

As he was wrapping up his thesis in the fall of 1983, Reed landed a faculty position at St. Mary's University in Halifax, Nova Scotia. Since then he has built up an extensive database of published photometry and spectral information on so-called OB stars and added some data from his own observations. He has published 90 papers and authored a quantum mechanics textbook.

Reed got involved with "physics and society" issues shortly after he moved to Alma College in 1992. While teaching a course in modern physics, he developed a special interest in the Manhattan Project. His research and calculations led to a number of pedagogical papers in journals such as the *American Journal of Physics* and *The Physics Teacher*. By 2002, he was offering an algebra-level general-education course for non-science students titled "The Making of the Atomic Bomb." In December 2007, he published a paper (in AJP) reporting his detailed analysis of the physics of fission weapons originally prepared by Arthur Compton in the fall of 1941.

Reed has been a frequent contributor to the book reviews in *P&S* since he volunteered to review a book on the Manhattan Project around 2005. The Executive Committee of the Forum on Physics and Society welcomes Cameron Reed to his new post.

Barbara G. Levi

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Editorial

When I was offered the editorship of *P&S* I felt deeply honored and humbled. *P&S* reaches a significant audience: the Forum on Physics and Society boasts some 5,900 members, the second-most of any Division, Topical Group, Forum or Section of the APS. Over 10% of APS members are members of FPS; since 2005, membership in the forum has grown by just over 20%, more than twice the growth rate of the Society as a whole. Fully one-quarter of the Forum's members are students. This level of engagement in the Forum reflects the seriousness with which physicists take the relationship between their science and the broader human society of which we are all members, and we can be rightfully proud of this. To be entrusted with the editorship of *P&S* is a significant level of professional recognition. Under the guidance of the Editorial Committee (currently Ruth Howes, Barbara Levi, and Lee Schroeder) and the superb work of my predecessors Martin Perl, John Dowling, Art Hobson, Al Saperstein, and Jeffrey Marque, *P&S* has evolved into a timely and engaging publication greatly respected for its scientifically objective coverage of a wide variety of issues. I have my work cut out for me in building upon the high standards they established over the course of nearly four decades. It is more than a little daunting to think of the shoes I have to fill, but I look forward to this task for the very selfish reason that I have been given a tremendous opportunity to make contact with a wide spectrum of interesting people and ideas. Also, as this issue was being prepared for publication, I am very pleased that Dr. Jonathan Wurtele of UC-Berkeley will join P&S as Assistant Editor. His experience and contacts within the community should be a powerful asset as we work to identify writers to prepare contributions on issues of interest to our readers, and I look forward to working with him.

Be active in the Forum; it can be no more than what its members make of it. The quality of *P&S* depends critically on that of the contributions we receive. In addition to soliciting contributions on topics of broad interest to the community, we are always on the lookout for interesting letters, articles, news, commentary, reviews and exchanges of ideas. There is practically no current societal issue that does not in some way directly involve the findings of physics or cannot benefit from application of the skills of physicists and allied researchers. If you have an idea for a contribution, feel free to contact Dr. Wurtele or myself at wurtele@berkeley.edu or reed@alma.edu.

I am especially pleased at the wide variety of contributions we have for this issue of *P&S*. Kevin Trenberth's article on changes in the flow of energy through the Earth's climate system is based on an invited talk he presented at the March APS meeting and nicely complements the discussions on climate change that appeared in our July 2008 edition. David Hafemeister gives an extensive review of the recent APS energy efficiency report. An AIP FYI news article on the Yucca Mountain nuclear waste repository and an interesting article concerning a historic plutonium find at Hanford are complemented by an article on the Yucca issue by David Bodansky. We are pleased to be able to run testimony on the future of US nuclear weapons presented to the Congressional Commission on the Strategic Posture of the United States by longtime nuclear weapons expert Dick Garwin. Erin Owens, a FPS Student Fellowship Award recipient, describes her 2008 summer research on light pipes at Eastern Michigan University. In addition, we have two letters to the Editor, two book reviews, and statements from the outgoing and incoming chairs of the Forum. I would especially draw your attention to incoming chair Don Prosnitz's call for ideas on how to establish more of an outreach presence for the Forum. We welcome feedback on all of these items. Enjoy.

Statement from the Outgoing Forum Chair

Andrew P. Zwicker, Princeton Plasma Physics Laboratory, azwicker@pppl.gov

When I became Chair of FPS last April, I expected a fascinating and challenging year – I just had no idea of how fascinating and challenging it would be! We are the second largest group within APS, with more than 12% of the total membership. It seems to me, however, that our actual membership should be 100%. The administration in Washington may have changed, but nearly every day the headlines include a topic that is of relevance to FPS members. As physicists, regardless of our individual fields of interest, each and every one of us has an obligation to be an active participant in topics that are at the intersection of physics and society.

It's not just the headlines that show the breath of these issues. Just take a look at the remarkable range of topics FPS is sponsoring or co-sponsoring at the March and April meetings. Green technology, managing nuclear fuels, physics contributions to the intelligence community, and communicating science to the public are just a few of the sessions on the agenda. I thank the Program Committee, chaired by Don Prosnitz, for the tremendous amount of work they put into organizing these sessions. Having a large range of potential topics is a far cry from finding the speakers and handling all of the details that goes in to putting together a successful session.

The other area of fascination and challenges I encountered this year centered on our newsletter, Physics & Society. As you already know, our Editors produce an outstanding combination of articles, news items, and book reviews four times a year. This year we welcomed a new Editor, Cameron Reed, and this is the first under his guidance. We also rein-

vigorated our Editorial Board, consisting of Barbara Levi (Chair), Ruth Howes, and Lee Schroeder. The quality of this newsletter is a testament to the hard work of each of them and I am grateful to all. This issue also contains an article by a student, Erin Owens, the current FPS-sponsored fellow. I'm pleased to read her work here and look forward to watching this program expand as we move forward. Finally, I would also like to personally reconfirm what the entire Executive Committee already expressed and offer my sincere gratitude to our outgoing Editors, Al Saperstein and Jeff Marque. For more than a decade, they worked tirelessly and produced the highest quality newsletter each and every time. As noted elsewhere, they often heard the complaints, but rarely heard the compliments they always deserved.

In closing, I would like to thank the members of the Executive Committee and all the others that have made FPS a productive and vibrant organization. It was truly a pleasure to work with each of you.

Statement from the Incoming Forum Chair

Don Prosnitz, Don@prosnitz.org

As we move into calendar year 2009 it may be a bit presumptuous to state that the need for an informed public debate on science policies has never been greater, but only a bit. Climate change and energy policy, stem cell research, technologies for a sustainable environment, nanotechnology risks, the use of advanced technology by terrorists, surveillance technology and privacy, the value of big (global) basic research projects, science education, and the role of science and technology in economic growth are just a few of the issues that must be addressed. Fortunately, the opportunity for thoughtful debate in front of a receptive audience may also never have been greater.

President Obama stated in his Inaugural address that

"We'll restore science to its rightful place, and wield technology's wonders to raise health care's quality and lower its cost. We will harness the sun and the winds and the soil to fuel our cars and run our factories. And we will transform our schools and colleges and universities to meet the demands of a new age."

We can be optimistic that these are more than just words. The stimulus package just signed provides $21.5B for research and development. The 2009 budgets appear to have increases for the science agencies and in a recent directive from the White House on scientific integrity President Obama stated

"Science and the scientific process must inform and guide decisions of my Administration on a wide range of issues… The public must be able to trust the science and scientific process informing public policy decisions."

So what does this mean for physicists and the Forum on Physics and Society? Recently I spent a day visiting Congressional offices with 50 or so other members of the American Physical Society. We went to thank members of Congress for their support and to discuss the value of scientific research in the context of the current economic crisis. We heard from several offices that we needed to better articulate "our successes"—what they were, why they were important and why, for example, it might be more important to fund basic research than water projects when areas of the country are facing drought. We need to work harder to explain the benefits of what we do— to make certain our successes (and failures) and the implications of those successes (and failures) are known and understood.

The Forum on Physics and Society needs to redouble its efforts to be a "forum" for discussion and open debate of the scientific issues facing our society and to provide thoughtful, understandable, technically sound information to the public on these issues. Society must believe that its resources are being well spent and that the scientific community is cognizant of the implications of its research. The Forum's principal means for communication are the annual meetings and our newsletter. Over the next year, we would like to engage a broader community in these activities. For example, it is not generally known that all Forum sessions are open to the public, free of charge. We are working with APS/HQ and the conference managers to advertise this fact and entice the public to attend our April panels. We would also like to explore the possibility of using available web applications (blogs, facebook presence…) to extend thoughtful, professional discussion of topics presented in our newsletter to a greater community of interest. Our new assistant editor, Jonathan Wurtele, will be taking on this project. I encourage all FPS members to send in suggestions as to how we can enhance our outreach and promote greater engagement with members of the public to Jonathan at JSWurtele@lbl.gov.

Finally I want to thank Andrew Zwicker, last year's FPS chair, for his tireless efforts on behalf of the Forum and for guiding us through some very difficult issues. I look forward to the coming year and hope many of you will actively participate in the activities of the Forum.

FORUM NEWS

Nominations for APS Fellowship

The Forum on Physics and Society has the opportunity to nominate candidates to Fellowship in the APS. All candidates for APS Fellowship should have demonstrated outstanding contributions to physics and the advancement of societal and public policy issues connected to physics. It is important that such contributions beyond routine scientific collaborations be well documented in the nominating materials. This is a great opportunity to recognize your colleagues who are devoted to the advancement of physics and society. Any member of FPS can submit a nomination and, therefore, we urge you to nominate fellow physicists of any nationality who fit this profile. Instructions for nominations can be found at: http://aps.org/programs/honors/fellowships/index.cfm. At that website, one can also find descriptions of past APS Fellows nominated by FPS. The deadline for nominations is May 15, 2009.

FPS to Honor Award Winners and New Fellows at APS Denver Meeting

FPS will hold its annual awards session on Monday, May 4, at 1:30 pm during the APS spring meeting in Denver. The recipients of two FPS-sponsored awards will receive their certificates and then give a talk.

Raymond Jeanloz will be given the 2009 Leo Szilard Lectureship Award "for contributions to development of sound public policy for nuclear weapons management and nuclear non-proliferation." He will speak about "Science and International Security."

Jeanloz is a professor of earth and planetary science and of astronomy at the University of California, Berkeley. He chairs the National Academy of Sciences Committee on International Security and Arms Control, which focuses on scientist-to-scientist dialogs around the world on topics ranging from nuclear weapons and non-proliferation to biological threats and counter-terrorism. Jeanloz previously chaired the National Research Council's Board on Earth Sciences and Resources, and has served as an adviser to numerous governmental agencies and national laboratories.

Jeanloz's scientific research concerns the properties of materials at high pressures and temperatures and the constitution and evolution of planetary interiors. He is a member of the National Academy of Sciences and a MacArthur fellow, and fellow of several scientific societies. Jeanloz earned his bachelor's degree from Amherst College in 1975 and a Ph.D. from the California Institute of Technology in 1979. He was on the Harvard University faculty before moving to UC Berkeley in 1981.

Patricia Lewis will receive the Joseph A. Burton Forum Award "for her contributions to arms control and international security, through experiments to demonstrate verifiability of arms control treaties and through her leadership of two international institutes, VERTIC and UNIDIR." Her talk is titled: "Remembering our Humanity: The Deep Impact of the Russell-Einstein Manifesto."

Lewis is the Deputy Director and Scientist-in-Residence of the James Martin Center for Nonproliferation Studies at the Monterey Institute of International Studies. Prior to this appointment, she was the Director of the United Nations Institute for Disarmament Research (UNIDIR) in Geneva. From 1989 to 1997, she was the Director of the Verification Technology and Information Centre (VERTIC) in London. She holds her BSc(Hons) in physics from the University of Manchester (1978) and her PhD in nuclear physics from the University of Birmingham (1981). Before taking her position with UNIDIR, Lewis worked in India, New Zealand, Australia and the United Kingdom.

From 2004-06, Lewis served on the Weapons of Mass Destruction Commission, chaired by Dr. Hans Blix. In 1998–99, she was a Member of the Tokyo Forum for Nuclear Non-proliferation and Nuclear Disarmament, having previously served as an external reviewer for the Canberra Commission. Currently, Lewis is an Advisor to the International Commission on Nuclear Non-proliferation and Disarmament. She was appointed UK Governmental Expert to the 1990 UN Study on the Role of the UN in Verification and appointed consultant on conventional forces verification to the UK Foreign and Commonwealth Office 1989-90. Dr. Lewis sits on the Advisory Boards of the Bonn International Conversion Center and the Center for Policy Studies in Moscow.

Also at the Awards Session, FPS will introduce the 2008 APS fellows nominated under FPS auspices. The new fellows and their citations are as follows:

Michael Berman of the Air Force Office of Science Research. Citation: For his outstanding leadership, advocacy, and support of physical science research and for fostering and developing innovative and visionary multidisciplinary partnerships.

William S. Hammack of the University of Illinois, Urbana-Champaign. Citation: For enhancing public awareness about physics, science, and technology via his radio commentaries and for his governmental service at the State Department.

Allen Sessoms of the University of District of Columbia. Citation: For exceptional contributions to the global society in understanding and addressing the challenges posed by nuclear and other advanced energy technologies.

Dean Wilkening of Stanford University. Citation: For his extensive contributions to understanding ballistic missile defense, bioterrorism and civil defense, and for his training of the next generation of physicists involved in arms control.

REPRINTS OF INTEREST

DOE Report Recommended Increasing Nuclear Waste at Yucca

We present here an article from the American Institute of Physics FYI news service on the issue of nuclear waste storage at Yucca Mountain. The web version may be found at http://www.aip.org/fyi/2009/006.html.

One of the many issues facing the Obama Administration is the future disposition of the nation's nuclear waste. The proposed Yucca Mountain Repository, originally slated for a 1998 opening, has been delayed by years of conflict between Congress, the Department of Energy, environmental groups, and the State of Nevada. A new report suggests that, when completed, the Yucca Mountain facility will already be inadequate under current nuclear waste storage regulations.

The Nuclear Waste Policy Act of 1982 (NWPA), as amended in 1987, requires the Secretary of Energy to submit a report to the President and Congress regarding the necessity of a second repository for the nation's spent nuclear fuel (SNF) and high-level radioactive waste (HLW). Former Energy Secretary Samuel Bodman produced that report, The Report to the President and the Congress by the Secretary of Energy on the Need for a Second Repository, in December of last year. The report may be found at http://www.ocrwm.doe.gov/info_library/program_docs/Second_Repository_Rpt_120908.pdf

The DOE report calls on Congress to amend a statute in the NWPA that limits the amount of SNF and HLW that may be stored in a repository to 70,000 metric tons heavy metal (MTHW) until a second repository is open. The report also notes that by 2010, "inventories of commercial and federal government SNF and HLW… are projected to exceed 70,000 MTHM."

In considering how best to address the issue of nuclear waste storage, DOE considered three contingencies:

(1) "Removing of the statutory limit of 70,000 MTHM for Yucca Mountain and disposal of currently projected quantities of SNF and HLW at the Yucca Mountain repository";

(2) "Beginning the process of siting, designing, licensing and constructing a second repository as soon as possible so it will be ready to receive SNF and HLW by the time 70,000 MTHM has been emplaced in the Yucca Mountain repository";

(3) "Deferring the decision and prolonging the time commercial SNF generated after 2010 will be stored at reactor sites, as well as the time DOE SNF and HLW will be stored at DOE sites."

Regarding the first option to remove the storage limit, the report argues, "the Yucca Mountain repository would likely have sufficient capacity to dispose of the entire defense waste inventory plus the commercial SNF expected to be produced by the existing fleet of nuclear power reactors." The report continues, "the 70,000 MTHM statutory limit on capacity of the first repository until a second repository is in operation is not based on any technical considerations related to the characteristics of possible repository sites or geologic media." DOE believes that a 4,200 acre layout of the facility is reasonable, "more than three times the area of the layout currently used to accommodate 70,000 MTHM." The repository's current layout is 1,250 acres.

The second option, to build a second repository posthaste is dismissed by the report, in large part because "the need for legislation before any site-specific work could be performed introduces uncertainty in the schedule for a second repository." Additional appropriations would also be necessary.

When DOE reviewed the final option to defer the decision, it found that "additional liabilities under the Standards Contracts" were likely. Current law required DOE to begin accepting waste for disposal in 1998. DOE estimates that the "liability associated with the delay in waste acceptance… may be up to $11 billion, and could increase significantly for each additional year operations are delayed or interrupted."

DOE concludes that "lifting the statutory limit on the disposal capacity at Yucca Mountain provides an opportunity to defer the need to reassess repository capacity requirements." During this time, DOE suggests that additional information regarding the potential growth of the nuclear energy industry, and nuclear fuel recycling can be incorporated into waste growth models.

DOE submitted a license application to the Nuclear Regulatory Commission for approval to construct the Yucca Mountain repository in June of last year. That review process may take four years to complete. The earliest possible year of completion for the repository is 2020.

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Found Plutonium Reveals Clues to T Plant's First Run

Annette Cary, Hanford News

This article appeared in the January 24, 2009 Hanford News, a publication of the Tri-City (WA) Herald. P&S is grateful to the Herald's Managing Editor, Rick Larson, for reproduction permission. The original article may be found at http://www.hanfordnews.com/news/2008/story/12725.html – Ed.

Nuclear archaeology has solved the mystery of a jug of plutonium that was found sealed inside a safe dug up as workers cleaned up an early Hanford burial ground. Science showed the plutonium was historic: Researchers at the Department of Energy's Pacific Northwest National Laboratory in Richland traced its origins to the first batch of weapons-grade materials ever processed at Hanford. It's also the second oldest known man-made plutonium 239, said Jon Schwantes, a PNNL senior research scientist who led the investigation. The oldest is held in the Smithsonian. The results of the investigation are not just historically significant. Schwantes believes the research also may have applications in the field of nuclear forensics and efforts to keep nations safe from terrorists.

When researchers received the plutonium, they suspected it came from the beginnings of the Atomic Age, after the 586-square-mile Hanford nuclear reservation was created during World War II as the United States raced to make enough plutonium to make an atomic bomb. Hanford's B Reactor was built as the nation's first production-scale reactor. It irradiated nuclear fuel that was sent to Hanford's T Plant, the world's first industrial-scale reprocessing facility, which chemically extracted the plutonium. During WWII and particularly in the early years of the Cold War, debris from research and operations were disposed of in burial grounds that government officials believed would remain permanently off limits. But to meet modern environmental standards, old burial grounds the size of football fields are being dug up to clean up Hanford.

Among rusty, radioactively contaminated debris in three burial grounds excavated from late 2004 to early 2007 near Hanford's 300 Area, workers unearthed five forklifts and a flatbed trailer. But the biggest surprise for former contractor Bechtel Hanford may have been the safe in the 618-2 Burial Ground. Bechtel expected to find radioactive material, but not plutonium in the burial grounds, which were used for trash from research work and uranium fuel fabrication. Workers guessed the safe might contain classified documents. But after part of the back separated from the safe as it was lifted out, workers could see six containers. One was a gallon glass jug that appeared to be labeled "Walt's Group" and still contained liquid. Rather than dispose of the plutonium, Washington Closure Hanford, the next contractor assigned to 300 Area cleanup, turned over the liquid in the jug and a small amount of the solids caked to its walls for research paid for by the Department of Homeland Security.

Schwantes and other PNNL investigators used state-of-the-art instrumental analyses, reactor model simulations and investigative science techniques that are described in a paper published in the Analytical Chemistry journal this month. "We had some pretty strong clues to start with," Schwantes said. Writing on the jar included the notation "LaF3" for lanthanum fluoride, a chemical used at T Plant from its startup in 1944 to the mid-'50s. The time frame in which the plutonium originated was further narrowed by studying the ratio of plutonium to uranium in the sample, since plutonium decays over time into uranium. That put the probable date of creation at 1945, give or take 4.5 years. The latest the plutonium could have been made was about 1950. But an analysis of the minor plutonium isotopes was puzzling. Irradiating fuel for weapons production produces not only plutonium 239, the type used in weapons, but also plutonium 238, 240, 241 and 242. Determining the ratio between the amounts of different isotopes created a "fingerprint" of the reactor that produced it. That fingerprint matched a reactor that operated at a power of 3.7 megawatt days per metric ton of uranium. "That was really surprising," Schwantes said. B Reactor and the two other Hanford reactors operating in the mid-1940s were 200 MWd/MTU reactors, Schwantes said.

There was one other possibility, a research reactor that produced plutonium 239 in the 1940s. The X-10 reactor in Oak Ridge, Tenn., was a prototype for production-scale reactors later built at Hanford. Its power at 3.6 MWd/MTU was close enough to be a match. Historical records also told a story that corroborated what Schwantes concluded. B Reactor and T Plant were built at the same time, but T Plant was finished before B Reactor had irradiated fuel ready to be reprocessed. To test T Plant, plutonium from the X-10 reactor was shipped to Hanford for the plant's first full-scale test on Dec. 9, 1944, Schwantes said. In the next eight months, Hanford would produce plutonium for the world's first nuclear explosion in the New Mexico desert on July 16, 1945, and plutonium for the bomb dropped on Nagasaki, Japan, on Aug. 9, 1945, helping end World War II.

Documentation also was found that included information about disposal of a safe in 1951 with contents that matched

those found in the safe. The jug belonged not to "Walt's Group" as workers first read the label, but "Watt's Group," a research group led by a scientist named Watt who was in charge of measurements to optimize T Plant operations, Schwantes said. That also explained why the safe with the plutonium from T Plant in central Hanford was unearthed in the 300 Area. The only known sample of plutonium 239 that is older was produced by Glenn Seaborg and his associates in 1940 when they were trying to produce enough plutonium to weigh.

The PNNL study demonstrated the capabilities of nuclear forensics and highlighted the tools that can be used, Schwantes said. It not only demonstrated the ability to trace a sample back to one of several reactors with similar designs, but a red herring in the research may provide information that will help advance nuclear forensics. The plutonium sample included radioactive sodium 22, which has a half life of 2.5 years. With half of its radioactivity decaying every 2.5 years, none should have been detected more than half a century after the sample was produced. Schwantes believes that as the sample was repackaged, the equilibrium between the plutonium and sodium was disturbed. As a result, a reaction between chemicals produced sodium 22 and indicated to researchers when the sample was split. The resulting information could help nuclear forensics experts determine whether a smuggled sample also has been split and more exists.

Nuclear forensics will become more important to protect against the threat of terrorists as nuclear material becomes more available worldwide, Schwantes said. If nuclear forensics can be used to trace nuclear materials to their origin, it provides an incentive for nations to ensure their nuclear materials are well protected and kept off the black market, he said. The national lab in Richland plans more tests on the plutonium sample, and it could be used at other national labs to verify Schwantes' results. As a well-characterized material, it also can be used in forensics exercises and analytical chemistry.

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LETTERS

To the Editor:

In their comment on Yucca Mountain radiation standards, Robert and Susanne Vandenbosch give insufficient attention to the context in which such standards are applied (P&S, January, 2009).

When NRC applies safety standards, the usual practice is to make conservative assumptions about what is unknown. As one looks into the more distant future, uncertainties grow, and therefore an increasing number of conservative assumptions go into predictions. To some degree, this makes the resulting predictions more conservative. In a standard that unavoidably represents a compromise among competing public policy goals, testing more conservative predictions against less stringent thresholds is a reasonable way to arrive at consistent compromises. One can surely disagree with EPA's judgment about the degree of change in conservatism over time, but the Vandenbosches are wrong to dismiss the entire concept as illogical.

In regulating chemical wastes, EPA has chosen (with a few exceptions, mainly one for deep well injection of hazardous wastes) to require predictions only for 30 years into the future. Furthermore, in my experience the models used to predict exposures to chemical wastes are applied with much less conservatism than the models used for radioactive wastes.

Our society has unfortunately a long way to go to reach full sustainability in its waste disposal activities. Nuclear energy is much farther along in that quest than fossil fuel use, chemical production, and many other industrial activities. We should insist on steadily improving standards of waste management in all of these areas, but we need to be realistic in what we ask for. If we strangle nuclear power with unsatisfiable demands and cause coal or oil to be used instead, we are making the perfect the enemy of the good.

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To the Editor:

Hafemeister and Schwartz state (Phys. Society, **37**, 3, p. 3, July 2008) state that carbon released worldwide from burning carbon and deforestation has recently been about 7.1 Gt/yr. No source is cited. The total coal production in the United States in 2003 has been 0.970 Gt (Encyclopedia of Energy Engineering, Energy Information Administration, 2006). In 2002 the United States consumed 1.02 Gt of petroleum. As

carbon constitutes 84 percent of the weight of petroleum 0.860 Gt of carbon is burned when all the above petroleum is consumed. Thus, the United States can be responsible for not more than 1.83 Gt of the worldwide 7.1 Gt or 25% of the carbon cited by the authors.

Unfortunately it cannot be established where the carbon dioxide in the atmosphere is coming from and this leaves the field wide open for speculations a la Hafemeister and Schwartz.

The question arises whether destroying the United States economy would have a significant effect on the global warming trend.

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Hafemeister & Schwartz respond:

Vladislav Bevc's "question" implies the incorrect idea that improving US energy use would come at the expense of the economy. In fact, the transition to energy efficiency and renewable energy is *necessary* for long-term economic health. Our present difficult economic state provides great opportunity for this needed transition in order to prevent increased energy dependence (often on countries we are not friendly with) and the associated foreign debt, higher energy costs, and environmental destruction. The question as we see it is this: "Given that we are presently planning to financially assist private companies to rescue the economy, are we going to build infrastructure in a direction that will benefit us and our children, or continue to support the wasteful, inefficient technologies and institutions that are partially responsible for the present crises?"

Vladislav Bevc's challenge implies he is not convinced that the observed increase in CO_2 is due to burning fossil fuels. We direct you to the IPCC Fourth Assessment Report: The Physical Science Basis, page 138-139. Most or all the CO_2 increase is from burning of fossil fuels as supported by atmospheric carbon isotope measurements. So, contrary to Vladislav Bevc's claims, it *can* be established where the CO_2 in the atmosphere is coming from, and in fact it *is* from the burning of fossil fuels.

The 2008 APS study, "Energy Future: Think Efficiently" gives many examples on cost effective actions to increase end-use efficiently. Figure 2 of the APS report displays mitigation measures that can reduce 3.0 Gtons/yr of carbon dioxide per year (0.8 Gtons/yr of carbon) for no net cost. Figure 3 of the APS report compares per capita income in California and the US with the results of strict energy conservation in California. From 1975 to 2005, per capita income rose from $7,000 to $37,000 in the U.S., while in California it rose from $3,000 to $44,000. US per capita electrical consumption rose from 8,400 to 12,000 kWh/yr while in California the use of electricity remained approximately constant at 7,800 kWh/yr. While US per capita electrical use rose by 30% (and remained flat in California), California incomes rose more than average US incomes. Other factors are also involved, but saving energy didn't seem to hurt per capita income.

We agree with Bevc that the US produces about 25% of the annual global carbon dioxide rate. The data we used in the article and this note comes from the US Energy Information Administration. Recent EIA data: Petroleum (2007, Mbbl/day): US/Earth = 20.7/85.9 = 24.1%, Natural gas (2006, TCF/yr): US/Earth = 23.1/104.4 = 22.1%, Coal (2007, Gtons/yr): US/Earth = 1.1/7.2 = 15.2%.

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ARTICLES

The Future of US Nuclear Weapons

Richard L. Garwin, www.fas.org/RLG/

[One of the most important issues that the administration of President Barack Obama will face with is that of the future makeup and role of the United States' nuclear forces. Since 1950, physicist Richard Garwin has worked with the U.S. government on nuclear weapons technology and numerous defense-related issues. Dr. Garwin has very kindly shared with P&S a draft of his testimony to the Congressional Commission on the Strategic Posture of the United States(http://tinyurl.com/c6noap), from which we reproduce a very slightly edited excerpt of his comments on the future of nuclear weapons and strategic missile defense– Ed.]

The Science-Based Stockpile Stewardship Program

The Science-Based Stockpile Stewardship Program (SSP) has been a tremendous success. New experimental capabilities, both bench scale and large facilities such as DARHT (dual axis radiographic hydrotest facility) and NIF (national ignition facility) have combined with the million-fold increase in computer speed and advanced analytical and mathematical tools to enable far more sophisticated 3-D simulation of nuclear explosive phenomena. We are close to routine "button-to-boom" simulations, which, of course, to make any sense must be validated against experiment. The experimental base includes the more than 1000 underground nuclear explosions of the past, plus additional current simulations that include so-called "sub-critical" experiments that may use segments of actual nuclear weapon primaries, for instance.

One of the fruits of the SSP program is the announcement in late 2007 by NNSA that the weapon laboratories have established that the plutonium pit at the core of each of the U.S. nuclear weapons will survive more than 85 years. An ongoing result is the ability of the Directors of the weapon laboratories to assess each year that the legacy weapons under the SSP remain safe and reliable. And we now have at LANL the proven capability to manufacture certifiable W88 replacement pits. The striking agreement of boost-cavity shape predicted by the simulation with that observed in radiography now and in PINEX tests before 1992 exemplifies the increase in understanding that makes it possible to imagine putting a new-design weapon into the stockpile without verification by nuclear explosions.

Of course many problems are discovered in the SSP, and the so-called significant findings ("SF") are now promptly investigated and resolved. Almost all of the significant findings have to do with elements outside the nuclear package, and these can be re-engineered, tested without nuclear yield as they always have been, and modified, with great care that they do not impact the performance of the nuclear package itself.

The Reliable Replacement Warhead – RRW

With the knowledge gained from the SSP, it has been possible to undertake the design of the Reliable Replacement Warhead-- RRW-- with the constraint that it not require a nuclear explosion test. As I indicated in my December 2008 Arms Control Today article (http://www.armscontrol.org/act/2008_12/Garwin), I think the RRW effort has energized the nuclear laboratories and is something that should be encouraged and repeated every five years or so. That does not mean that I now believe that the RRW could now be certified without a nuclear test, a question that depends on the detailed design and probably on the acquisition of more expertise under the SSP. But I think it would have a good chance in a few years to be so certified.

A January 2008 description by Bruce T. Goodwin, Associate Director for Defense and Nuclear Technologies at LLNL, summarizes the intent of the RRW program:

> *"The goal of the RRW approach is to replace aging warheads with ones manufactured from materials that are more readily available and more environmentally benign than those used in current designs. RRWs can include advanced safety and security technologies, and they are designed to provide large performance margins for all key potential failure modes. Large margins enhance weapons reliability and help to ensure that underground nuclear testing will not be required for design certification."*

I see the RRW as an option and not a necessity. In this I differ with the apparent meaning of a statement by Defense Secretary Robert Gates, who said

> *"There is absolutely no way we can maintain a credible deterrent and reduce the number of weapons in our stockpile without either resorting to testing our stockpile or pursuing a modernization program."*

In short, I believe that the legacy weapons can remain closer to their test pedigree than the RRW will be to any specific nuclear test, and that responsible choice of modifications to the legacy weapons would result in *increased* confidence in their performance with time, rather than the *erosion* of confidence.

It will always be to someone's bureaucratic interest to claim that a new device or system is better and more reliable than the existing system, and that the existing system cannot be responsibly maintained. This was the case in the 1960's when I chaired the Military Aircraft Panel of the President's Science Advisory Committee under Presidents Kennedy and Johnson, when the Air Force argued that the B-52 could not be flown beyond about 1970 because of metal fatigue. B-52s are still a mainstay of the U.S. bomber force. It was the case with the proposed MX missile, which has now come and gone.

Some believe enhanced surety against theft and misuse dominates all other considerations and that the RRW is absolutely necessary because a new development permits improved surety that cannot be achieved in most of the legacy weapons. Even if this priority were to be accepted, what counts is the overall vulnerability of the United States to nuclear attack from our own weapons, and that depends not on the characteristic of the individual weapons but on the characteristic of the entire force. Thus, if we were to maintain a 5000-weapon force, and if RRWs were built at the rate of 50 per year, it would take 50 years for them to replace half of the existing force. And it is likely that this would not improve the surety of the force one bit, since miscreants could concentrate on the non-RRW portion of the force. Of course, if the United States were maintaining a force totaling 500 weapons, a 50/yr production rate for the RRW could replace the entire force in ten years.

Evidently, an ongoing stream of RRW types would be required. First, to satisfy those who believe that the introduction of weapons of new design (even if they don't provide new military capability) is the only way to maintain the expertise of the laboratories; and, second, to avoid dependence of the future stockpile on cloning a single design. In any case, this highlights the importance of the Commission's setting a number of warheads vs. time in order to guide the complex. This is not a matter for the Department of Defense or STRATCOM. It is something that must be done on the national level. I am concerned, though, that if the RRW were to be certified without nuclear test, it would not be long before from some influential quarter would come the complaint that the United States security was based on untested nuclear weapons. I think it likely that this would lead to a test and therefore to the destruction of the CTBT regime and of the NPT with it. In particular, both China and Russia appear quite ready for nuclear explosion testing if the CTBT moratorium should end, and China could add significant military capability from a few tests beyond its current base of 40.

Overcoming Problems With Legacy Weapons

I realize that there may be specific problems identified with legacy warheads. If there are specific limitations on a particular legacy weapon, one cannot automatically say that an RRW program will immediately fix it. In fact, the RRW would need to be a substitute for that bomb or warhead, for instance, and it would not be available until after a substantial time for development and manufacturing. If the need for such a capability were urgent, there would be no alternative to modifying (repairing) the legacy weapon. This would need to be done with common sense and judgment and responsibility, and verified by the full simulation of at least that portion of the explosion process.

Even if laboratory management in the future would find it easier, as the SSP expertise and tools advance, to do the annual assessment of legacy weapons and to find them safe, reliable, and secure, why would not some influential critic in the future-- even a STRATCOM commander-- simply state that she could not be responsible for a fleet of weapons that had not been tested for 30 years, for example?

But what would be the function of a nuclear test?

In an underground test, one typically removes much of the flight hardware, or disables it. One cannot mimic underground the specified stockpile-to-target sequence that is required for arming the warhead. If part of the operation depends on the vacuum of space, that needs to be simulated. One often uses a different initiator (neutron source), and, of course, the fuzing system is entirely different. Furthermore, the environment underground is significantly altered from that for an explosion in air. There is no strong deceleration as is the case for the airburst of a warhead, and no spin of the warhead in test.

What would be tested? A nominal weapon under nominal conditions? Or a weapon near the end of boost-gas life, under the most stressing temperature conditions, and under the greatest conditions of combat stress? Of course there would be very many experimental data obtained because the opportunity to test instrumentation and to diagnose every aspect of the weapon performance would not be missed, but the benefit to a skeptic who urged the test would largely be the yield-- whether the weapon "worked" or not.

In the era of US underground nuclear tests, concerns were sometimes expressed that much of the fleet had not undergone a test of weapons that had been in the stockpile for years or decades. In fact, production verification tests were often delayed for years. After congressional insistence on stockpile

confidence tests, I believe that only two were conducted. On the other hand, high-fidelity flight tests (without nuclear yield) provide essential information.

Comments on US Strategic Missile Defense

I oppose the deployment of this mid-course defense because it will be nullified by balloon countermeasures and antisimulation. As for the "demand" of allies for protection by missile defense and by the deployment of nuclear weapons on their territories, see a January 9, 2009, article by 4 leading German personages who argue for the elimination of BMD sites in Europe and for progress toward reduction and elimination of nuclear weapons. [Declaration on Freedom from Nuclear Weapons, by Helmut Schmidt, Richard von Weizsäcker, Egon Bahr and Hans-Dietrich Genscher, http://www.iht.com/bin/printfriendly.php?id=19226604]

I am reminded of the experience of the late Don Brennan [a former director of the Hudson Institute, founded in 1961 by futurist Herman Kahn – Ed.], who had been an avid supporter of BMD and was a smart and honest man. As I recall, he spent a month in Europe to personally assess the views of national leaders and analysts and was dismayed to find no real interest in missile defense.

Our motives in deploying missile defense are mixed, as demonstrated by the testimony of a panel that included me and Jim Woolsey to the Senate Committee on Foreign Relations. Senator Biden asked Secretary Woolsey whether he would favor the deployment of a limited BMD stipulated effective against Iran and North Korea but ineffective against China; Woolsey replied that he would not.

For years BMD spokespeople credited the system with the potential to protect against ballistic missile delivery of WMD, but in recent years they are silent about the effectiveness against the militarily preferable attack with chemical or biological agents delivered by scores or hundreds of bomblets separated at the end of boost phase and thus not subject to intercept by the mid-course system. Nor has MDA provided a solution to the combination of balloon countermeasures and "antisimulation" that would enclose a nuclear warhead in a similar balloon in the vacuum of space.

Summary

There is a national need for the Commission to recommend numbers of nuclear weapons vs. time.

It should be recognized that confidence in the reliability of legacy weapons under a responsible stockpile stewardship program is likely to *increase* with time rather then diminish.

RRW programs lack quantitative assessment of benefit and cost streams as RRW are assumed to enter the force—overall improvements in surety, reliability, safety within the force numbers from (1).

The MDA program for defense against strategic ballistic missiles similarly lacks quantitative assessment of effectiveness and benefit, in view of feasible countermeasures in the case of nuclear warheads, and zero effectiveness against bomblet-delivered biological or chemical weapons.

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Changes in the Flow of Energy through the Earth's Climate System

Kevin E. Trenberth

1. Introduction

Weather and climate on Earth are determined by the amount and distribution of incoming radiation from the sun. For an equilibrium climate, outgoing longwave (infrared) radiation (OLR) necessarily balances the incoming absorbed solar radiation (ASR), so that the Net =ASR-OLR =0. There is a great deal of fascinating atmosphere, ocean and land phenomena that couple the ASR and OLR and the balance is only for the annual mean, not individual months or seasons. Incoming radiant energy may be scattered and reflected by clouds and aerosols, or absorbed in the atmosphere. The transmitted radiation is then either absorbed or reflected at the Earth's surface. Radiant solar (shortwave) energy is transformed into sensible heat, latent energy (involving different water states), potential energy (involving gravity and height above the surface (or in the oceans, depth below)) and kinetic energy (involving motions) before being emitted back to space as longwave radiant energy. Energy may be stored for some time, transported in various forms, and converted among the different types, giving rise to a rich variety of weather or turbulent phenomena in the atmosphere and ocean. Moreover, the energy balance can be upset in various ways (so the Net $\neq 0$), changing the climate and associated weather.

The atmosphere does not have much capability to store heat. The heat capacity of the global atmosphere corresponds to that of only a 3.5 m layer of the ocean. However, the depth

of ocean actively involved in climate is much greater than that. The specific heat of dry land is roughly a factor of 4.5 less than that of sea water (for moist land the factor is probably closer to 2). Moreover, heat penetration into land is limited by the low thermal conductivity of the land surface; as a result only the top few meters of the land typically play an active role in heat storage and release (e.g., as the depth for most of the variations over annual time scales). Accordingly, land plays a much smaller role than the ocean in the storage of heat and in providing a memory for the climate system. Major ice sheets over Antarctica and Greenland have a large mass but, like land, the penetration of heat occurs primarily through conduction so that the mass experiencing temperature changes from year to year is small. Hence, ice sheets and glaciers do not play a strong role in global mean heat capacity except on greater than century time scales, while sea ice is important in those places where it forms. Unlike land, however, ice caps and ice sheets melt, altering sea level, albeit fairly slowly.

The oceans cover about 71% of the Earth's surface and contain 97% of the Earth's water. Through their fluid motions, their high heat capacity, and their ecosystems, the oceans play a central role in shaping the Earth's climate and its variability. The seasonal variations in heating penetrate into the ocean through a combination of radiation, convective overturning (in which cooled surface waters sink while warmer, more buoyant waters below rise) and mechanical stirring by winds. These processes mix heat through the mixed layer. Accordingly, it is vital to monitor and understand changes in the oceans and their effects on weather and climate.

The present-day climate is changing mainly in response to human-induced variations in the composition of the atmosphere as increases in greenhouse gases, such as carbon dioxide from burning of fossil fuels, promote warming. In contrast, changes in visible pollution (particulate aerosols) add many complications regionally and can add to or subtract from any warming depending on the nature of the aerosols

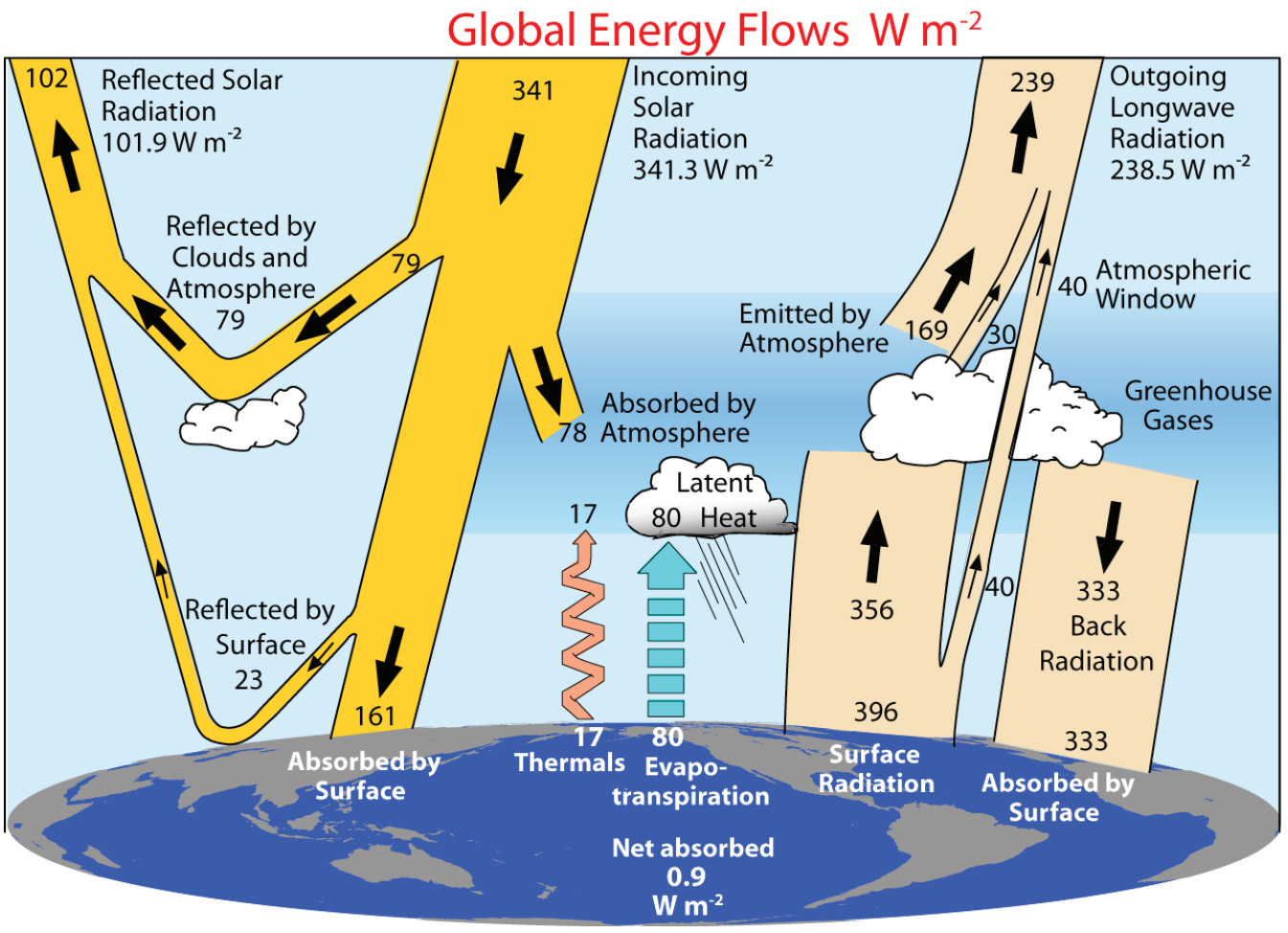

Fig. 1. The global annual mean Earth's energy budget for the March 2000 to May 2004 period in W m^{-2}. The broad arrows indicate the schematic flow of energy in proportion to their importance. From Trenberth et al. (2009). http://www.cgd.ucar.edu/cas/Trenberth/trenberth.papers/10.1175_2008BAM2634.1.pdf

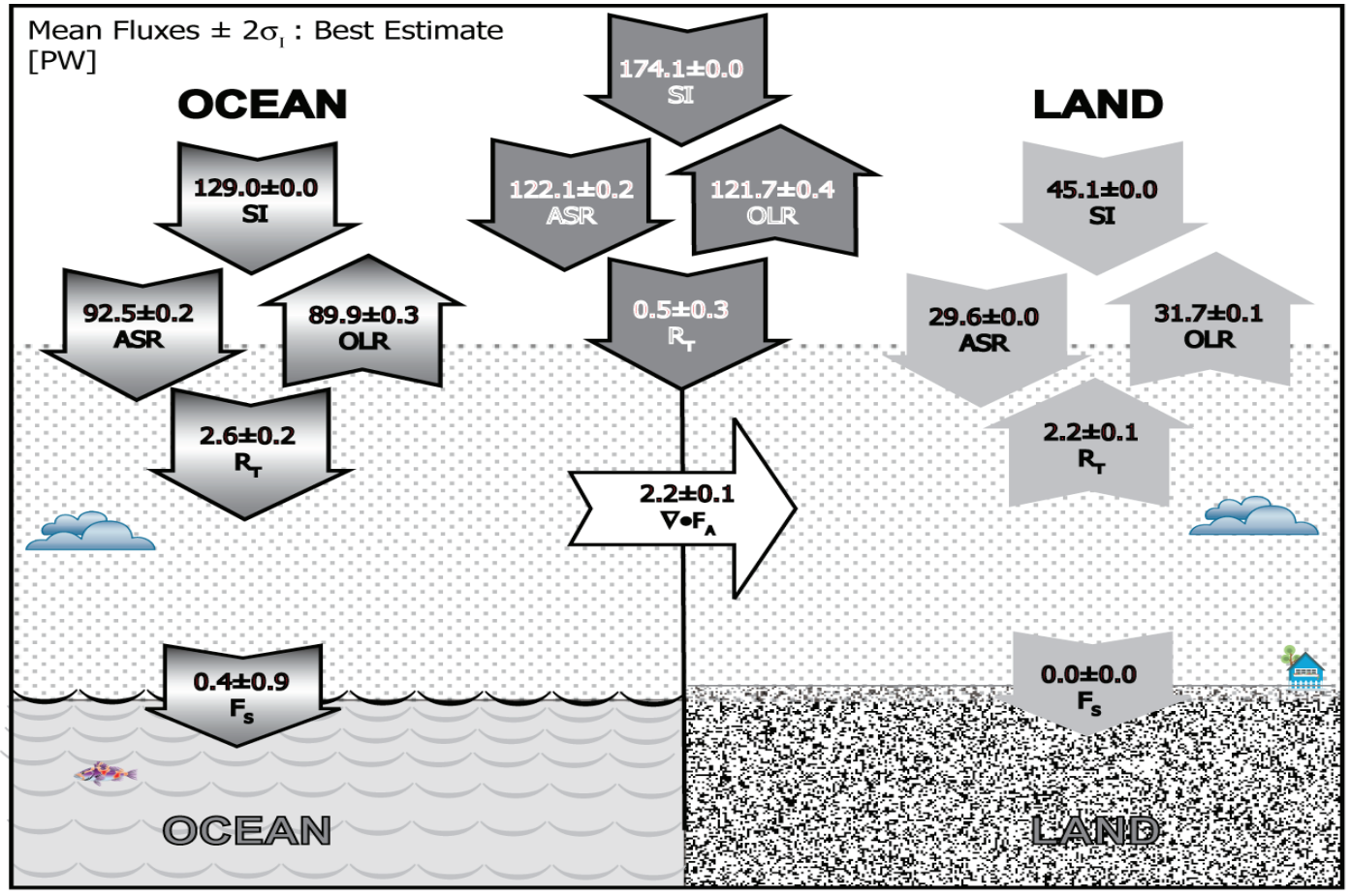

Figure 2: CERES-period March 2000 to May 2004 mean best-estimate TOA fluxes [PW] globally (center grey) and for global-land (right, light grey) and global-ocean (left) regions. SI is the solar irradiance and the net downward radiation RT =ASR-OLR. The arrows show the direction of the flow. $\nabla.F_A$ is the divergence of the atmospheric energy transport and the center arrow indicates the energy flow from ocean to land. The net surface flux is also given. Adapted from Fasullo and Trenberth (2008a).

and their interactions with clouds. The normal flow of energy through the climate system is about 122 PW (1 Petawatt =10^{15} watts) (see Fig. 2 presented later below). Human activities also contribute directly to local warming through burning of fossil fuels, thereby adding heat, estimated globally to be about 1/9000 (0.01%) of the normal flow of energy (Karl and Trenberth, 2003), while radiative forcing from increased greenhouse gases (IPCC, 2007) is estimated to be about 1.3% (1.6 PW), and the total net anthropogenic radiative forcing once aerosol cooling is factored in is estimated to be about 0.7%. [Radiative forcing is the change without factoring in the effects of the response and feedbacks]. The main negative feedback is from radiation: warming promotes higher temperatures and thus more longwave cooling. The actual imbalance at the top-of-atmosphere (TOA) would increase to about 1.5% once water vapor and ice-albedo feedbacks are included, but the total is reduced and is estimated to be about 0.5 PW (0.4%) owing to the other responses of the climate system; by increasing temperatures, outgoing longwave radiation (OLR) is increased as partial compensation. Unfortunately, these values are too small to yet be directly measured from space, but their consequences can be seen and measured, at least in principle.

Understanding and tracking the changes in the flow of energy through the climate system as the climate changes are important for assessments of what is happening to the climate and what the prospects are in the future. Here we comment on our ability to track the energy flow changes.

2. Global mean energy flows

Since about 2000, measurements from instruments on satellite platforms have provided new estimates of global radiation from the Clouds and the Earth's Radiant Energy System (CERES) instrument. A summary of the overall energy balance for the global atmosphere for the recent period (about 2000 to 2004) (Fig. 1) has the units of Watts per unit area. The global flows in Fig. 1 include reflection by clouds and the surface of solar radiation, and absorption by water vapor

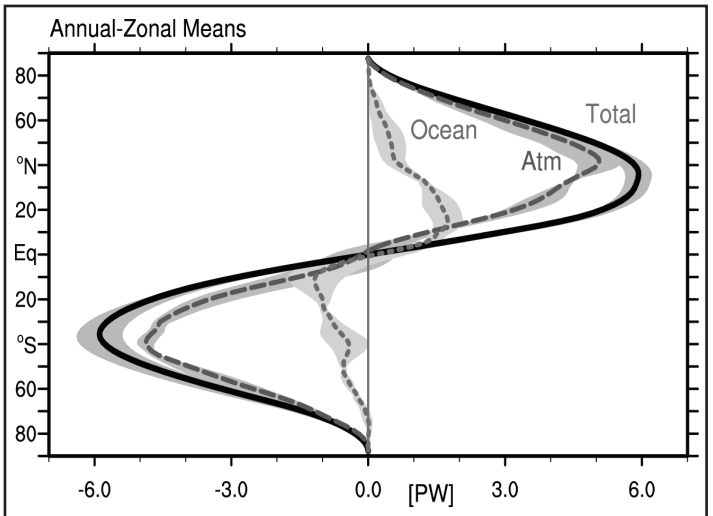

Figure 3: Zonal mean meridional energy transport by total (solid), the atmosphere (dashed), and by the ocean (dotted) accompanied with the associated ±2σ range (shaded). Adapted from Fasullo and Trenberth (2008b).

and aerosols. The energy balance at the surface is achieved through the incoming solar being mainly compensated by evaporative cooling (which drives the hydrological cycle), longwave radiation, and direct sensible heating. The very large surface longwave emissions are compensated by large back radiation by greenhouse gases and clouds, such that the evaporative cooling is larger as a whole. The global net imbalance is estimated to be 0.9 W m^{-2}.

Fig. 2 shows the flows for the atmosphere in the ocean and land domains. Here the areas are accounted for and the units are Petawatts. Plus and minus twice the standard deviation of the interannual variability is given in the figure as an error bar. The net imbalance in the top of the atmosphere (TOA) radiation is 0.5±0.3 PW (0.9 W m^{-2}) out of a net flow through the climate system of about 122 PW of energy (as given by the ASR and OLR). The fossil fuel consumption term is too small to enter into this figure. Hence the imbalance is about 0.4%. Most of this goes into the oceans, and about 0.01 PW goes into land and melting of ice. However, there is an annual mean transport of energy by the atmosphere from ocean to land regions of 2.2±0.1 PW, primarily in the northern winter when the transport exceeds 5 PW.

When all information is combined, there are residuals that indicate errors, which can be traced to ocean heat content in the historical record, and in particular to insufficient or no sampling of the ocean in the southern hemisphere in their winter. This situation has been alleviated since about 2002 when new ARGO floats (see http://www.argo.ucsd.edu/) have been deployed that drift freely at a depth of about 2000 m, and about once per 5 days, pop up to the surface using an ingenious small pump to change the float's volume, making a sounding of temperature and salinity along the way. The soundings are transmitted via satellite to land stations and processed to provide a comprehensive view of the ocean.

In the tropical ocean, the surface flux of energy is balanced principally by the transport of ocean energy (mainly heat), while in mid-latitudes surface fluxes are largely balanced locally by changes in ocean heat storage. The annual and zonal mean meridional energy transport by the atmosphere and ocean, and their sum (Fig. 3) show that the atmospheric transports dominate except in the tropics. There is a pronounced annual cycle of poleward ocean heat transport into the winter hemisphere exceeding 4 PW in the tropics, but the annual mean value across the equator is near zero. For the annual mean, the poleward transport by the ocean peaks at 11°S at 1.2 PW and 15°N at 1.7 PW.

3. Changes in energy and sea level rise

As noted above, there is a current radiative imbalance at the top-of-the-atmosphere of about 0.9 W m^{-2} owing to increases of greenhouse gases, notably carbon dioxide, in the atmosphere. This has increased from a very small imbalance only 40 years ago when carbon dioxide increases and radiative forcing were less than half of those today. Where is this heat going? Some heat melts glaciers and ice, contributing mass to the ocean which is called eustatic sea level rise. Some heat enters the ocean and increases temperatures and ocean heat content, leading to expansion of the ocean which is called thermosteric sea level rise. Only very small amounts of heat enter the land. Hence the main candidate for a heat sink is the oceans, and sea level rise synthesizes both expansion and added mass from melting of ice elements. Accordingly, it is an excellent indicator of warming.

To be more concrete, a 1 mm rise in sea level requires melting of 360 Gt of ice which takes 1.2×10^{20} J. Because the ice is cold, warming of the melted waters to ambient temperatures can account for perhaps another 12.5% of the energy (total 1.35×10^{20} J). Sea level rise from thermal expansion depends greatly on where the heat is deposited as the coefficient of thermal expansion varies with temperature and pressure (the saline ocean does not have a maximum in density at 4°C as fresh water does). The amount of warming required to produce 1 mm sea level rise due to expansion if the heat is deposited in the top 700 m of the ocean can take from 50 to 75×10^{20} J, or ~110×10^{20} J if deposited below 700 m depth. Hence melting ice is a factor of about 40 to 70 times more effective than thermal expansion in raising sea level when heat is deposited in upper 700 m; the factor is ~90 when heat is deposited below 700 m depth. For comparison, 0.9 W m^{-2} integrated globally is equivalent to about 1.4×10^{22} J/yr, which is a sea level equivalent of ~84 mm from ice melt or 1.3 to

2.7 mm from thermosteric ocean expansion. Note however that ice-laden land occupies only a few percent of the globe, which reduces the potential ice melt to only 1 to 2 mm/yr. Accordingly, for sea level rise to relate to energy budgets it is essential to know the eustatic and thermosteric components.

Sea level is estimated to have risen throughout the 20th century by 1.8±0.5 mm/yr. The rate of sea level rise from 1993 to 2007, when accurate satellite-based global measurements of sea level from TOPEX/Poseidon and Jason altimetry are available, average about 3.1 mm/year (Fig. 4). For 1993 to 2003, there is a reasonable accounting for how this comes about. Contributions from glaciers and small ice caps and from the ice sheets of Antarctica and Greenland add mass to the oceans and eustatic rise of about 1.2 mm/yr. Contributions from changes in storage of water on land in reservoirs and dams may account for –0.55 mm/yr sea level equivalent, but these are compensated for by ground water mining, urbanization, and deforestation effects. Direct temperature measurements within the ocean show that ocean heat content increased and sea level rose from thermal expansion by 1.6 to 1.8 mm/yr. About 0.3 mm/yr is from slow isostatic rebound of the Earth's crust.

Since 2003, however, when ARGO floats have provided better data, increase in ocean heat content has slowed, while Greenland and Antarctica melting has picked up. Whether or not the sea level budget is closed, it is not clear that the global energy budget is closed because sea level rise is much greater for land ice melt versus ocean expansion for a given amount of heat, as noted above. Accordingly, another much needed component is the TOA radiation, but CERES data are not yet processed beyond 2004 and are not yet long enough to bring to bear on this question.

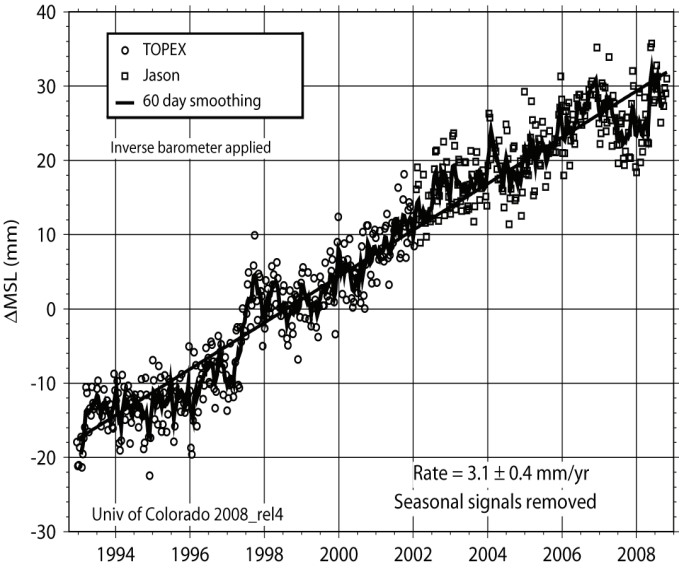

Fig. 4. Global sea level since August 1992. The TOPEX/ Poseidon satellite mission provided observations of sea level change from 1992 until 2005. Jason-1, launched in late 2001 continues this record by providing an estimate of global mean sea level every 10 days with an uncertainty of 3-4 mm. The seasonal cycle has been removed and an atmospheric pressure correction has been applied. http:// sealevel.colorado.edu/ Courtesy Steve Nerem (reproduced with permission).

4. Climate Change

A consequence of the energy imbalance at the TOA is global warming. In 2007 the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), known as AR4, clearly stated that "warming of the climate system is unequivocal" and it is "very likely" due to human activities. Since the IPCC report, nature continues to provide evidence that it is under duress with impacts affecting people and animals. Increasing rates of carbon dioxide emissions raise the specter that future climate changes could be much larger and come much quicker than IPCC suggests.

The AR4 found that warming of the climate system is unequivocal based on an increasing body of evidence showing discernible physically consistent changes. These include increases in global average surface air temperature; atmospheric temperatures above the surface, surface and sub-surface ocean water temperature; widespread melting of snow; decreases in Arctic sea-ice extent and thickness; decreases in glacier and small ice cap extent and mass; and rising global mean sea level. The observed surface warming at global and continental scales is also consistent with reduced duration of freeze seasons; increased heat waves; increased atmospheric water vapor content and heavier precipitation events; changes in patterns of precipitation; increased drought; increases in intensity of hurricane activity, and changes in atmospheric winds. This wide variety of observations gives a very high degree of confidence to the overall findings. Because these changes are now simulated in climate models for the past 100 years to a reasonable degree, there is added confidence in future projections for more warming and increased impacts. Moreover, these changes in physical variables are reflected in changes in ecosystems and human health.

Carbon dioxide concentrations are increasing at rates beyond the highest of the IPCC scenarios, suggesting even bigger and faster climate change than IPCC projected. Warming is manifested in multiple ways, not just increases in temperatures. Most dramatic is the loss of Arctic sea ice in 2007 and 2008, which affects surrounding areas, polar bears and other native species and promotes changes in permafrost. Distinctive patterns of temperature and precipitation anomalies in the winter of 2007-08 were characteristic of the strong La Niña that had

a signature over most of the world. In the first 6 months of 2008, record heavy rains and flooding in Iowa, Ohio, and Missouri, led to overtopped levees along the Cedar River in Iowa and the Mississippi, and point to increases in intensity of rains associated with more water vapor in the atmosphere: a direct consequence of warming. The record-breaking numbers of tornadoes and deaths in the U.S. in 2008 probably also have a global warming component from the warm moist air coming out of the Gulf of Mexico adding to instability of the atmosphere. Longer dry spells also accompany warming, as heat goes into evaporating moisture, drying and wilting vegetation, and thus increasing the risk of wild fire enormously. Wild fires in California early in 2008 and again last summer are evidence of the impacts. Hurricanes are becoming more active. In the Atlantic in July 2008, hurricane Bertha broke several records for how early and how far east it formed, and it is the longest lasting July hurricane. Fay made landfall 4 times and hurricanes Gustav and Ike caused devastation in the U.S. in 2008. Sea level rise continues at a rate of over a foot a century. Changes in ocean acidity accompany the buildup in carbon dioxide in the atmosphere with consequences for sea creatures, and bleaching of corals occurs in association with warming oceans. Melting permafrost exposes huge potential sources of methane and carbon dioxide that can amplify future climate change. Global warming is not just a threat for the future, it is already happening, endangering the health and welfare of the planet. There is a crisis of inaction in addressing and preparing for climate change.

Dr. Kevin E. Trenberth is Head of the Climate Analysis Section at the National Center for Atmospheric Research. He was a lead author of the 1995, 2001 and 2007 Intergovernmental Panel on Climate Change (IPCC) Scientific Assessment of Climate Change

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Review of the 2008 APS Energy Study, *Energy Future: Think Efficiency*

David Hafemeister

Shortly after the oil embargo of 1973-74, the American Physical Society played a significant role in advancing U.S. energy policy with its study, Efficient Use of Energy (AIP Conference Proceedings 25, 1975). Now we have reached another crisis time, when US security is threatened by its heavy dependence on imported oil (an issue that contributed to Gulf Wars I and II); when urban air has improved but could be better; when U.S. oil imports cost $250 billion/year (2% GDP at $50/barrel); and when concern grows over carbon-induced climate change. The APS study examines energy use in buildings (36% of US carbon emissions) and transportation (32% of US carbon emissions).

The time was ripe for the APS to take a fresh look at energy efficiency. An APS panel has just produced a report, Energy Future: Think Efficiency, which will be published in the Reviews of Modern Physics and it is now available at www.aps.org/energyefficiencyreport/index.cfm. This APS study was chaired by Nobel-Laureate Burton Richter with a distinguished committee of knowledgeable physicists and engineers. The study examines energy use in buildings (36% of US carbon emissions) and transportation (32% of US carbon emissions). The report stresses that "making major gains in energy efficiency is one of the most economical and effective ways our nation can wean itself off its dependence on foreign oil and reduce its emissions of greenhouse gases." I am comfortable with the APS study conclusions given below. One can really only debate the timing of events. That is, one can ask when (not if) will the lithium battery propel autos at a competitive cost? The future cost of gasoline is as important as the future cost of batteries in this calculation. The day of economic competitiveness for journeys of forty miles is not far away, and it will be hastened with large-scale production economics.

Energy Efficient Cars: Automobile efficiency improved by 20% (from 36 to 43 ton-miles/gallon) over two decades (1985-2005, Figure 6; Figure numbers refer to the APS report).

But, over the same period of time auto fuel economy (FE) stagnated at 28 miles/gallon (mpg). The APS study finds that improved internal combustion cars and hybrids could obtain 50 miles/gallon by 2030 by weight reduction and engineering (p. 33). Perhaps this is too cautious a time frame. If we reduce the weight of cars and remove the special regulatory status of SUV's, considerable progress can be made. Car weight dropped from an average of 4100 pounds in 1975 to 3200 pounds in 1980, but sadly it returned to the former 4100-pound level in 2004. What happened is that improved car efficiency and reduced mass easily satisfied the Corporate Average Fuel Economy (CAFE) standard of 27.5 mpg by 1985. But then further progress in fuel efficiency was dedicated to increasing the engine mass (horsepower) to reduce acceleration time to 60 mph from 14 seconds to 10 seconds.

The APS study notes that "a 10-percent reduction in weight, for example, yields a 6 to 7 percent increase in fuel economy." Thus, reducing car mass by 22% back to 1980 levels increases fuel economy by 15%. The 1.15 factor gain in fuel economy translates to reducing fuel consumption by 13%. Energy savings is not proportional to fuel economy (miles per gallon), but to the inverse of fuel economy (gallons per mile). Consider the case of two cars with fuel economies of 10 mpg and 20 mpg. If the two cars travel 20 miles each, one consumes 1 gallon and the other consumes 2 gallons for a total of 3 gallons. The forty-mile trip consumed 3 gallons, for a fleet average of 13.3 mpg. Note that the fleet average of 13.3 is lower than the numerical average of 15 mpg, closer to the guzzler at 10 mpg than the car at 20 mpg. This makes good physics sense, and that why CAFE standards impose limits on fuel economy rather than fuel efficiency.[1]

CAFE Scenarios: In this section I estimate energy savings from the APS study conclusions, placed into a table below, comparing fuel economy, inverse fuel economy and the fractional and barrel savings from 2007 (before collapse) when light vehicle sales were 50% cars at 28 mpg and 50% SUVs, minivans, and light trucks (SUV+) at 22 mpg. This gives a 2007 fleet average fuel economy FE of 24.6 mpg, much closer to SUV's (22 mpg) than cars (28 mpg). Next consider the case of the entire light vehicle fleet as having the same fuel economy as cars (SUVs at 28 mpg). Then consider the fleet at 35 mpg by 2020, as mandated by the 2007 CAFE standards (42 mpg in California?). The new fleet might consist of improved internal combustion (IC) engines and hybrids. Next we look at 50 mpg by 2030, a goal that the APS study concludes (p. 33) "is achievable if technological improvements are focused on reducing fuel consumption" with a mix of cars with fuel economies typical of today's hybrids. Then I consider advanced hybrids at 90 mpg by 2030 (p. 32). Lastly consider all cars to be plug-in electric vehicles with 40-mile batteries, saving 60% of vehicle miles (Figure 37). Since the miles saved are urban miles, we arbitrarily raise this to 65% savings. In the table below we obtain the steady-state (after 10-20 years) savings by multiplying the fractional savings times the light vehicle consumption rate of 9.3 Mbbl/day. The results show that the US can save more than 50% of petroleum used in cars. This could be done with plug-in electrics or very good gasoline hybrids.

Mass and Safety: The mass, momentum and aggressive design of a Hummer can severely inflict damage on a Prius in a crash. But, a Prius hitting a Prius, with good engineering and ample "crush zones," is similar, to first order, to a Hummer hitting a Hummer. From conservation of momentum, we know that a light car with half the mass of a heavy car experiences twice the velocity change (twice the deceleration and twice the force on humans) of the heavy car. The APS study points out (p. 35) that "the linkages among fuel economy, vehicle size, weight, and safety are manageable and are more a function of smart vehicle design than any other single factor." Some researchers conclude that "reducing vehicle weight while maintaining the key dimensions of wheelbase and track width could decrease the total number of fatalities." The increased volume of crush-zones reduces deceleration and increases safety.

Plug in Electric Cars: If all cars had 40-mile batteries, 60% of vehicle miles would be powered by electricity and not gasoline (Figure 12). The savings in carbon emissions would be less than 60% since 50% of US electricity is generated from coal. APS recommends (p. 41) the following: "Time-of-use electrical power metering is needed to make charging of batteries at night the preferred mode. Improvements in the electrical grid must be made if daytime charging of electrical is to occur on a large scale or when the market penetration of electrical vehicles becomes significant." Thus, in the near term, the smart grid is not needed, but it will be needed in the future with more electrical cars and with more solar and wind renewable power that varies during the day. The plug-in electric car is a good fit with the grid since it can use wasted electricity from base-load power plants operating at night, and it can use wind power, since charging is not concerned with fluctuations of wind power. A smart grid of the future could vary the rate of charging batteries, helping to stabilize the grid from the fluctuations of wind power.

Chevrolet Volt: The Chevrolet Volt is scheduled to enter the market in 2010 with the capacity to drive 40 miles on electrical energy stored in a lithium battery. The Volt is a plug-in, series-hybrid electrical vehicle (PHEV) that is propelled only with its electric motor, the first forty miles on electricity from the grid and successive miles from gasoline converted into electrical energy. The Volt it is not a plug-in parallel-hybrid

Situation	fraction at FE	fleet FE	fleet 1/FE	Savings	(%, Mbbl/day)
2007	fi = 0.5, 28 mpg fi = 0.5, 22 mpg	24.6 mpg	0.0406 gpm	0	0
SUV = car	fi = 1, 28 mpg	28 mpg	0.0357 gpm	12%	1.1 Mbbl/day
2020	fi = 1, 35 mpg	35 mpg	0.0286 gpm	30%	2.8 Mbbl/day
hybrid std.	fi = 1, 50 mpg	50 mpg	0.02 gpm	51%	4.7 Mbbl/day
hybrid(2030)	fi = 1, 90 mpg	90 mpg	0.0111 gpm	73%	6.8 Mbbl/day
all PHEV	fi = 1, 40-mile battery			65%	6.0 Mbbl/day

that is propelled by both the motor and the IC engine. After its battery has been drained, the Volt only uses its three-cylinder IC engine to recharge the battery. The advantage is that the IC engine operates only at its optimal operating point (RPM and torque), which has a reasonable efficiency at that point. IC engine efficiency drops quickly when operating away from its optimal point. Electric motors have a much broader region of high-efficiency operation than do IC engines. The Prius battery has a capacity of only 1.3 kWh, to drive but 4 miles without being recharged. The 40-mile Volt battery has a capacity of 28 kWh, which is twice the minimum size to prevent deep discharging of the battery. Today, this battery costs about $20,000, but it is generally believed that increased production rates will cut the cost to $10,000.

Simple Economics of Electric Cars: Let's use the APS study's results for some basic economics. I am on a list to buy a Chevy Volt. I am not sure if I will buy the Volt at the projected cost of $40,000, but I plan to buy if it costs $30,000. Because of my interests I have carried out some basic economics below. Let us assume travel of 10,000 miles per year in urban traffic at 40 miles/day, five-days per week all year. The APS study states that the off-peak electricity costs in California are about 3 cents/mile (p. 38), or $300/year. We will ignore the cost of this operating electricity since a typical IC car has this magnitude of expense because of its many moving parts. At 33 mpg, a car consumes 300 gallons a year, which costs $600/year at the current price of $2/gallon, or $1200/year at $4/gallon (a year ago), and $1800/year at $6/gallon (in Europe). These savings on gasoline must be compared to the cost of buying the battery pack (and associated equipment) and the interest paid during the lifetime of the battery. At tomorrow's battery price ($10,000), the capital recovery rate at 5% interest on a 20 year loan is 8%/year.[2] The annual cost is then 8%/year times the cost of the battery of $10,000, or $800/yr. Of course, the battery may only last 10 years, then the capital cost recovery factor grows to 13%, raising the annual cost of $10,000 battery to $1300/year. Let's also double these figures for today's batteries at $20,000. Let us take the favorable case first: The all-electric car with a $10,000 battery with a 20-year life costs $800/yr. That's only $200.year more than the cost of operating an IC engine at $2 gasoline ($600/yr), but it is $400/year less than the cost at $4 gasoline ($1200/yr). The 10 year battery at $10,000 is a very good deal for Europe. Things look darker with the present $20,000 battery, costing $1600/yr (20 yr) and $2600/yr (10 yr). Will the future bring a 20-year battery life? I would bet that in two decades, the price of gasoline will be considerably higher than today's $2/gallon in 2009 dollars and also higher than last year's $4/gallon. Recall, we used an IC engine car at 33 mpg. If we had used a more likely car at 25 mpg in the city, we would have consumed 400 gallons/year, raising the cost of the IC car by 33% to $800/yr ($2/gal), $1600/yr ($4/gal) and $2400/yr ($6/gal). Thus, an all-electric car looks like a safe bet once the "bugs" are out of the system. This conclusion is very scenario dependent. For those that drive 30,000 miles/year it should be very attractive, but recall that the battery drives only 40 miles/day on electricity from the grid, and then the Volt efficiently uses gasoline for the other 80 miles/day. For those who drive 5,000 miles/year, it is less attractive. Some will make the investment for sake of our local planet. Do we have to save all of our money for our children?

Cost of Conserved Energy: Another approach to determine the economics of saving energy is to calculate the cost of conserved energy (CCE), which is the annual cost of the capital investment divided by the annual fuel saved. This approach has the advantage that we do not speculate on future fuel costs, but merely determine what cost of gasoline would be needed to break even. We will not add in the $300/yr for electricity since we have avoided the maintenance of the IC car. The annualized costs are $800/year ($10k battery, 20 yr), $1300/yr ($10k, 10 yr), $1,600/yr ($20 k, 20 yr), and $2,600/yr ($20 k, 10 yr). We divide these figures by 300 gallons of gasoline/year, and obtain CCE of a gallon of gasoline

of $2.70, $4.30, $5.30 and $8.70. At 25 mpg and 400 gal/yr, the CCE per gallon is 25% lower at $2.00, $3.25, $4.00 and $6.50. Remember, this is the cost of gasoline over the future 10 and 20 years. I estimate that the first three scenarios will be cost effective over that time period. It is only the expensive, short-lived battery at $8.70 and $6.50/gallon that would fail in the market place. There was a very nice debate in the letters section of APS News (p. 4, January 2009): Robert Levy wants the APS to be more bullish on the lithium battery, stressing that any problems with them are legal and political, not technical. The APS study chair, Burton Richer, responds that he thought the report clearly stated that the study group regarded plug-in electric vehicles as "one of the most important developments in the automotive industry to reduce both gasoline consumption and emissions." He goes on to say that "the batteries for the Chevy Volt…. are the first generation of a new Li-Ion battery and as such are not likely to be good enough for the FULL span of all the light vehicles on the road."

Lithium batteries: The APS calls for a more balanced portfolio "across the full range of potential medium- and long-term advances in automotive technologies, including plug-in battery electric vehicles." Lithium batteries are the only significant technical barrier to the wide-spread adoption of plug-in electric cars, which would be a significant improvement over the electric hybrids of today. We have adored our lithium batteries in our laptop computers, but yet we know that the $100,000 Tesla, which uses computer batteries, is too pricey for us. The good news is that lithium batteries are getting better and will, hopefully, power the Chevy Volt in 2010. The bad news is that Asian battery manufacturers appear to be doing better than the American counterparts. Recently, General Motors awarded a big contract for lithium batteries to a Korean firm and not to a US firm. This is one of the reasons why the APS study recommends (p. 38 and 88) increased funding for research and development.

Lithium Details: The APS report prints a schematic (Figure 16) from Venkat Srinivasan of Lawrence Berkeley National Laboratory, which compares the specific energy, specific power and acceleration for several vehicle power sources, including the lithium-ion battery. Srinivasan's Figure 17 gives estimates for the success factors for eight key parameters for lithium batteries. To discuss these parameters is useful, but most of us lack the details to understand fully their true meanings. For example, the efficiency of charging a battery decreases as its state of charge (SOC) is raised from empty to full. On the other hand, the efficiency of draining a battery decreases as it is drained from full to empty. Thus, there is an optimal point to operate the battery. A hybrid that continually drains and fills a smaller battery, keeping the SOC near 50% capacity, can do this better than a car with a 40-mile battery for a 40 mile trip. But if we want long range from a smaller battery pack, we would need to discharge the battery deeply, operating it in its less efficient mode. How much do deep discharges hurt lithium batteries? We have all occasionally emptied the battery of our laptops without noticeable damage. But on a daily basis is this wise? You can see that this discussion is just beginning. And are the 28-kWh lithium battery packs safe? (I believe they can be made safe in collisions, but this needs to be proven.) Will large amounts of lithium be available beyond Bolivia and China? Srinivasan's 2007 data is listed below in terms of the percent of goals achieved: Specific power (W/kg) is 100%; power density (W/m^3) is 100%; specific available energy (Wh/kg) is 80%; available energy density (Wh/m^3) is 80%; cycle life (cycles) is 70%; calendar life (years) is 60%; production price ($) is 55%; operating temperature range is 43%.

Hydrogen cars: The APS study gives a death blow to the hydrogen car which was part of the "Freedom Car" partnership between DoE and US automobile companies (2003) to promote high risk research on light cars to use less oil and generate fewer harmful emissions. The study group concluded the following (p. 39): "Hydrogen fuel cell vehicles are unlikely to be more than a niche production without scientific and engineering breakthroughs in several areas. The main challenges are durability and costs of fuel cells, including their catalysts, cost-effective onboard storage of hydrogen, hydrogen production and deployment of a hydrogen-refueling infrastructure." I am even more pessimistic about hydrogen cars than the APS statement. Clearly hydrogen from natural gas is not reasonable since natural gas is valued for other uses and is in relatively short supply. It takes electrolysis at about 50% efficiency to produce hydrogen energy, and then the fuel cell makes electricity at about 50% efficiency to propel the car. This approach is much less efficient than batteries charged from the grid. Charge/discharge efficiency can be 90%, but it will be less with a fast charge and it depends on the SOC of the battery. The APS POPA study, The Hydrogen Initiative, clearly pointed out these problems in 2004.

APS Facts on Energy and Buildings: Buildings (2005) account for 36% of US greenhouse gas emissions related to energy use and they consume 72% of the nation's electricity. But the buildings sector has little impact on imported oil. The four largest end-uses of primary energy in residential buildings are space heating (32%), air conditioning or space cooling (13%), water heating (13%) and lighting (12%), totaling 70%. For commercial buildings, the four largest end uses of primary energy are lighting (27%), space heating (15%), space cooling (14%) and water heating (7%), totaling 63%. Energy codes adopted in California since 1975 have resulted in energy savings of more then $30 billion, more than $2,000 per household. The energy

needed to cool a new home declined by two-thirds to 800 kWh per year, although homes are about 50% larger than in 1975. The energy program at Lawrence Berkeley National Laboratory on advanced window coating and electronic fluorescent ballasts has saved consumers $23 billion, as well as additional savings from computer simulation modeling, house doctor technologies, new types of insulation, infiltration mitigation, passive solar and day-lighting technologies.

Zero Energy Buildings: In California a ZEB means a reduction of energy use to zero with better insulation, passive solar heating, solar daylighting and energy storage, plus electricity generated with renewable technologies, such as photovoltaics. The trend is definitely in this direction, but the goal line will still take some effort. APS concludes (p. 56) that "energy demand in the building sector could be reduced from the projected 30% increase to zero between now and 2030." Recall that there is much inertia in the building sector because buildings last for 50 to 100 or more years. The APS study concludes (p. 61) that "The goal of achieving significant levels of construction of cost-effective new zero-energy commercial buildings by 2030 is not obtainable without significant advances in building technology and without the development and widespread adoption of integrated building design and operation practices." The APS study points out (p. 66) that the US spends only $100 million/year for research on energy in buildings, less than the $250 million/year (today's dollars) spent in 1980. The APS study recommends (p. 71) that "Building energy standards, such as those promulgated in California, should be implemented nationwide. States should be strongly encouraged to set standards for residential buildings and require localities to enforce them. For commercial buildings, performance-based standards that rely on computer software to compare a building design with a reference building are implemented only in California. The federal government should develop a computer software tool much like that used in California to enable states to adopt performance standards for commercial buildings. States should set standards that are tight enough to spur innovation in their building industries."

Appliances: The progress has been phenomenal: Since 1975, refrigerator energy use has dropped form 1850 kWh/yr to 450 kWh/yr, saving 50 power plants with improved refrigerators and freezers. At the same time refrigerators have gotten 15% larger. This isn't the only low-hanging fruit, as energy for central air conditions has been reduced by 40% and that for furnaces has been reduced by 25%. And these opportunities are synergistic; a tightly insulated house can downsize its air conditioners. And as the price of electricity rises (as it will), additional improvements are feasible, making energy-savings a renewable resource. On the other hand, standby energy use in California has risen to 980 kWh/year (or 112 Watts), and corresponds to 13% of the state's total residential electricity use in 2006. This wasteful use of energy amounts to 70% of the 1400 kWh/year saved with an improved refrigerator. The APS study recommends (p. 71) that "DOE should promulgate appliance efficiency standards at levels that are cost-effective and technically achievable as required by the federal legislation enabling the standards." Apparently DOE has been slow moving in this area as the APS study comments that "A streamlined procedure is needed to avoid delays in releasing these standards."

Conclusions: The nation has received a thoughtful clarion call for action from the APS energy study. The APS study has examined the advancing technologies to reduce energy use at a profit to the nation. The APS report issues 17 recommendations that should be heeded as soon as possible. They are well-balanced, and based on facts and not hopes. For further technical details on many of these topics, I recommend the APS Forum on Physics and Society's conference proceedings, Physics of Sustainable Energy.[3] I appreciate comments on the draft paper by Jeff Abramson, Ben Cooper, Allan Hoffman, Barbara G. Levi, Peter Schwartz and Richard Scribner.

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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.

Endnotes

1 *The CAFE formula, devised by Allan Hoffman in the 1975 EPCA law, determines the fleet-averaged fuel economy. The inverse of the fleet averaged FE is the sum, over all classes, of the ratio of its fractional population fi divided by the fuel economy of that class FEi, or 1/<FEfleet> = Σi fi/FEi. Applying the formula to the case of the 10 mpg and 20 mpg cars, we obtain <1/FEfleet> = (0.5/10) + (0.5/20) = 0.05 + 0.025 = 0.075, or FEfleet = 13.3 mpg!*

2 *Capital recovery rate = CRR = i/[1 – exp(-iT))] where i is the interest rate (continuously compounded) and T is the lifetime of the battery. D. Hafemeister, Physics of Societal Issues (Springer, 2007), p. 412.*

3 *D. Hafemeister, B.G. Levi, M. Levine, and P. Schwartz, Physics of Sustainable Energy: Using Energy Efficiently and Producing it Renewably, AIP Conference Proceedings 1044 (2008), p. 438.*

Comments on Yucca Mountain and Nuclear Energy[1]

David Bodansky

In December 2008 the Department of Energy (DoE) recommended that Congress remove the limit of 70,000 metric tonnes of heavy metal (MTHM) on nuclear waste storage at Yucca Mountain.[2,3] TheSuch a proposal is astonishing considering that the Yucca Mountain project was already facing great and perhaps decisive opposition with its capacity capped by statute at 70,000 MTHM. Proposing an expansion, if meant seriously, could be seen as hopelessly quixotic.

In any case, the expansion issue, described in a bulletin of the American Institute of Physics in January 2009, may now be moot.[4] A Yucca Mountain project of any size seems unlikely for the predictable future, given the opposition of Senator Reid of Nevada, the Senate Majority Leader, with the now confirmed support of President Obama. In this paper we will review the Yucca Mountain situation, partly for perspective on nuclear waste disposal and partly because the Yucca Mountain project might some day be revived.

Under the Bush administration, which favored going ahead with Yucca Mountain, the DOE had no very good alternative to recommending an expansion. The Nuclear Waste Policy Act of 1982 (NWPA), as amended, stipulates that "The Secretary [of Energy] shall report to the President and to Congress on or after January 1, 2007, but not later than January 1, 2010, on the need for a second repository."[5] The need for additional capacity is inescapable because the accumulation of spent fuel from commercial reactors will reach the Yucca Mountain legal limit by 2010, and will continue to grow thereafter. The obstacles to establishing a second repository might have seemed even more formidable than those facing a Yucca Mountain expansion, given the difficulties of selecting a site and demonstrating its adequacy.

Another alternative mentioned by the DOE is to continue to store spent fuel at the reactor sites. The fuel remains in the form of solid pellets in assemblies of metal fuel rods. The assemblies are initially put in cooling pools. After about five years, when the heat output is reduced sufficiently, they can be transferred to on-site, air-cooled casks. This dry-cask storage was first utilized in the United States in 1986 and by now is employed at most reactor sites, using durable, NRC-approved casks.[6]

The on-site alternative could be adopted as part of a coherent waste disposal program or slipped into as a continuation of the present default practice. This path was not favored by the DOE, because it would further delay the fulfillment of the federal government's obligation to assume responsibility for the spent fuel by 1998 and keep adding to the government's resulting financial liabilities.

Yet another alternative, not discussed in the DOE report, would be to establish a number of centralized interim storage facilities, to provide dry-cask storage for a century or more. However, the DOE is now barred from developing such a sitesites until a permanent repository is licensed and past private efforts have been thwarted by state and local opposition.

As the policy of the Obama administration becomes clearer, it now appears probable that our actual program for the near future will be on-site storage, perhaps supplemented later by centralized interim storage. Nuclear opponents would surely cite this course as showing that there is no long-term solution for waste disposal. We will return to these alternatives, after a brief review of the Yucca Mountain situation itself.

The performance of the presently conceived (70,000 MTHM) Yucca Mountain project has been analyzed by the DOE in a long series of *Total System Performance Assessments* (TSPAs). The most recent TSPA was issued in January 2008 (with a March 2008 addendum) in support of the DOE's June 2008 application to the Nuclear Regulatory Commission (NRC) for a Yucca Mountain Repository License. The application is over 8600 pages — the culmination of years of intense study. The NRC's review is scheduled to take three or four years.

The repository must meet new radiation standards, put forth by the EPA in September 2008.[7] The dose to the "reasonably maximally exposed individual" living near Yucca Mountain is limited to 15 mrem/year for the first 10,000 years and to 100 mrem/year for up to 1 million years — both well below the average U.S dose from natural sources of about 300 mrem/year. This standard has been variously criticized as inappropriately relaxed after 10,000 years and, from a different perspective, as misguided in attempting to establish specific standards for times so far in the future. In the recent TSPA, the mean calculated Yucca Mountain doses are always far below these limits.

The physical capacity of the Yucca Mountain repository has been studied by the Electric Power Research Institute (EPRI) and the DOE.[8,3,] The EPRI study concluded that a closer placement of the waste containers, with increased ventilation, and an expansion of the site area could increase the capacity of the Yucca Mountain repository by a factor of four to nine. From an independent analysis, the DOE concluded that an expansion of "three times, or more" is possible.[9]

Any serious plan for such an expansion would be greeted with outrage by Nevada's political leaders. They view as

unjust the initial designation by Congress in 1987 of Yucca Mountain as the single candidate site for the entire nation's commercial spent fuel, even with a ceiling of 70,000 MTHM on the repository size. To now breach that ceiling would add to the insult.

The context of Yucca Mountain decisions has been changed by the Obama administration's opposition to the repository's construction, and funding reductions are forcing major reductions in the staff.[10] A remaining point of contention is the fate of DOE's license application.[11] Yucca Mountain's opponents want the DOE to withdraw the application, ending NRC's study of Yucca Mountain and lessening any chance that the Yucca Mountain project might be revived. Steven Chu, the new Secretary of Energy and a Nobel Laureate physicist, is reported to favor completing the NRC study of the application, with the DOE continuing to respond to NRC questions. At a minimum, the NRC analysis of this major document could have lessons for the planners of a future repository.

The termination of the Yucca Mountain project would be a major victory for Nevada officials and for more general nuclear opponents. The opponents have long sought to use the nuclear waste issue, in the words of Michael McCloskey, then-chairman of the Sierra Club, as a way "to drive a final stake in the heart of the nuclear power industry."[12] Correspondingly, this outcome would be seen as a defeat by the nuclear industry and by others who see nuclear energy as essential to addressing global climate change and the problematic oil market.

Although it gives nuclear opponents a valuable talking point, the full consequences of this defeat are uncertain. Nuclear energy retains strong, albeit not unanimous, support in the scientific community, and this setback may not terminate a nuclear energy revival. The scientific support is reflected, for example, in a statement entitled *A Sustainable Energy Future: The Essential Role of Nuclear Energy* that was signed in August 2008 by the ten Directors of the U.S National Laboratories, including Dr. Chu.[13] The Directors term nuclear energy "the only existing technology with capability for major expansion that can simultaneously provide stability for base-load electricity, security through reliable fuel supply, and environmental stewardship by avoiding emissions of greenhouse gases and other pollutants." The statement noted nuclear's "exemplary safety" and added that it could also contribute to the production of hydrogen and the desalination of seawater.

The statement gave endorsements to both Yucca Mountain and dry cask storage:

> *Confidence regarding the disposal of waste is needed before the NRC will grant a license for a new plant….In the short term, this confidence can be achieved by continuing the licensing of a geologic repository at Yucca Mountain and enabling the continued interim storage of used nuclear fuel in dry casks and fuel pools.*
>
> *Dry cask storage is a safe and secure interim solution, either at existing reactor sites or consolidated regionally if future circumstances dictate.*

For the near future, with or without new reactors, the storage of spent fuel in on-site dry casks will increase. Although this course may seem an ad hoc stopgap, there are many endorsements of its safety. The Directors' statement (above) is one example. Similarly, an American Physical Society panel concluded that "There are no technical barriers to long-term safe and secure interim storage of spent nuclear fuel either at nuclear plant sites or at one or more consolidated sites."[14] Importantly, the NRC proposed in October 2008 a revised "Waste Confidence Decision" affirming the safety of spent fuel storage "for at least 60 years beyond the licensed life for operation… in a combination of storage in its spent fuel storage basin and either onsite or offsite independent spent fuel storage installations."[15]

The NRC's position is important because the NRC will issue licenses for new reactors only if it has "reasonable confidence that the wastes can and will in due course be disposed of safely."[16] In the end, however, the contribution that nuclear energy makes to addressing our energy problems will depend on the policies of the Obama administration, which at the moment appears to have unusual freedom of choice.

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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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2. *The term metric tonnes of heavy metal (MTHM) usually refers to the mass of the original uranium fuel.*
3. *U.S. Department of Energy, "The Report to the President and the Congress by the Secretary of Energy on the Need for A Second Repository," Report DOE/RW-0595 (Washington, DC: U.S. DOE, December 2008).*
4. *American Institute of Physics, "DOE Report Recommended Increasing Nuclear Waste at Yucca," Bulletin of Science Policy News, No. 6: January 21, 2009. Available at: http://www.aip.org/fyi/2009/006.html#*
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Light Pipes: An FPS Student Fellowship Research Project

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[During the summer of 2008, Erin Owens, a physics major at Eastern Michigan University, held a FPS Student Fellowship in Physics and Society. Fellowships consist of a stipend of up to $4000 and are awarded to undergraduate or graduate students in physics in support of projects that apply physics to a societal issue. (See http://www.aps.org/units/fps/awards/student-fellowship.cfm) Erin worked with Prof. Ernie Behringer of the physics department at EMU. – Ed.]

The objective of this project was to develop an online-accessible calculator which would estimate the cost savings that can be realized by installing a light pipe. In order to increase the likelihood that people will adopt new technology, an easy means to examine the costs and benefits of the technology should be available so the consumer can better make an informed decision about implementation. When it becomes apparent that money can be saved by implementing a mechanism which allows the utility of the sun as a renewable source of energy, more consumers will adopt this technology.

The fossil fuel resources used to support our standard of living are finite, and consequently their continued use is not sustainable. According to the 2007 Annual Energy Review by the U.S. Department of Energy, 86.2% of total U.S. energy was generated from a combination of petroleum, natural gas, and coal[1]. These same sources furnished 70% of the total electric power generated in the U.S.[1] By increasing the energy efficiency of buildings, the use of fossil fuels for energy and electricity can be significantly reduced. Developing more efficient and affordable technologies to increase the 6.8% of total energy and 9% of electricity generated using renewable energy sources[1] should also be a major objective. If we can concurrently find ways to replace fossil fuel energy and electricity sources with sustainable sources, we can further reduce our level of dependence on fossil fuels. This two-tiered approach will prolong the practical exhaustion of fossil fuel resources. Taking action before fossil fuel costs become prohibitive as their resources are depleted will help us to maintain our standard of living.

Around 8.8% of total residential electricity use, and up to 30% of total commercial electricity use goes to lighting[2,3]. One sustainable way to reduce electricity consumption for lighting is to find ways to utilize sunlight. Ironically, the buildings we use to protect us from the weather also largely block this energy source, but modifications can be made to buildings that allow sunlight to illuminate interior spaces from above (daylighting). In addition to conserving energy and reducing electricity costs, daylighting has been associated

with the improved performance of elementary-school students on tests[4].

Light pipes allow sunlight to be transmitted into a building to illuminate interior spaces. A light pipe consists of a collector, a tube, and an emitter that is usually fitted with a diffuser to improve light quality [Figure 1]. Standard light pipes are coated internally with reflective material, which allows the pipes to transmit sunlight using internal reflection[5]. This allows installation in buildings with large roof-ceiling separations that are less amenable to skylights. Integration of light pipes, especially in conjunction with artificial lights and dimmers controlled by sensors, can significantly reduce the amount of energy used for lighting[6]. However, current light pipe designs do have some disadvantages. They are less effective in cloudy weather as clouds obstruct incident sunlight from the rooftop collector[5]. Additionally, light pipes can still allow some heat transfer as well as condensation, which can increase the heating or cooling load for the space[5].

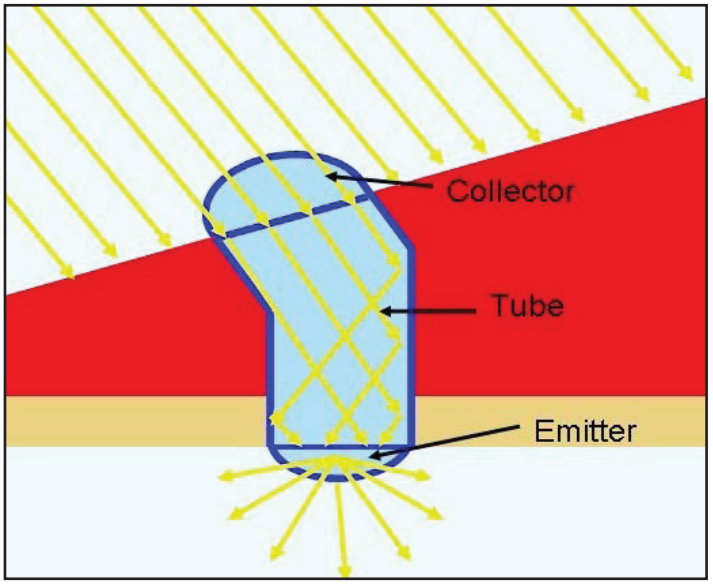

Figure 1: Light Pipe Schematic

The longer the pipe is, and the more bends that it has, the more times the light is internally reflected before reaching its intended target. Each time the light is reflected within the light pipe, the transmitted intensity decreases. One way to counter this effect is by increasing the width of the light pipe, so the light travels further down the pipe between reflections. But even with a very reflective surface, unless the sun is aligned with the axis of the light pipe to reduce the number of reflections, intensity and efficiency will be diminished. Newer, more complex light pipe designs include a "sun-tracking" feature to address this issue, allowing the collector to effectively follow the direction of incident sunlight and thus increase efficiency[5]. The drawback is that the added complexity to increase efficiency results in more expensive designs.

In order to determine the light output that can be expected from a light pipe, Jenkins and Muneer developed models both for straight pipes and for pipes with bends[7,8]. They use their straight pipe model to calculate the luminous flux inside of a light pipe for a given external illuminance. This flux also depends on the transmittances of the collector, the pipe, and the diffuser as well as the cross-sectional area and aspect ratio of the pipe, and is used to predict the internal illuminance at a given point below the diffuser. This model is the basis of an online calculator I am writing that will calculate the amount of light that will be emitted into an area by a straight light pipe. I decided not to consider pipes with bends on the rationale that they have more variables than most users would be likely to know about for their particular installation.

The online calculator will use the average daily illumination data from the National Solar Radiation Database as the initial value for the external illuminance[9]. The user will be able to select the nearest weather station in his or her state from a drop-down menu in the calculator. The user can also specify the aspect ratio of the light pipe, the vertical distance that the light will be traveling in his or her specific room application, and typical time duration for light use. Using the Jenkins and Muneer model for straight pipes as described above as well as the user's specifications, the external illuminance is used to determine a predicted internal illuminance[7]. The annual cost savings per year is then estimated by converting this internal illuminance to kilowatt-hours avoided and multiplying by an average cost per kilowatt-hour. Having a predictive tool of this nature is important so that an estimate can be made of the energy and cost savings that can be realized by installing light pipes.

As disproportionate consumers of the Earth's finite fossil fuel energy resources, Americans must conserve their remaining energy resources and begin increasing the use of sustainable sources of energy. It is in our best interest in the long term to use sustainable energy sources to power our economy. Using light pipes to supplement artificial lighting of our interior spaces is one way that we can begin to reduce our dependence on fossil fuel energy resources.

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REVIEWS

Heat: How to Stop the Planet Burning

By George Monbiot, Allen Lane, London (2006), 277 pp., hard-cover, ISBN-13: 978-0-713-99923-5

This book tackles the issue of global warming. Monbiot, author and columnist for the Manchester Guardian, teams up in this effort with Dr. Matthew Prescott, who provides research assistance. He starts with a consideration of what society will be like in the United Kingdom if the huge reductions in greenhouse gas emissions necessary to prevent catastrophic climate change can be made, reductions which will require both a massive shift from fossil fuel to renewable energy sources and the use of substantially less energy through conservation and efficiency. The magnitude of these shifts will require a huge change in the way we live and do business; it is not at all obvious at first glance that our way of life can survive. Thus the question he poses in the book: Is it possible for a modern economy such as the United Kingdom to cut its greenhouse gas emissions by 90% by 2030 and still remain a modern economy?

Because of the huge societal changes required, it is important to understand the necessity for a reduction of this magnitude. In his first chapter Monbiot sketches out the calculation. Although familiar in its general form, it bears repeating. The goal must be to keep the global average temperature from rising more than 2˚C above pre-industrial levels (1.4˚C above the current point). Two degrees Celsius is important because that is the point at which non-linear effects are expected to kick in, beyond which human intervention to prevent runaway heating will become impossible; with business as usual, we'll reach that point by 2030. Holding the temperature increase to 2˚C by 2030 means stabilizing greenhouse gases at or below the equivalent of 440 ppm of CO_2 (the level of greenhouse gases now in the atmosphere is 380 ppm equivalent). By 2030 we must reduce global anthropogenic CO_2 production to what the ecosphere can absorb, which will be 2.7 Gt/y in 2030 (it is 7 Gt/y now). If we assume a global population of 8.2 billion then, that means a CO_2 allotment of 0.33 tonnes per capita per year (Monbiot assumes "contraction and convergence"--a contraction in emissions that converges on equal per capita emissions worldwide). But the UK currently produces 2.6 tonnes per capita per year, so it must reduce its CO_2 emissions by 87% (rounded to 90%) by 2030.

The task Monbiot sets for himself is to show how to achieve this 90% reduction in greenhouse gas emissions in each sector of the economy, housing and transportation in particular, using existing technologies. Housing is considered in Chapters 3 through 7. Houses (and by extension offices and hotels) require electricity and heat. To meet the UK's demand for 400 TWh/y of electricity, he proposes that 50% come from wind and 50% from natural gas-fired power stations, with the CO_2 sequestered; he rejects nuclear energy because of the waste disposal problem and the cost of waste disposal and decommissioning. For the 2.4 exajoules/y the UK uses for home heating, he proposes to save 40% by better home insulation, to get 25% from burning renewables, mostly wood (using 20% of the UK's land area for wood energy crops), and 25% from home-installed hydrogen micro-boilers (this last seems a bit of a stretch).

Chapters 8 and 9 look at transportation. For personal transport, Monbiot cites a study showing that emissions from buses are 90% less per passenger-mile than for cars, and proposes that most car travel be replaced by bus travel; intercity bus travel could be made more palatable, he says, by mov-

ing bus stations from city centers to outlying junctions with trunk highways, to speed it up. Citing a study which shows that the fuel per passenger-mile is the same for air travel as for travel by automobile, he concludes that commercial aviation is incompatible with reducing carbon emissions; it can survive only if we reduce by 90% the number and length of the journeys we make.

Monbiot then turns to the retail and industrial sectors in Chapter 10. He cites a study which shows that retailing counts for more energy by far per square meter for both space heating and electricity than factories, offices, or warehouses–not surprising when one considers the intense lighting and the freezers without doors in supermarkets to make the merchandise more visible and more appealing to customers. His solution to achieve 90% reduction: Replace all shopping in distant stores with internet shopping and deliveries straight from the warehouse.

From the industrial sector he chooses the cement industry as a significant example, since 5 to 10 percent of the world's anthropogenic CO_2 arises from cement production. Curiously, the CO_2 from cement production arises not from combustion but from a different chemical reaction in which the cement is produced. The cement usage of individuals can be significant; about five tonnes of CO_2 are associated with the cement for each new home, about four times a single person's yearly allotment in 2030. Monbiot resorts to a new technology for his solution: geopolymeric cements. Their fabrication produces 80 to 90 percent less CO_2 than conventional cement.

Monbiot's calculations show that it is indeed possible for the UK to reduce its CO_2 emissions by 90% by 2030 and remain a modern economy. But for this to happen, people in the UK will have to make their homes much more energy efficient, forsake the private car for mass transportation, give up commercial flying, and give up shopping at energy-intensive retail outlets. Is this inevitable? The future cannot be predicted; life in 2030 will almost certainly be different in some (and perhaps most) details from that described by Monbiot. The importance of his work is to point out a possible sustainable future, and to suggest the magnitude of the changes and sacrifices we will have to make to achieve it.

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Hiroshima: The World's Bomb

By Andrew J. Rotter, (Oxford, Oxford University Press, 2008). viii + 371 pp. $29.95. ISBN 978-0-19-280437-2.

(This review is reprinted from Teachers Clearinghouse for Science and Society Education Newsletter, Fall 2008, pp 23-25. Contact jlroeder@aol.com for subscription information.)

I have continued reading works about Oppenheimer and Galileo ever since teaching a course focused on them called "A Humanistic Approach to Science" in December 1971. I was drawn to Rotter's Hiroshima when I learned that the author begins by raising a series of questions that were for me a lingering after-effect of teaching that course:

- "Was the bomb necessary to end the war?"
- "Were both bombs needed?"
- "In their absence, or with a decision not to use them, would it have taken a bloody American invasion of Japan itself to achieve surrender?"
- "Would it have been enough for the United States to have modified its demand that Japan surrender unconditionally, perhaps by signaling that the imperial system, the kokutai, could be retained?"

Rotter deals with these questions, but not within the narrow scope of World War II alone. Because of the efforts of scientists across the world to probe the possibilities of energy from nuclear reactions, whether it be as part of the Manhattan Project or as part of a program in their own country, he sees the nuclear bomb dropped at Hiroshima as a product of the entire world--and hence "the world's bomb."

Rotter does this in the context of two other broad themes, the first of which is Michael Polanyi's concept of "the republic of science," which is based on a mutual authority of scientific opinion that is "established between scientists, not above them" (p. 12). The other theme is that of weapons that are so horrible that their use is justified by being able to hasten an end to a war and thus save lives that otherwise would have been lost through conventional fighting. In this category Rotter considers first chemical weapons, then massive bombing from the air, and, lastly, nuclear weapons. Starting with chemical weapons in World War I, these weapons violated the republic of science, as Fritz Haber, Otto Hahn, and James Franck in Germany secluded themselves from the free exchange of scientific information.

It was between the two world wars that air power matured and that nuclear fission, the basis of the first nuclear weapons, was discovered. Rotter describes the evolution of both, but particularly the latter, not only in England and, later, the United States, but also in Japan and Germany. Then he comes to what he regards as his "pivotal" fifth chapter: "The United

States II: Using the Bomb." He looks at the justifications for using the bomb in the context of President Roosevelt's avowal of utter destruction of the Axis powers, a view which was continued by President Truman after Roosevelt's death. Although Secretary of War Stimson, Undersecretary of State Grew, and Navy Secretary Forrestal drafted surrender terms that would open the opportunity for "a constitutional monarchy under the present dynasty" in 1945, Secretary of State James Byrnes's fear that this would lead the Japanese to bargain for further concessions and Truman's vow to live up to Roosevelt's demand for unconditional surrender scuttled this. Other factors brought up for consideration were anti-Japanese feeling arising from the attack on Pearl Harbor, the desire to preclude the Soviets from playing a role in post-war Japan, and the desire to shorten the war and save American lives, but Rotter feels that the absence of any or all of these factors would have made no difference: "A kind of bureaucratic momentum impelled the bomb forward. . . . Truman and his advisors saw no reason not to drop [it]" (p. 170).

Rotter also considers alternatives:

- *A noncombat demonstration (recommended by the Franck report, written by the same James Franck who had worked on chemical weapons in World War I Germany)*
- *Guaranteeing the continuance of the emperor to make surrender more attractive*
- *Responding to Japanese peace-feelers*
- *Relying on Soviet intervention*
- *Continuing the blockade and conventional bombing of Japan.*

Here Rotter quotes his graduate school advisor Barton Bernstein, who felt that the last of these (alone) was the most likely to have achieved Japanese surrender by 1 November 1945, and that with only 25-30% likelihood, although a combination might have achieved it with higher probability.

Although the Soviet Union had served notice of abrogating their neutrality pact with Japan after Germany had been vanquished, the Japanese "peace faction" continued to pin their hopes for a negotiated settlement of the war on working through the Soviets, knowing that the Americans had broken the Japanese codes and were listening. However, the continued attempts, by hardliners in the Japanese cabinet, to fight on meant that the cabinet did not speak with a unified voice. One reason the Japanese could keep fighting on, at least without unconditional surrender, is the damage they knew they could inflict on Americans seeking to invade their homeland. Even after the second bomb was dropped on Nagasaki, a minority of what Rotter characterizes as the Japanese "Big Six" preferred to continue fighting or hold out for additional conditions rather than surrender unconditionally.

The primary figure on the Japanese side in bringing about the eventual surrender turned out to be the Emperor himself. Rotter also points out that, as many have not realized, Emperor Hirohito was not a figurehead. He sought to spur his people on after they had been demoralized by the firebombing of Tokyo in March 1945. But by summer, he sought a negotiated settlement that would guarantee continuance of his position. Though this would not normally be a condition of unconditional surrender, Rotter notes that it emerged as a condition for consideration after the bombs had been dropped, and it was accepted by the "Byrnes note," which placed the authority of the Emperor under the Supreme Commander of the Allied Powers.

The Cold War following the Japanese surrender ended the American monopoly on nuclear weapons and gave rise to a nuclear arms race between the U.S. and U.S.S.R. Rotter goes on to describe the arms race, noting that the Acheson-Lilienthal plan for an international Atomic Development Authority, which would have returned nuclear energy to the republic of science, never had a chance. Rotter also describes the development of nuclear weapons by Great Britain and France (who needed a new status symbol now that their colonial empires were crumbling), Israel and South Africa (who wanted their hostile neighbors to be concerned about their possible nuclear capability), China (which felt the need for its own nuclear weapons after the Korean War and subsequent crises in the Taiwan Strait), and India (which looked at nuclear weapons as a political and scientific status symbol as well as a deterrent against Pakistan, which developed nuclear weapons of its own).

Thus the nuclear bomb dropped on Hiroshima ushered in a new age of military weapons. It is encouraging to Rotter that they have not been used in warfare since World War II and that there is similar objection to using biological or chemical weapons. But, he writes, "That such weapons continue to exist, however . . . , suggests a more sobering reality" (p. 306). The greatest danger of their use is by terrorists, who perceive everyone else as waging an unjust war against them. This, coupled with the nuclear flirtations of North Korea and Iran, has led the Bulletin of Atomic Scientists to move its doomsday clock from 11:53 to 11:55 p.m.

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