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PHYSICS & SOCIETY

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Editor's Comments

To open this edition, if you turn to the next page you will see that Assistant Editor Jonathan Wurtele and myself will be stepping down from our positions with *P&S* following publication of the April 2013 edition. Jonathan is involved in a number of research projects, and I am looking forward to a sabbatical during which I will be consumed with a lengthy book project; we feel that it is only appropriate to turn over our keyboards to successors. Barbara Levi is ably chairing a committee to search for successors, and we encourage nominations and expressions of interest. Speaking for myself, taking on the editorship of *P&S* has proven to be one of the best things I ever decided to do: it has given me the opportunity to learn a lot of interesting physics, and it has brought me into contact with a number of fascinating people in our community. If you enjoy reading and writing about a broad range of physics topics, please consider this opportunity – you would not regret it. You will have the help of a very capable editorial board and reviews editor, and a superbly professional production staff at APS headquarters. The Forum Executive Committee is committed, as funding permits, to covering to a reasonable degree the cost of attendance at one APS meeting per year for each of the Assistant Editor and Editor. These will normally be for the March and April meetings, respectively.

We extend congratulations to the winners of elections to positions on the FPS Executive Committee: Micah Lowenthal has been elected Vice-Chair; Lowell Brown has been elected Councilor; both Lawrence Krauss and Douglas Wright have been elected as Members-At-Large (replacing Jessica Clark and David Harris), and Phil Taylor has been elected as the Forum's representative to the APS Panel on Public Affairs (POPA). Thanks are extended to all candidates, and also to the Nominating Committee for their good work in developing a strong slate of candidates.

In this edition we report on the many very interesting invited papers given at FPS-hosted sessions at the March and April APS meetings. The Program Committee put together truly excellent and informative sessions; the Forum remains vibrant and relevant.

Wally Manheimer's article in the April edition on energy supply stimulated feedback from Arthur Smith and Philip Taylor; their comments and Manheimer's reply appear in our Commentary section. Our feature articles for this edition have their origins in issues that we have previously reported on. In our April 2010 edition we ran an AIP FYI announcing that Secretary of Energy Steven Chu had appointed a Blue

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Ribbon Commission to provide advice on dealing with nuclear waste. A follow-up FYI in October 2011 examined the Commission's draft report. The Commission has now completed its final report, which Susanne and Robert Vandenbosch expertly summarize.

In the Reviews section of our April 2012 edition, Paul Craig described papers given at a conference on sustainable energy held at Berkeley in March, 2011. We are pleased to be able to publish an abbreviated version of Christopher Yang and Sonia Yeh's paper, which examines the future of low-carbon transportation fuels. We hope to run more of the conference papers in future editions.

Our book reviews for this edition deal with two very disparate topics. Frank Lock reviews Maggie Jackson's book *Distracted*, which examines the seemingly epidemic erosion of attention and growth of inefficient multi-tasking in our society. William Ingham reviews James Powell's *The Inquisition of Climate Science*, which looks at the battles between climate scientists and their detractors.

President Obama Extends Congratulations to the Forum on its Fortieth Anniversary

At the Forum's Executive Committee meeting in Atlanta, outgoing chair Peter Zimmerman read a letter from President Barack Obama congratulating the Forum on its 40th anniversary. The President praised the Forum for its work in promoting societal awareness of physical-science issues, and wished the Forum well in its future endeavors. White House protocols do not permit us to print the text of the letter, but your Editor was present for the reading and can attest that the President's letter is a tremendous recognition that all Forum members can rightfully take great pride in.

Seeking New Editors for *Physics & Society*

Our capable *Physics & Society* editor, Cameron Reed, and his dedicated assistant editor, Jonathan Wurtele, plan to step down next spring from the positions they have so ably filled since early 2009. We are currently seeking a new editor and assistant to replace them.

The editor, with help from his or her assistant and from the editorial advisory board, is responsible for preparing the content for the four quarterly issues of *P&S*. Some articles are spontaneously submitted; others are solicited by the editor, with input from the editorial advisory board. The editor edits the articles and prepares an introduction to each issue. The edited newsletter is then submitted electronically to the APS offices for distribution to the FPS membership.

The assistant editor, in addition to helping the editor with articles, prepares content such as news of FPS election results or FPS sessions at APS meetings. Editors serve for a term of 3 years, renewable by a vote of the FPS Executive Committee.

The editor is an ex officio member of the FPS Executive Committee and is provided the funds to travel to that committee's annual meeting at the APS Spring Meeting. The position affords the opportunity to explore at greater depths various topics at the interface of physics and society and to contribute to the education of and communication among our fellow physicists. The new editor will be encouraged to innovate, especially in the online format of the publication.

Those interested in applying or in suggesting candidates should submit (1) a resume and (2) a brief letter stating why the position is of interest and highlighting any writing or editing experiences. Please also provide one or two names of references the committee might contact. Email the material to Barbara Levi, the chair of the *P&S* Editorial Search Committee (bglevi@msn.com). Submission deadline is September 15.

FORUM NEWS

FPS-Hosted Sessions at APS March Meeting

Brian Schwartz

[The annual March meeting of the APS was held at the Boston Convention center From February 27-March 2, 2012. In conjunction with the Forum on Education, FPS sponsored a session on "Novel and Proven Methods of Communicating Science to the Public" on Tuesday, February 28, organized by Brian Schwartz of Brooklyn College and the Graduate Center of CUNY. The following paragraphs summarize the papers presented during this session. The complete scientific program of the March meeting can be found at meetings.aps.org/Meeting/MAR12/Content/2295 *– Ed.]*

Creating Catalytic Collaborations between Theater Artists, Scientists, and Research Institutions. In the first talk in this session, Debra Wise, Artistic Director of the Underground Railway Theater (URT; Cambridge, MA: www.centralsquaretheater.org/about_ccmit.html) described the establishment of collaborative programs between MIT and URT, known as the Catalyst Collaborative@MIT. The collaboration is dedicated to creating and presenting plays that deepen the understanding of science while taking advantage of the artistic and emotional experience provided by theatrical presentations. Through performances and conversations with scientists and artists, the collaborative engages the audience about themes in science as related to science and technology in our culture and its impact on our lives.

Using Cartoons to Communicate Science. In this talk, Todd Rosenberg, who founded the eponymous Odd Todd Studios (www.oddtoddstudios.com) described the science animations he has created for ABC World News, National Public Radio (www.npr.org) and Time.com. He described his technique of working with scientists and journalists to inform the public about science using animation with humor and scientific accuracy. The two science animations he presented included *Can Ants Count?* www.oddtoddstudios.com/npr/ants-that-count.html and *It's All About Carbon*, a five part series on the role of carbon in global warning that he created for NPR with Robert Krulwich as the moderator www.oddtoddstudios.com/npr/episode-one-its-all-about-carbon.html

Drawing at the Speed of Talk: doodling complex discussions in real-time to create animated "Conversation Portraits." The third talk in this session was given by Flash Rosenberg, a freelance photographer and founder of Flash Rosenberg Studio (vimeo.com/flashrosenberg). Rosenberg is also artist-in-residence for LIVE from the New York Public Library, which describes itself as "cognitive theater with a mission to provoke, engage, enlighten, instigate, and agitate the mind" (www.nypl.org/events/live-nypl/about). Rosenberg draws discussions in front of live audiences to create real time "Conversation Portraits," five-to-eight minute animations which translate complex ideas into simple lines. She squeezes an hour seminar into a five to eight-minute animation. She illustrated an example of her technique by showing her animation of a talk at the Graduate Center of CUNY by Richard Panek, the author of the book The Four Percent Universe: Dark Matter, Dark Energy, and the Race to Discover the Rest of Reality. A number of videos are available on her website.

The New Wave of Science Festivals and their Establishment. In the fourth talk in this session, John Durant, Director of MIT Museum and the Cambridge Science Festival (www.sciencefestivals.org) described the newly established Science Festival Alliance. The alliance was created between the San Diego Science Festival and the Cambridge Science Festival. In 2009 the National Science Foundation provided funding for a network and collaboration that would generate the establishment of new festivals and exchanges between festival organizers. The NSF-supported Alliance offers funds for the direct support for the organization of regional science festivals, connects festival organizers and festival partners for the exchange of best practices, organizes national meetings dedicated to the advancement of science festivals, evaluates science festivals, and disseminates the results in order to provide resources for individuals who wish to become connected with and initiate festivals.

Celebrating 24 years of Public Outreach of Science and Engineering in Portland Oregon. The last talk in this session featured Terry Bristol, President, Institute for Science, Engineering and Public Policy, a Portland, Oregon based public non-profit corporation dedicated to the development of local understanding of issues concerning science, technology and society (www.isepp.org). Bristol described ISEPPs highly successful 24-year outreach program in Portland. The major effort described was the Public Speakers Series, which explores and presents the latest discoveries in our understanding of the universe. The objective of the Series is to establish informed public dialogues and policy networks to improve the public understanding of science and technology.

It was heartening to see such a broad-based combination of educational institutions, foundations, theatrical groups and independent artists working to contribute to science literacy in a multitude of formats which physicists would consider non-traditional. More such efforts should be encouraged and supported by the professional scientific community.

FPS-Hosted Sessions at APS April Meeting

Cameron Reed

The annual April meeting of the APS was held at the Hyatt Regency Atlanta Hotel in Atlanta, GA, from March 31 – April 3, 2012. FPS-hosted sessions dealt with Forum Award recipients, the fortieth anniversary of the Forum, developments in radiation detection and nuclear security, a panel discussion on American science and America's future, and post-Fukushima nuclear energy, safety & security. The following paragraphs summarize many of the papers presented during these sessions. The complete scientific program of the meeting can be found at meetings.aps.org/Meeting/APR12/Content/2312

Session B6: *FPS Awards Session.* This session was chaired by outgoing Forum Chair Pete Zimmerman, and featured two talks. Zimmerman opened the session by reading aloud a letter received from President Barack Obama congratulating the Forum on its fortieth anniversary and praising its work in bringing science-and-society issues to the attention of the physics community.

The first speaker was Forum Burton Award recipient Arian Pregenzer, whose talk was titled "Managing Nuclear Proliferation Risks: Building a Resilient System." Pregenzer opened by reminding the audience of the goals of the Nuclear Non-Proliferation Treaty, which has been very successful in slowing nuclear proliferation. She then addressed how in addition to proliferation-prevention strategies, a successful non-proliferation system also requires strategies for achieving system resilience in order to be able to maintain its vital functions in the face of continuous unpredictable changes. A number of prevention strategies are in place, including security alliances, export controls, IAEA monitoring protocols, dismantling missiles and submarines, fissile-materials protection systems, security upgrades at weapons sites, and a Proliferation Security Initiative which has the goal of halting trafficking in WMD-related materials and technologies. Strategies for increasing resilience include developing increased international response capabilities, focusing on non-coercive means of decreasing demand for nuclear weapons by addressing root causes of political tensions, and applying an overall "systems" approach to structuring the non-proliferation system.

The second speaker was Szilard Award winner Siegfried Hecker, who spoke on "North Korea, Reactors, Bombs, and People (and Missiles)." Hecker has made seven visits to North Korea and opened by reviewing how that country has come to acquire nuclear weapons. Acquisition began in the 1950's and 60's with participation in a Soviet "atoms for peace" program similar to the one advanced by the United States. The second phase, from the 1970's to 1992 (the time of the collapse of the Soviet Union) was what Hecker described as "going solo," with work carried out under the cover of civilian power development. After the collapse of the Soviet Union, North Korea entered into an "Agreed Framework" in which it would give up bomb development in exchange for light-water reactors. This agreement collapsed in 2002, following which bomb development was resumed; tests were conducted in 2006 and 2009. Thus, the North Korean program has been 50 years in the making. The North Koreans have shut down a plutonium-producing gas-graphite reactor and are now developing their own light-water reactor and associated enrichment facilities. [See the article by Hecker in the April, 2011 edition of *P&S* – Ed.] Hecker stated that the planned reactor could probably produce 10-15 kg of plutonium per year, but he is much more concerned with the safety of the facility as the North Koreans are isolated from the reactor-operation experience of the international community. Hecker considers the threat of a North Korean attack to be low, but their ability to produce highly-enriched uranium could lead to export concerns and might open the possibility of development of a miniaturized warhead that could be missile-mounted. To close his talk Hecker showed some photos of average North Koreans going about their daily lives – a reminder that they are ordinary people just like everybody else.

Session D5: *The Forum at Forty.* This session was chaired by incoming Forum Chair Pushpa Bhat (Fermilab) and featured four speakers. (Martin Perl, one of the "founding fathers" of the Forum, was also scheduled to speak but unfortunately could not attend due to illness.)

The first speaker was Brian Schwartz, who has been involved with the Forum since the 1970's. Based on information gleaned from personal files, Schwartz described how the Forum came to be established. To that time APS meetings had dealt only with pure physics issues, but concerns with the job market for new PhD's, social upheavals, and relations between the scientific community and defense industries led a number of members to try to found a "Committee on Problems of Physics and Society." Following the procedure laid out in the APS by-laws, Schwartz and Emanuel Maxwell gathered the necessary 1% of member signatures necessary to petition for creation of a new Society unit to be named the "Division of Physics and Society." A committee determined that the term "Forum" would more appropriately capture the sense of the broad nature of such a group. Thus were Fora established as a new class of APS units.

The second speaker was David Hafemeister, who has been involved with the Forum since its founding meeting in 1972. Hafemeister reviewed the activities of the Forum: over 300 meeting sessions, two conferences on employment in physics, several short courses, studies on civil defense, land-based missiles, and energy; establishment of the Burton and Szilard Awards, and regular publication of the Forum newsletter. Hafemeister noted that three individuals who were closely involved in the Forum went on to serve terms in Congress.

The third speaker was Peter Zimmerman, who encouraged members to reflect on where they would like the Forum to be at age 45: What sort of course offerings, invited and contributed sessions and studies do members wish to see undertaken?

The final speaker was Andrew Zwicker, who became involved in the Forum in the 2000's. Zwicker reviewed how the Forum was particularly innovative in the first decade of the new millennium in adapting early-on to conducting elections electronically and moving the Newsletter to purely electronic publication, a transformation which resulted in significant cost savings. In this same spirit, Zwicker opined that it is important for the Forum to engage in blogs and social media to secure greater outreach to younger physicists.

Following the individual presentations the floor was opened to questions and comments, with Pushpa Bhat serving as moderator. Discussions involved issues such as the fact that scientists cannot avoid politics and that they indeed have responsibility to get involved in a world where most people are not scientists, how one should deal with controversial (or just plain nutty) speakers, the difficulty of getting objective scientific facts on controversial issues (evolution, climate change) before the public in the face of well-funded opposition, how to encourage a culture based on reason, and promoting development of "Physics and Society" classes at colleges and universities.

The panel generated some media coverage, which can be found at: www.huffingtonpost.com/2012/04/06/science-america-crisis-physics-society_n_1408244.html, and www.aps.org/publications/apsnews/201206/panel.cfm

Session Q5: ***New Developments in Radiation Detection Technologies & Nuclear Security*** This session was chaired by Douglas Wright and featured three speakers.

The first speaker was Warren Stern, Director of the Domestic Nuclear Detection Office (DNDO), an agency of the Department of Homeland Security. Stern spoke on "A Revolution in Homeland Security Affairs." He opened by reviewing the DNDO's mission, which is to develop global nuclear detection architecture, threat detection capabilities, nuclear forensic capabilities, and to coordinate such activities with overseas counterparts. The fundamental difficulty in detecting illicit nuclear materials is that they can be shielded and their radiation is also difficult to distinguish from background counts; the background radiation can be quite variable in urban areas. Uranium-235 is hard to detect because it is a relatively modest alpha emitter; Plutonium-239 is easer to detect because of the inevitable presence of neutron-emitting Pu-240. The only practical detection options are to deploy bigger detectors, bring them closer to sources, and better characterize background counts by working with nets of distributed sensors. Stern summarized some of the detection capabilities now in place in place around the United States: over 1400 fixed-portal monitors, mobile portals, and some 20,000 handheld radiation detectors. In the New York City area alone over 5,800 pieces of detection equipment have been deployed and 11,000 personnel trained in their use; over 100 drills have been conducted. The future should see deployment of stand-off systems, roadside trackers with video capabilities, truck and trailer-mounted systems, and "active interrogation" systems where external radiation sources are used to induce detectable reactions (for example, fissions) in hidden materials. This, however, is difficult because the interrogating sources must be intense and detecting the induced reactions is an "inverse r^4" problem.

The second speaker was Michael Kuliasha, Director of the Nuclear Technologies Directorship of the Defense Threat Reduction Agency. Kuliasha's talk was titled "Nuclear Threat Intelligence, Surveillance, and Reconnaissance." Kuliasha described how the DTRA's Global Nuclear Detection Architecture is configured to fuse data from a variety of detection techniques to assess radiological threats; these include X-ray imaging, optical and infra-red imaging to detect actively-cooled material, weighing of vehicles (to detect shielding), acoustic and radiochemical analyses, active interrogation (as in Stern's talk above), and human and signals intelligence. The overall goal is to shift from primary reliance on radiation detection to the use of many mutually-supporting detection approaches.

The final speaker was Michael Larson, who is retired from Lawrence Livermore National laboratory. Larson's message was "Don't Mess With the NEST." NEST is an acronym for Nuclear Emergency Support Team, which was formed in 1975 in response to various nuclear extortion threats. The mission of NEST, which maintains 24/7 deployable response teams around the United States, is to conduct, direct, and coordinate search and recovery operations in response to nuclear threats. Since 1970, some 350 threats have been received; this large number led to the establishment of a Credibility Coordination Center, which assesses threats from the viewpoints of behavioral resolve, technical feasibility, and operational practicality. Exercises and drills are regularly carried out; one significant real-life deployment followed the crash of the Soviet Cosmos 954 satellite in northern Canada in 1978. Current work involves research into disposition of devices and nuclear forensics. In response to a question regarding whether any credible threat had ever been received, Larson related that there was one incident where use of a radiological dispersion device involving stolen material was threatened. The material was recovered and the perpetrator apprehended.

Session T4: ***American Science & America's Future.*** This panel discussion was chaired by Pushpa Bhat and featured four speakers: Frank Wilczek (MIT; 2004 Nobel Laureate), Neal Lane (Rice University, Former Presidential Science Advisor), Tim Hallman (Associate Director, DOE Nuclear Physics Division), and Jim Siegrist (Associate Director, High Energy Physics Division, DOE).

Participants in the American Science and America's Future Panel Discussion. Left to right: Frank Wilczek, Neal Lane, Tim Hallman, Jim Siegrist, and moderator Pushpa Bhat. Photo courtesy Michael Riordan, APS.

Bhat opened the session with a brief description of how so much of twentieth-century American prosperity was a result of scientific and technical innovation, but that this climate of innovation is now threatened by funding crises, lack of STEM graduates, and outsourcing of research and development. The central question she posed to the panelists was: "How can we strengthen and enhance the science and technology enterprise in the United States for the twenty-first century?" Each panelist then offered some individual remarks.

Lane framed his remarks by asking what is the way forward in the disorder of today's world? He pointed out that the post World-War II Government-University funding model has now evolved into a Government-University-Industry system. While current priorities are directed toward biomedical research as opposed to the physical sciences, Lane remarked that the "age of medicine" funding priority may be coming to an end in that NIH funding has now been flat for eight years. A serious issue is that the United States has no formal energy or technology/innovation policies, a situation aggravated by the fact that Congress has no mechanisms (committees, staff) through which to focus on research and development issues. Lane believes that what is needed is for policy makers to be more willing to enter into multi-year commitments, as well as more evidence-based policy development and public engagement by scientists. He also advocated the development of a non-partisan voice for science that might take the form of an independent organization supported by government, universities, and industries which would be charged to collect data, carry out analyses, develop rational policy options, and inform the public of its conclusions.

The second speaker, Tim Hallman, echoed much of what Lane had said, particularly emphasizing the need to better target research and development and be more effective in communicating the value of science to the public. Siegrist seconded Hallman's comments, remarking that effective communication is particularly important in the particle physics community.

Wilczek focused his comments around the theme of "What we have to Offer – Thoughts on Science and Society," arguing that the scientific community is losing opportunities to speak to the economic, political, cultural and moral value of science. In the economic area, market incentives do not reflect opportunities in that science does not produce a "product" as such but rather non-proprietary "public knowledge." Politically, science can serve as an "honest broker" to inform decisions in contentious areas such as climate and biotechnology policies. In the cultural and moral arenas, physics is a powerful, true body of knowledge established through honest and transparent processes.

The session was then opened to comments and questions. Some of the comments raised involved issues of how to best identify pressing problems and assure success in dealing with them, how to remind the public that science makes the nation wealthy, how to encourage Congress to engage in international collaborations in a more welcoming and adaptive way, how scientists can become politically effective (go to DC and experience work in a government agency), how to keep young people interested in science, and how scientists need to understand the concerns of the public. Comments also dealt with the role of industry in supporting basic research, pressures on granting agencies to support directly-applicable work, and the conservativeness of grant-review processes.

LETTERS

Dear Editors,

Wallace M. Manheimer's article [1] on energy choices in the April 2012 issue makes a number of important points, but also goes wrong on many fronts, and I hope *Physics & Society* will allow at least some correction of these misstatements.

To start at the end, Manheimer asserts that "one cannot talk about climate and ignore energy supply. Yet, these organizations [AIP and APS] have done just that." One need only read the same issue of Physics and Society to know that claim is false - the book review by Paul P. Craig [2] mentions "the first APS energy study [...] in 1973", which has been followed by many others. Manheimer himself cites the recent APS "Energy Efficiency Report" - and then appears to dismiss it as parochial. This is ironic since he earlier claims that cutting US energy use would be "worse because distances are much greater in the United States, it is colder here, and we have responsibilities as a major world power" Manheimer's argument pertains to Italy, but in general technology developments allowing efficiency gains in the US apply equally well or better elsewhere.

An examination of the numbers in Manheimer's first concluding paragraph shows one deep inconsistency that permeates his piece. He asserts we need 30 TW of "energy" supply by 2050. He suggests meeting most of this with 20 TWth of nuclear power - but notice the little 'th' appended, meaning "thermal", not "electric" energy. Energy quality matters, and lumping different types together in this way is quite misleading. The actual electric supply from 20 TWth nuclear reactor capacity would be about 7 or at most 8 TW of actual useful energy. He then refers to the "3-4 TW" from renewables as a "small amount," but that would be entirely in the useful electric form, i.e. even in his budget by 2050, renewables supply half as much electric energy as from nuclear power.

The 30 TW by 2050 is a "thermal," not "electric" number. About 40% of thermal power used now [worldwide – see ref. 3] goes to steam turbine generators that run at about 30% efficiency in converting to electricity; another 20% is in transportation where conversion of thermal to mechanical power is similarly low relative to electric-powered transportation. A good fraction of the rest goes to space heating which has very low energy quality requirements: a given quantity of room-temperature heat can be obtained through a heat pump running against outside or underground temperatures on 1/3, 1/5 or even less electric energy (ref. 4). Only a small fraction (perhaps 20%) of the world's "thermal" energy consumption actually goes to high-temperature industrial process heating that makes efficient use of close to the full energy content of the consumed fuels. So the 30 TW of thermal energy Manheimer worries about translates to perhaps 6 TW of high-quality thermal energy and 24 TW of low-quality thermal energy, which can be met equally well with about 8 TW of electric energy. The real requirement for energy supply by 2050 is 14 or 15 TW of high quality (say electric) power, not 30.

Manheimer's analysis of solar and wind power is not in substantive numerical error, although modern PV panels are usually close to 20% efficient (not 10%), and solar will most likely be deployed where incoming sunlight is well above the global average. However, he leaves a lot out. He makes no mention of the dramatic fall in costs for those technologies, particularly solar photovoltaic systems, nor their dramatic growth rates of 40% or 50% or more per year in recent years [5]. Solar photovoltaic production is almost 3 orders of magnitude higher than it was 20 years ago. Manheimer notes that 1 TW of solar would take roughly 25,000 km^2, but says little about how realistic or unrealistic such a level of installation would be. 2011 installations amounted to about 25 GW (peak) or about 5 GW average power. So, 1 TW is 200 years production with no further growth and does still seem distant. Another 20 years of photovoltaics growth like the last, however, and by 2032 we would have not just 1 TW average power from photovoltaics, but close to the full 15 TW the world needs. The area used, 15 times 25,000 km^2 or 375,000 km^2 (to use Manheimer's estimate), amounts to just 0.25% of Earth's land area. Also, there is no fundamental reason these have to be placed entirely over land. Neither historical production growth rates nor Earth's surface area are limitations on powering the world's 2050 energy needs entirely from the Sun, if that's what we choose to do.

The other key question then is one of economics, but Manheimer's analysis of that is purely based on subsidy levels, and even there is mostly speculative. Capital-intensive energy sources like solar power have fundamental economic characteristics very different from those of fossil-fuel systems. Nuclear power is somewhere in between. Other than interest costs (which can be highly variable but at present for the US government are close to zero), the annualized cost of a solar facility costing $10,000 per average kW (roughly where present-day solar stands) is almost entirely that up-front capital divided by the likely plant lifetime. If the solar plant can be expected to run for 25 years, that comes to $400/kW-yr or about 5 cents/kW-hr. If a 60-year lifetime could be realized, amortized solar plant costs would be less than 2 cents/kW-hr. Interest costs, maintenance and transmission and distribution (and utility profits) would add another few cents/kW-hr, but even now the base cost is not at a point that it would break anybody's electric bill. There is one complication of large-scale solar or wind adoption, also not mentioned in Manheimer's article. Due to the variability of renewable sources, some mechanism for large-scale energy storage needs to be simultaneously integrated to the grid, and grid capacity itself needs to be enhanced to allow power to flow under these more variable conditions. The experience in Germany, which has recently seen over 50% of electric power coming from solar [6] shows this is not an impossible barrier, but it does mean a small additional cost associated with renewable sources.

The more important economic point is that solar's $10,000/kW-avg is continuing to drop quickly. The "learning curve" for solar photovoltaics has been consistently over 20% (about 22%) per doubling over more than 10 doublings [7, 8]. That is, costs per kW for an annual production level of 50 GW-peak or 10 GW-avg (double the present year's) should be $8,000/kW-avg or less. At 1 TW-avg, with the same historical learning curve, costs would be below $2,000/kW-avg, less than one fifth what they are today. The importance of subsidies is in allowing the industry to scale more quickly to the higher production levels and lower cost that make it truly competitive without long-run subsidy. The Solyndra case is one worth examining in detail: the reason the company received a subsidy is that its costs looked good several years ago, but solar PV prices dropped so fast it became uncompetitive. This price drop is a good thing, but nowhere to be found in Manheimer's article.

The fact is that fossil fuel plants themselves have capital costs in the range of one to several thousand dollars per average kW. Recent experience with constructing nuclear plants has seen costs several times as high - as much or more than the cost of solar photovoltaics. Both fossil and nuclear facilities also have much higher annual continuing costs than solar, from fuel and operations.

Manheimer hardly discusses economics in his article, other than to claim that a switch to renewables "[will] almost certainly condemn the vast majority of the human family to abject poverty". That sounds rather "alarmist" - while he repeatedly accuses the APS and climate scientists of "alarmism." Manheimer states that "standard 'renewable' energies, solar and sequestration, are nowhere near ready to provide for societal energy needs, and likely never will be" but the reality of the situation is quite otherwise if we give any weight to historical patterns of development in the solar industry (wind has been similar though slower to improve).

Manheimer is absolutely right that global society will need substantially more energy than it uses today. Solar and other renewable technologies are perfectly capable of delivering on that need, with prices lower than fossil fuels and nuclear power well before mid-century. Market forces will take over from that point, but the timing and populations that benefit from the transition will be dependent on the action of entities able to provide the hundreds of billions of dollars needed. Climate change is only one of the compelling reasons we should be pushing the United States and other governments into earlier and faster action on the energy technologies of the 21st century.

1. *Wallace M. Manheimer, "American Physics, Climate Change, and Energy," Physics & Society, vol. 41(2), p. 14, (April 2012).*
2. *Paul P. Craig, review of "Physics of Sustainable Energy II: Using Energy Efficiently and Producing it Renewably," Physics & Society vol. 41(2), p. 24 (April 2012).*
3. *US Department of Energy International Energy Outlook 2011 www.eia.gov/forecasts/ieo/*
4. *US Department of Energy, "Geothermal Heat Pumps": www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12640*
5. *See for example the following recent news reports on solar industry growth: cleantechnica.com/2012/03/19/worldwide-solar-pv-market-grew-in-2011/ or www.sciencedaily.com/releases/2011/09/110905085957.htm*
6. *"Solar power generation world record set in Germany", The Guardian, 28 May 2012 - www.guardian.co.uk/environment/2012/may/28/solar-power-world-record-germany*
7. *Alvin Compaan, "Photovoltaics: Clean Electricity for the 21st Century", APS News (April 2005) - www.aps.org/publications/apsnews/200504/forefronts.cfm*
8. *Kees van der Leun, "Solar PV rapidly becoming the cheapest option to generate electricity," Grist magazine (11 Oct 2011): grist.org/solar-power/2011-10-11-solar-pv-rapidly-becoming-cheapest-option-generate-electricity/*

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Dear Editors,

The article "American Physics, Climate Change, and Energy" by Wallace M. Manheimer (*Physics & Society*, April 2012, p. 14) was truly inspirational. In fact, it inspired me to announce a remarkable scientific discovery, namely that the use of underarm deodorant is essential if we are to increase our national GDP, and, in Manheimer's words, to "have more educated populations who live more pleasant, longer lives." Figure 1 shows a modified version of Manheimer's Figure 2, which displays the correlation between per capita gross domestic product and per capita energy consumption. Manheimer uses this correlation to argue that a great increase in world energy use is essential for human wellbeing. My modification of the figure consists of the addition of some selected points representing my estimation of the per capita use of underarm deodorant.

From this figure it becomes obvious (if we follow Manheimer's logic) that the US government should immediately establish a new sister department to the Department of Energy, namely a Department of Underarm Personal Hygiene. It should clearly have a level of funding equivalent to that of the DOE, which is currently about 30 G$ per year. This is about $100 per capita, which should be sufficient to maintain odor-free underarms for the entire population, and lead us into a new era of prosperity.

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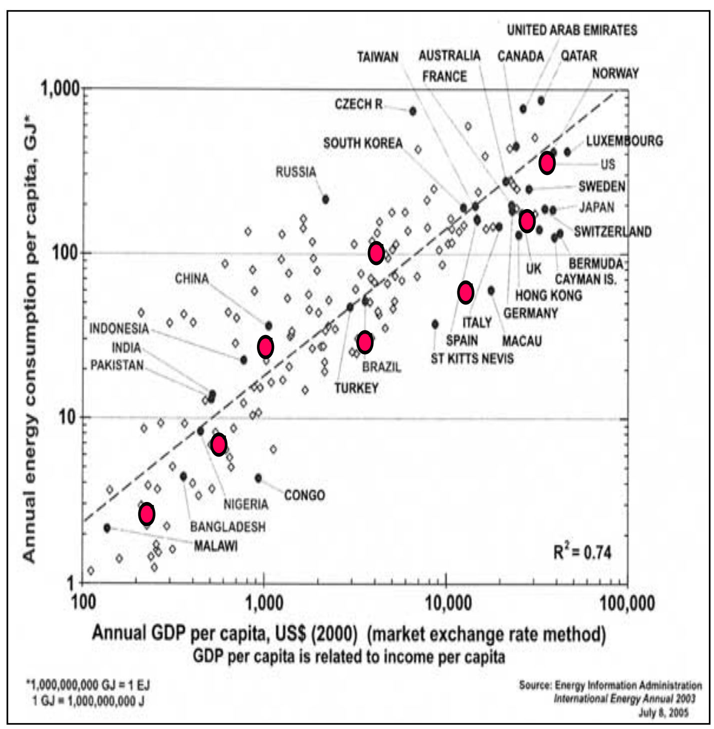

Figure 1: Annual energy consumption versus annual GDP per capita. Superimposed red circles are sample hypothetical points representing the scaled per capita use of underarm deodorants. Actual data available from the report "Men's Grooming Products: A Global Analysis" (Product Launch Analytics, November 2009).

Manheimer responds:

I would like to thank Arthur Smith for his interest in my article. As is apparent from the first sentence of his last paragraph, it is likely that on the major issue, we agree on more than we disagree on. The importance of energy for civilization is an issue of supreme importance, and one which the AIP ignored in both articles in the October 2011 issue of *Physics Today*. Smith sees solar as the ultimate solution, I see nuclear. I would say the empirical evidence up to now favors me.

France has shown that even a poorer country than the United States can get a major part of its energy from nuclear power in an economical and environmentally sound manner. Solar can make no such claim at this point. Solyndra, and many other 'Green' companies did, after all go bankrupt, even with their large government subsidies. The Japanese are now subsiding solar Voltaic power at 60 cents per kwhr, as my article pointed out. If this subsidy is a true reflection of the cost, there is no way it will be economical.

As I said in my article, nuclear has to be scaled up by about an order of magnitude to meet mid-century requirements, while solar has to be scaled up by about three. Nuclear power is expensive, but a significant part of its cost is from Green delaying tactics and lawsuits, and NIMBY (Not In My Back Yard) and BANANA (Build Absolutely Nothing Anywhere Near Anything) attitudes. Surely the same thing will happen to solar Voltaic as it gobbles up more and more scarce land, land for which other users have other plans. Wind power is also experiencing some pushback from the public. Off the coast of Maine, for example, the island of Vinalhaven voted nearly unanimously to install three 1.8 MW (Nameplate) wind turbines; but this once close knit community has since been torn asunder by bitter disputes and lawsuits related to the turbine noise.

A few other comments on Dr. Smith's points, very briefly in bullet form:

- Smith pointed out that I mentioned 30 TW of "energy" (instead of power), but he repeatedly made the same error. We should both have been more careful.
- I certainly did NOT dismiss the recent APS study on efficiency and conservation as parochial, but pointed out its tremendous importance. I cited it and nuclear power as the "two tall poles" which could support mid-century civilization. I did say that its recommendations were in line with other studies of the importance of decrease of energy intensity.
- Where appropriate, my article clearly spelled out the difference between electrical and thermal power. My figure of 30 TW of total power (i.e. coal, gasoline, nuclear, wind...) is in line with other studies which I referenced and which have often been cited. These papers (and mine) did not distinguish between this type of power and that. This is certainly the simplest way to count up power. However, Smith does make a valid point.

  Smith realizes that the sun does not shine on solar Voltaic systems at night (or in the rain), and points out that "Due to the variability of renewable sources, some mechanism for large-scale energy storage needs to be simultaneously integrated to the grid,... ." To my mind, this need for enormous energy storage is not some minor detail, but is more likely a show stopper. As I pointed out in my article, this is an important advantage of solar thermal over solar Voltaic.
- My estimate of 3-4 TW or total power for renewables included what I considered the major players, hydropower and biofuel from waste products. These already generate significant power. I doubt that solar and wind will give even 1 TW by mid century. Time will tell.
- Perhaps my alarmism over pulling the plug on civilization, in the next decade or two, as the AIP and APS seem to advocate, is more reasonable than their alarmism over man-made climate change, which if it occurs at all, will occur over a century or two. It is unlikely that civilization can adapt to the former, but it is likely that it can adapt to the latter.

I do not wish to comment on the comment written by Phillip Taylor.

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These contributions have not been peer-refereed. They represent solely the view(s) of the author(s) and not necessarily the view of APS.

ARTICLES

The Future of Low-Carbon Transportation Fuels

Christopher Yang and Sonia Yeh

[Editor's note: This article is an abridged version of a paper presented at a conference on the physics of sustainable energy held at UC-Berkeley in March 2011. A review of the conference proceedings was published in the April 2012 edition of P&S.]

Introduction

According to the Energy Information Administration's Annual Energy Outlook projection, petroleum fuel uses make up essentially all transportation fuel usage today and will continue to account for 95% of transportation fuel usage in 2035 if we continue on our current path [1]. Biofuels are projected to make up the largest increase in the use of alternative fuels, to about 4% of fuel usage in 2035. As is well-known, fossil fuel use has many economic and environmental impacts, including reliance on imported energy sources that weakens our energy security, air pollution, and greenhouse gas (GHG) emissions that contribute to climate changes.

In this article we qualitatively examine the possibilities for low-carbon transportation fuels. Specifically we consider biofuels, electricity and hydrogen as displacers of petroleum-based fuels. The discussion here focuses on fuels, though fuels such as electricity and hydrogen are intimately tied to the vehicle platform and their success will be influenced by the success of the other. We will emphasize fuels for light-duty vehicles (passenger cars and trucks), which make up around 55% of energy use in the transportation sector. We will discuss the transition challenges to alternative fuels, particularly the infrastructure challenges, and the issues of making a transition to sustainable transportation over the long run.

Biofuels as Transportation Fuel

While biofuels can comprise a range of forms including liquids, solids and gases, we will focus only on high energy-density liquid fuels to be used as substitutes for petroleum-based fuels. As shown in Table 1, biofuels can be produced from a wide array of potential feedstocks and technology. Thus, biofuels can have potentially very different fuel properties, energy use, emissions, and environmental effects throughout their production lifecycle.

Biomass feedstocks for liquid fuel production can be categorized into four types: lignocellulosic biomass, sugars/starches, oils and animal fats, and algae. These feedstocks can come from a variety of sources including grain-based crops (such as corn or soy), oilseeds and plants (such as oil palm and sugarcane), agricultural residues, energy crops, forestry resources, industrial and other wastes, and algae. The technology for the conversion of these feedstocks to a liquid fuel can also take several different forms, including biological, chemical and thermochemical processing (Table 1). First generation biofuels, those that are commercially available today, include sugar- and starch-based ethanol (a gasoline substitute) and vegetable oils and biodiesel, which are diesel substitutes. Advanced biofuels are derived from processes currently in development and include alcohol fuels from cellulose, algal-based fuels, and thermochemical conversion of biomass to hydrocarbon that can be converted to a full range of fuels including gasoline, diesel fuel and jet fuel that meet the same specifications as today's petroleum fuels.

Conversion of biomass into a biofuel can take many forms. Commercially available conversion processes used for first generation biofuels include biological fermentation (via yeast) of sugars into ethanol, and chemically catalyzed transesterification of oils/fats and alcohols into biodiesel. More advanced processes are currently being developed, including ethanol production from lignocellulosic biomass (wood, grass, and straw), thermochemical conversion of lignocellulosic biomass via gasification, a Fischer-Tropsch synthesis process to produce diesel fuel, and algae biofuels, which require development of cultivation, separation of cells and oils and conversion to useful fuels.

While biomass resources are plentiful, not all are technically, economically and environmentally viable for conversion to transportation fuels. Limitations on sustainable biofuel supply will play an important role in determining the extent

TABLE 1. Biofuel feedstock and production pathways. *Adapted from Parker et al. [2]*

Feedstock category	Feedstock type	Conversion technologies
Starch & sugar-based biomass	Corn, sugarcane, sugar beet, sweet sorghum	Bioethanol through hydrolysis & fermentation
Ligocellulostics	Forest biomass, herbaceous energy crops, agricultural and food production residues, municipal solid wastes	Cellulostic ethanol through hydrolysis and fermentation; upgrading of pyrolysis oils to gasoline; Fischer-Tropsch diesel
Lipids	Seed oils, yellow grease, animal fats	Fatty acid to methyl esters, hydro-treatment of fatty acids to hydrocarbons
Algae		Transesterfication

to which petroleum fuels can be displaced by biofuels, as will limits on the use of specific biomass resources because of sustainability concerns [3]. Estimates of US biomass indicate that it could be sufficient to supply somewhere around 80-100 billion gallons of gasoline equivalent per year. Depending upon vehicle efficiency and projections of future travel demand, this could correspond to anywhere from approximately 1/3 of transportation fuel demand in 2050 in a business-as-usual scenario to nearly all liquid transportation fuel demand in a highly efficient and electrified demand future [4].

The sustainability of biofuels is an important question and is dependent on the specific feedstock to produce the biofuel. While there is no agreed-upon definition of sustainability, many different metrics and potential impacts have been proposed: ecosystem/habitat disruption, deforestation, soil quality impacts, net GHG emission reductions, air and water pollution, water usage, competition with food crops that leads to high food prices, and land rights and labor issues [4]. These impacts are important to quantify because, if not done carefully, they can negate or even exceed the environmental benefits that using biofuels is supposed to provide.

While some transportation modes can be electrified (such as light-duty plug-in electric vehicles or fuel cell vehicles), other modes, specifically aircraft, marine shipping, and heavy-duty trucks are most likely to use liquid fuels for the next few decades because of vehicle range and fuel energy density issues. Given that these modes are projected to have significant travel demand growth [1], a low-carbon biofuel is perhaps the only option for lowering the GHG intensity in these transportation modes.

Electricity as a Transportation Fuel

Plug-in electric vehicles (PEVs) are powered, at least in part, by electricity from the power grid that is stored in an onboard battery. They can be either plug-in hybrid electric vehicles (PHEVs), which can run on electricity or gasoline, or battery electric vehicles (BEVs), which run entirely on electricity. PEVs operating on electricity are much more efficient than conventional internal combustion engine vehicles (ICEVs) running on petroleum fuels. PEVs are beginning to be commercialized in 2011 but as yet make up a tiny fraction of vehicle sales.

While batteries are the key technology for the success of PEVs, the electricity supply and infrastructure side of the equation is also important to understand from a technology and deployment perspective.

PEVs need to be plugged in to "refuel" the onboard batteries, which can store an amount of energy of from about 3 kWh for a low-range PHEV to over 50 kWh for a longer range BEV. While current PEVs can be recharged at a conventional 120V outlet (often called level 1 charging), the rate of energy transfer is quite slow (~1-2 kW). To recharge more quickly it is necessary to use higher voltage and current and a dedicated PEV charger. Level 2 charging is 240 V and up to 40 amps for up to 9 kW, while level 3 charging is being designed to allow for very fast charging (up to 80% of battery capacity in less than 30 minutes).

Given the low penetration of PEVs it is not surprising that there are very few PEV chargers deployed. There is concern that deployment of home-based charging equipment could be an issue if PEVs are to be widespread and electricity is to be a primary fuel for light-duty transportation. A survey by Axsen and Kurani [5] found that only about 50% of new vehicle buyers have a 120 V outlet within 25 feet of their household vehicle parking space and only 35% within 10 feet. In urban areas such as San Francisco, fewer than 20% of cars are parked overnight in dedicated off-street parking. Deployment of public infrastructure at workplaces, retail establishments, and along major highways is likely to be needed to increase the utility of PEVs and to ease drivers' "range anxiety". Charging times will be much longer than refueling a gasoline tank (tens of minutes to several hours) so chargers should be placed in locations where the driver can engage in other activities (e.g. workplace, shopping, eating out).

The supply of electricity is an important part of the equation for electrified transportation. In the near-term, the amount of electricity that would be demanded from PEVs would be a tiny fraction of total electricity generation [6]. In California, for example, charging of one million PEVs (about 4% of total cars and light trucks) would only require about 1% additional electricity generation. The timing of the demand for PEVs charge is an important issue. For example, charging during off-peak hours will tend to flatten the demand profile, reducing the need for additional generating capacity. Smart-grid technologies will allow for communication between vehicles and utilities (or grid operators), thus enabling PEV charging to be managed to ensure grid stability and minimize system costs. Given that cars are parked approximately 95 percent of the time and potentially plugged in for a large fraction of the time that they are parked, this is a real possibility.

For a PEV, the carbon intensity of electricity (grams of carbon dioxide equivalent emissions per megajoule) is higher than that of gasoline and diesel, but the carbon per unit of useful work (i.e. per mile of travel) can be much lower than that of a conventional or even hybrid vehicle. This is because electricity is an intermediate energy carrier which has already been converted from a primary energy resource, and then is used in a PEV with very high efficiency. Gasoline and diesel on the other hand are fuels that have been only slightly modified from the original primary energy resource (crude oil) to achieve specific properties suitable for internal combustion engines. They are converted at much lower efficiency to mechanical work on board the vehicle. In addition, the carbon intensity of electricity will presumably gradually be reduced as low-carbon and renewable generation increases and due to other carbon policies.

TABLE 2. Infrastructure and deployment challenges for alternative fuel sources. *Grayed out boxes present special challenges that require more attention & efforts.*

	Hydrogen	Electricity	Biofuels
Collection & extraction	Existing infrastructure for fossil resources (natural gas, coal)	Existing infrastructure	Wastes require collection; crops require dedicated operation within larger agricultural system
Resource transport	Existing infrastructure	Existing infrastructure	Low energy density limits transport distances
Conversion	Large-scale reformers/gasifiersand electrolysis	Existing infrastructure	Biorefinery (including feedstock processing & conversion)
Fuel transport	Compressed gas and cryogenic liquid trucks, pipelines	Existing distribution infrastructure may require upgrades to avoid localized "hotspots"	Expanded infrastructure for transfer of feedstock & fuel (rail, trucks, barge, intermodal).
			Existing infrastructure for "drop-in" fuels; biogasoline, Fischer-Tropsch and bio-hydrocarbon fuels
Refueling locations	H2 refueling stations – new network with minimum coverage needed	Widespread vehicle chargers at home; require public charging facilities in urban areas and public spaces, including smart grid technologies	Dedicated bio-refueling stations.
			Existing stations can accommodate "drop-in" fuels; biogasoline, Fischer-Tropsch and bio-hydrocarbon fuels

Beyond light-duty vehicles, the main energy and emissions contributions from transportation come from aviation, heavy-duty long-haul trucking and marine shipping. These sectors present significant challenges to electrification and will likely rely on high-density liquid biofuels (or potentially hydrogen) in order to reduce fuel carbon intensity. Rail, buses and delivery trucks also offer some potential for running on grid electricity.

Hydrogen as a Transportation Fuel

Hydrogen has been widely discussed as a long-term fuel option to address environmental and energy security goals [7]. Fuel cell vehicles (FCVs) that use hydrogen are significantly more efficient than conventional vehicles, using less energy to produce a mile of vehicle travel. Additionally, the fuel can be made from a wide variety of domestic and low-carbon resources, providing solutions to the oil dependency and carbon challenges. While FCVs have not yet been commercialized, several automakers have announced plans to introduce vehicles in the 2015 timeframe.

Like electricity, hydrogen is an energy carrier that is produced from a primary energy resource. Almost any energy resource can be converted into hydrogen, although some pathways are superior to others in terms of cost, environmental impacts, efficiency, and technological maturity. Currently in the US about 9 million tonnes of H_2 are produced each year, mainly for industrial or refinery purposes. This would be enough to supply about 30 million FCVs. Natural gas reforming accounts for 95% of current U.S. H_2 production and in the near-term should continue to be the least expensive production method. In the longer-term, continued use of fossil resources to produce H_2 mainly for industrial or refinery purposes would necessitate the use of carbon capture and storage technologies to minimize the GHG emissions from H_2 production. H_2 can also be produced from biomass in a production process similar to that from coal (gasification). Electrolytic hydrogen production can also be an important H_2 production technology in the longer-term and offers the potential for zero carbon production from renewables such as solar and wind.

Hydrogen infrastructure includes all of the components associated with producing, delivering and providing H_2 to the vehicle at a refueling station and can generally be categorized into two types: on-site and central production. Onsite production uses existing energy distribution methods for electricity or natural gas to allow for H_2 production at the refueling station via electrolysis or natural gas steam reforming. Central production of hydrogen would require delivery of hydrogen, via compressed-gas trucks, liquefied H_2 trucks or gaseous pipelines, to the refueling station. Over the near- to medium-term, H_2 infrastructure is likely to be comprised primarily of onsite H_2 stations, while over time, as demand for H_2 fuel increases, it is expected to transition to an infrastructure primarily composed of central production and delivery [7, 8].

One key issue regarding the deployment of hydrogen infrastructure is the "chicken-and-egg" problem: ensuring that both the H_2 refueling infrastructure and FCVs will have access to the other as they are being deployed. One approach to this issue is to coordinate the deployment of vehicles and fuels in targeted locations or "lighthouse" regions. A "cluster strategy" is an even more targeted, coordinated introduction of hydrogen vehicles and refueling infrastructure in a few focused geographic areas such as smaller cities within a larger region [9].

Over the longer-term, if H_2 and FCVs are widely used, the H_2 infrastructure will become a massive energy system that will rival the current oil and gas infrastructure for production, delivery, storage and refueling. Estimated costs for hydrogen fuel at the large scale indicate that H_2 could be cheaper per mile than even advanced gasoline vehicles [7]. However, the challenge is that in the near term, both H_2 fuels and FCVs will be more expensive than conventional vehicles running on gasoline. This provides an important policy challenge to incentivize investments in lower cost, lower-carbon outcomes in the face of potentially many years of higher costs.

Hydrogen has some applicability in other transportation subsectors. Fuel cell buses and delivery trucks are potentially viable technologies. However, low energy storage density for H_2 is likely to limit its use as a fuel in long-haul trucks, aircraft and marine applications.

TABLE 3. Resource, technology, economic and transitional issues for alternative fuels

	Hydrogen	Electricity	Biofuels
Resources	Diversity of production resources	Diversity of production resources	Limits on providing enough low-carbon and sustainable biomass
Technologies	Production and storage are critical technologies	No major limitations	Biorefineries are critical technology
Economics	High initial cost; economies of scale with stations and central production	Incremental investment cost for home charging. Moderate investment cost for public charging infrastructure.	Feedstock costs are high and linked with food prices for first-generation biofuels. Biorefineries and distribution system are scale-dependent, but distribution cost can be minimized for bio- hydrocarbon fuels.
Transitions	Chicken-and-egg. Vehicle adoption will determine rate of infrastructure deployment; requires coordination	Vehicle adoption will determine rate of infrastructure deployment	Rapid deployment over next few decades due to federal policy. Slowed down in recent years due to concern about sustainability.

Summary

Considering the technologies and resources that are available to us, there are several alternative fuel sources that can significantly reduce our reliance on imported oil, improve air quality, and reduce greenhouse gas emissions. However, the transition to cleaner, lower carbon fuel sources will need significant technology advancement and sustained coordination efforts among the vehicle and fuel industry and regulators over a long period of time in order to overcome market barriers, consumer acceptance, and unaccounted externalities of imported oil in their fuel price. Also, policies will be needed to ensure that the environmental performance of these new fuel sources is better than that of fossil fuels and to avoid any unintended consequences that these new fuel sources may present [3, 10].

There are varying degrees of challenges associated with infrastructure design and deployment and transition to large-scale use for each of the three fuel types we have discussed. Infrastructure and transition challenges are summarized in Tables 2 and 3. A portfolio approach will give us the best chance of meeting environmental and energy security goals for a sustainable transportation future. It will be important to nurture all technologies along because we do not yet know which technologies will provide the most cost effective emissions and petroleum usage reduction while appealing to consumer preferences.

In closing, we offer three recommendations to making the transition to a future of sustainable transportation fuels:

Research is important Fundamental and applied research is needed to improve technologies associated with fuel production, conversion, storage, and utilization as well as scientific understanding of sustainability impacts of these fuels. This research can help to guide R&D as well as investment decisions by government, industry and other stakeholders.

Policies can help level the playing field Policies are needed to incentivize the development and use of low-greenhouse-gas/sustainable fuels through performance-based standards and market mechanisms. Policies such as emissions standards for automobiles or the low carbon fuel standard are essential for putting the different fuels (and vehicle platforms) into a common framework with which they can be assessed [11]. They allow industry the flexibility to choose different options and approaches to ensure that targets are met with lower compliance costs.

Sustainability standards should be developed Effective sustainability policies are needed to prevent impacts on ecologically sensitive areas, air and water pollution, and competition with food resources. Continuous monitoring and assessments of unintended consequences within or beyond the production areas will be essential for the successful transition to a sustainable transportation future.

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A Blue Ribbon Commission's Proposal for Breaking the Nuclear Waste Stalemate

Susanne E. Vandenbosch and Robert Vandenbosch

In the United States, the role of nuclear power in producing carbon-free energy is threatened by the failure to agree on how to safely dispose of spent fuel. For example, California has passed legislation prohibiting new power plants until this problem is solved. The California nuclear power moratorium was challenged by the Pacific Gas and Electric Company in lower federal courts and finally in the U. S. Supreme Court in 1983. The Supreme Court upheld the California moratorium, ruling that although the federal government under the Atomic Energy Act had the authority to regulate nuclear safety, it did not preempt State regulation in economic and other aspects of nuclear power. Specifically, the Court ruled under the Atomic Energy Act "the states retain their traditional responsibilities in the field of regulating electrical utilities for determining questions of need, reliability, cost and other related state concerns" [Pacific Gas & Electric Co. v. State Energy Conservation and Development Commission et al. 462 U. S. 190 (1983)]. A number of other states have tied licensing or relicensing to progress on waste disposal [1]. Some utilities and power plant operators are reluctant to add new nuclear power unless a path to getting rid of their waste is assured. In addition to the waste problem, there are economic and safety issues that challenge the future of nuclear power. Concern about safety may present a significant obstacle in the wake of Fukushima.

In early 2009 President Obama followed through on his campaign promise to abandon Yucca Mountain as a repository for permanent disposal of high-level radioactive reactor waste. This made a shambles of the nation's nuclear waste disposal policy, stranding waste at all of the nation's power reactors, waste from submarines and aircraft carriers, and waste from weapons activities at Hanford, WA and Savannah River, SC. In June 2008, President George W. Bush's Department of Energy had filed a license application with the Nuclear Regulatory Commission for the construction of the repository. The Obama administration's newly appointed Secretary of Energy, Stephen Chu, announced that Yucca Mountain was "not workable" and that the license application filed at the end of the previous administration would be withdrawn. He also announced that a Blue Ribbon Commission would be appointed to make recommendations on how to manage the disposition of used nuclear reactor fuel.

The Commission was given the somewhat misleading title of "Blue Ribbon Commission on America's Nuclear Future." In fact the mandate of the Commission was much narrower. Its charter states "The Secretary of Energy, acting at the direction of the President, is establishing the Commission to conduct a comprehensive review of policies for managing the back end of the nuclear fuel cycle, including all alternatives for the storage, processing, and disposal of civilian and defense used nuclear fuel, high-level waste, and materials derived from nuclear activities." [2] The Commission was asked to provide a draft report in June 2011, and a final report in January 2012. Both of these deadlines were met, and the final report, Blue Ribbon Commission on America's Nuclear Future Report to the Secretary of Energy, is available on the Commission's website at www.brc.gov [3]. In this article we review the work of the Commission and its major recommendations.

Work of the Commission

It took almost a year before the members of the Commission were appointed. The Commission has fifteen members and was co-chaired by Lee Hamilton, former Congressman from Indiana, and Brent Scowcroft, former Assistant to the President for National Security Issues during the Ford and George H. W. Bush administrations [4]. While neither of the co-chairs has a scientific background, the Commission included a member with a PhD in Geology, Allison Macfarlane, two with PhDs in physics: Richard Meserve (who has also served as chair of the Nuclear Regulatory Commission (NRC) and Ernie Moniz, who has been very involved in nuclear power issues in recent years and served in the DoE. There are also two mechanical engineers, Per Peterson (of the nuclear engineering department at UC Berkeley), and Albert Carnesale, who also has a nuclear engineering degree. The remaining members, Mark Ayers, Vicky Bailey, Pete Domenici, Susan Eisenhower, Chuck Hagel, Jonathan Lash, John Rowe, and Phil Sharp, had diverse backgrounds. The Commission operated in an open and transparent manner. During the first 15 months the Commission met bimonthly in public information-gathering meetings. Most of the time was spent listening to invited presentations by experts or stakeholders, followed by an opportunity for members of the public to present short statements. The present authors participated as members of the public [5]. The meetings were Webcast; the Webcasts, transcripts and visual aids were generally posted on the Commission's website soon after the meetings [6]. A concordance of the transcript material is also available on the website. Three subcommittees were initially formed. The Reactor and Fuel Cycle Technology Subcommittee considered technical alternatives to direct disposal of spent fuel in a repository. This subcommittee primarily heard testimony from experts on the pros and cons of reprocessing. The subcommittee also explored whether there were new reactor technologies which might impact nuclear waste disposal. The Transportation and Storage Subcommittee examined temporary storage and transportation issues. The pros and cons of interim storage were discussed. Transportation issues involved coordination of federal, state and local units of government. The Disposal Subcommittee studied the technical, political and social aspects of siting geological repositories. They visited foreign countries to learn from their experience with siting repositories. They also visited the WIPP repository for lower-level defense waste in New Mexico and examined the process for gaining acceptance for this facility. The draft and final reports drew heavily on the subcommittees' work [7]. The Commission staff played a major role in this process. Although the subcommittees had a few public meetings to hear presentations, any meetings where the actual recommendations were developed were not announced to the public. After the draft report was released in July 2011, several meetings were held throughout the country where the draft report was summarized by staff director John Kotek and public comment was solicited. Throughout the process written comments from the public were also encouraged and posted on the website.

We turn now to the eight specific key elements of the recommendation made by the Commission, six of which we discuss in some detail. The wording of the recommendations as given in the Executive Summary are reproduced in parentheses at the beginning of each section.

(1) Siting Waste Facilities

(A new, consent-based approach to siting future nuclear waste management facilities.)

The element of this recommendation that deviates most strongly from the approach used previously is the recommendation that siting should be consent-based. The legislative act that has governed the selection of Yucca Mountain allows the veto of the host state to be over-ridden by a majority of both houses of Congress [8]. Although the eventual fate of Yucca Mountain is not certain, this experience suggests that persistent opposition together with political power can thwart a top-down prescriptive approach. The Commission pointed to the eventual success of a consensual process for siting the repository for transuranic defense waste (the Waste Isolation Pilot Plant in New Mexico) and positive siting outcomes in Finland and Sweden as support for this proposal. The Commission however did not mention the current difficulty Japan is having in finding a disposal site using a consensual approach.

In its draft report the Commission was somewhat vague about how to define the communities whose consent would be required, nor was the precise role that state, tribal, and local communities would play described in any detail. This vagueness was the subject of considerable public comment. At the December 2, 2011 meeting of the Commission considering responses to public comment, Disposal Subcommittee co-chair Jonathan Lash summarized these comments: "What is the role of states? At what point can a state or locality opt out? At what point would their agreement be binding? What kind of incentives would the authority have to develop agreements with potential hosts?" [9] The Final Report continues to emphasize the need for an adaptive, staged, and flexible process. It concludes that previous siting legislation was too prescriptive. It suggests that state, tribal or local community opt-out would have to be exercised before license application submission. It does not recommend how state consent would be defined, rejecting specifying the use of referendum or a ballot question. The Report suggests that a good gauge of consent would be for states, tribes and local communities to obtain legally binding agreements with the implementing organization. We conclude that considerable work needs to be done to craft legislation to define a consensual approach.

In connection with the siting process, the Commission makes a number of positive suggestions. These include developing a set of basic initial siting criteria that would avoid wasting time on sites that are clearly unsuitable or inappropriate, and developing a final generic regulatory standard that would apply to any site. In the case of Yucca Mountain, Congress eventually mandated the development of a Radiation Standard that was specific to that site. This was partly in response to the failure of the Environmental Protection Agency to come up with a generic standard in a reasonable length of time after a Court decision rejected part of their first attempt at a standard.

(2) New Nuclear Waste Management Organization

(A new organization dedicated solely to implementing the waste management program and empowered with the authority and resources to succeed.)

This recommendation was occasioned principally by two factors. The Department of Energy's management record of defense nuclear waste has been poor, and there is a notable lack of confidence or trust in its stewardship. Secondly, it is felt that a single-purpose organization would bring more stability, focus and credibility to waste management. The responsibilities of a new organization would be to site, license, build, and operate facilities for both consolidated interim storage (see recommendation 5) and for final disposal (recommendation 4) of civilian and defense spent fuel and high-level nuclear waste. The Commission recommended a federally-chartered federal corporation directed by an eleven-member bipartisan board nominated by the President, confirmed by the Senate, and selected to represent a range of expertise and perspectives. This offers opportunities for politicization, but is probably as independent as one can get without losing accountability. The Board would appoint a Chief Executive Officer for the organization. Since this Officer would serve ex officio on the Board but is included in the recommendation for eleven members, the even number of voting members could lead to tie votes. Congress might want to reconsider the size of the board. It also recommended that the existing roles of the Environmental Protection Agency (setting public safety and health standards), the Nuclear Regulatory Commission (licensing and regulation enforcement), and the Nuclear Waste Technical Review Board (oversight) be preserved.

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(3) Access to Nuclear Waste Fund

(Access to the funds nuclear utility ratepayers are providing for the purpose of nuclear waste management.)

The 1982 Nuclear Waste Policy Act created a funding mechanism of a 0.1 cent per kilowatt hour fee to be paid by utilities to a Nuclear Waste Fund. Unfortunately the Act did not sufficiently isolate this fund from other Congressional funds, and the waste management program has had to rely on annual Congressional appropriations from this fund. Senator Harry Reid, presently Senate Majority Leader, has used the appropriations process to block funding for Yucca Mountain. The Commission makes two rather specific recommendations concerning funding. In the short term it suggests the Administration should allow the utilities to remit only the portion of the annual fee that is appropriated for waste management each year and place the rest in a trust account, held by a qualified third-party institution. At the same time changes in budget treatment of annual fee receipts would be required. In the longer term, legislation to transfer the unspent balance in the Fund to the new waste management organization would be needed. The Commission also wants to amend the legislation to allow the Waste Fund to be used for onsite storage.

(4) Develop a Geological Repository

(Prompt efforts to develop one or more deep geological facilities.)

Although there are a few people that believe that future reprocessing or recycling developments might make deep geological disposal unnecessary, the Commission does not accept this view. It states that "Deep geologic disposal capacity is an essential component of a comprehensive nuclear waste management system for the simple reason that very long-term isolation from the environment is the only responsible way to manage nuclear materials with a low probability of re-use, including defense and commercial reprocessing wastes and many forms of spent fuel currently in government hands." [10] We (the authors of this article) believe this recommendation is the key to a waste management program. Without a clear path to permanent isolation of long-lived hazardous waste there cannot be public acceptance of the nuclear energy option. Without it the Nuclear Regulatory Commission's assertion in its Waste Confidence Decision (whose satisfaction is required for reactor licensing) that "there is reasonable assurance that sufficient mined geologic repository capacity will be available to dispose of the commercial high-level radioactive waste and spent fuel generated in any reactor when necessary" is a charade [11]. Furthermore, implementing the following Commission recommendation on developing consolidated interim storage facilities will be very difficult without a clear path to permanent disposal. Potential hosts for an interim storage site will be wary that they might become de facto permanent storage sites.

(5) Interim Storage Development

(Prompt efforts to develop one or more consolidated storage facilities.)

The Commission identifies the strongest argument for this recommendation as enabling the transfer of "stranded" spent fuel from shutdown plant sites. This would allow these sites to be completely decommissioned and returned to other uses. Also, interim storage can be used if circumstances require removal of spent fuel from reactor sites in the case of exhaustion of safe storage space or an emergency. Creation of an interim storage site would enable the government to begin honoring the contractual agreement with utilities to start taking title to and removing spent fuel from reactor sites by 1998. The federal government has paid nearly a billion taxpayer dollars (not ratepayer Nuclear Waste Fund dollars, which cannot be used for interim storage) to pay for utility costs for extended onsite storage. The Commission recognizes a difficulty that can occur in siting an interim storage site because of the nature of the material and the potential host's concern that interim may de facto become permanent. This concern, together with the concern that the existence of an interim storage site might take the pressure off development of a permanent repository, led the framers of the 1987 Nuclear Waste Policy Amendments Act to link the authorization of interim storage sites to licensing of a repository. This Act will have to be amended to allow development of interim storage before a repository is licensed.

(6) Innovation in Nuclear Energy Technology

(Support for continued U.S. innovation in nuclear energy technology and for workforce development.)

It is under this key element that the Commission addresses the contentious issue of whether the U.S. should continue with the "open" fuel cycle, where spent fuel goes intact to a disposal repository, or move towards a "closed" fuel cycle where the spent fuel is reprocessed and some components are recycled into reactor fuel [12]. A form of the latter has been adopted in France, where plutonium is recovered from spent fuel and recycled into new fuel for existing reactors as Mixed Oxide Fuel (MOX). There still remains waste that will go to a geological repository. The Commission concludes that it is premature to reach consensus on closing the fuel cycle "given the large uncertainties that exist about the merits and commercial viability of different fuel cycles…." [13]. The Commission concludes that a geological repository is needed independent of whether spent fuel is reprocessed. It endorses the important assessment that "no currently available or reasonably foreseeable reactor and fuel cycle technology developments- including advances in reprocess and recycle technologies- have the potential to fundamentally alter the waste management challenge this nation confronts over at least the next several decades, if not longer." [14]

We agree with the above assessment. In order to understand its basis, we need to remind ourselves of some physics issues. All U.S. reactors are light-water reactors with a neutron energy spectrum dominated by low energy (eV) neutrons. These can induce fission in the fissile nuclides U-235 and Pu-239. They cannot fission the much more abundant U-238 and the troublesome (from a waste management perspective) Np-237 and other minor actinides such as Pu-240 and Am-241. Fissioning these nuclides requires higher energy ("fast") neutrons from "fast" reactors, usually liquid-sodium metal-cooled. Countries that have adopted a reprocessing strategy such as France had planned to have fast reactors but their development has been fraught with technical difficulties; no fast reactors are presently in use in France. Without fast reactors the energy gain from recycling reprocessed Pu into light water reactor fuel is modest, only about 19% (the Commission Report only mentions this in a rather obscure table [15]). A permanent disposal repository is still required for the fission products and higher actinides. And there are proliferation, safety, and terrorism issues with the separated Pu generated during reprocessing.

Two additional "Key" recommendations deal with transportation and global safety, security, and non-proliferation concerns. Actually the most substantive action of the Commission regarding non-proliferation is the conclusion discussed above that it would be premature to decide to reprocess spent fuel at the present time. Un-reprocessed spent fuel is the most proliferation-resistant medium. Reprocessing makes plutonium more accessible for making nuclear weapons.

Although not one of their key recommendations, the Commission also recommended that the National Academies of Science be charged with studying what lessons should be learned from the Fukushima incident.

Summary and Conclusions

In our opinion the most serious omission from the recommendations concerns learning from the Yucca Mountain experience. The Department of Energy has requested that its license application be withdrawn, giving no scientific justification but stating that Yucca Mountain is "not workable." An Atomic Safety and Licensing Board of the Nuclear Regulatory Commission has however rejected this request. The matter is presently before the District of Columbia Court of Appeals. Although the Commission was not a siting Commission and it would have been improper for them to offer an opinion on the suitability of the Yucca Mountain site, it could and should have made a recommendation that the license application review go forward. Many invited speakers and public commenters favored this [16]. Some objected to the lack of scientific justification for the license withdrawal. It is generally viewed as having been a political decision. A review could provide valuable information for future repository siting efforts. For example, if the Nuclear Regulatory Commission rejected the license application citing concerns about future seismic and volcanic activity at the site (the tectonic instability of the site), such a ruling could guide the screening criteria for possible future repository sites.

Overall, we find the Blue Ribbon Commission recommendations generally sound. The most important recommendations will require new legislation for their implementation. This includes a new facility siting process, authorizing interim storage facilities, establishing a new waste management organization, and ensuring funding access. The government will need to pay sustained attention to the waste problem to assure timely progress.

Nuclear power will undoubtedly comprise a significant percentage of America's energy needs in the coming decades. The waste disposal issue is as much political as it is technical. Time will tell if the Commission's recommendations can be brought to fruition in a rational, responsible manner.

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REVIEWS

Distracted: The erosion of attention and the coming dark age

By Maggie Jackson, Prometheus Books, Amherst, New York, 2008, 327 pages ISBN 978-1-59102-623-5, $18 paperback

This book is in the same vein as Mark Bauerlein's 1999 The Dumbest Generation, which investigated why today's younger generation seems less informed and literate while being more self-absorbed than generations which preceded it. Jackson, a journalist, opens her book with a description of her own natural tendency toward distraction, concluding the first chapter with the notion that "an epidemic erosion of attention is a sure sign of an impending dark age."

Jackson's research for the book included spending time at the University of Michigan's Brain, Cognition, and Action Laboratory. She learned a great deal from experimental psychologist David Meyer, whose work involves research on multitasking. Meyer is driven to inform anyone who will listen about the dangers of multitasking. His research indicates that people can train to improve their ability to multitask, "But except in rare circumstances, you can train until you're blue in the face and you'd never be as good as if you just focused on one thing at a time." Meyers began concentrating his research on multitasking after his son was killed by a distracted driver in a traffic accident. Jackson explains that Meyer "is convinced that (multitasking) exemplifies a head-down, tunnel vision way of life that values materialism over happiness, productivity over insight and compassion."

In a chapter on bound books, the author indicates that although 174,000 books were published in one recent year, nearly 57 percent of Americans don't read a single book in a year. This reviewer can't imagine going a week, let alone a year, without reading a book. Despite this dearth of book reading, Jackson asks, "Can we Google our way to wisdom?" She includes an insightful quote from former Librarian of Congress Daniel Boorstin: "The greatest menace to progress is not ignorance, but the illusion of knowledge." Information obtained from Google has the potential to create an illusion of knowledge.

Jackson describes innovative uses of technology in education, including an experiment in such technology by Professor Norbert Elliot at the New Jersey Institute of Technology. Elliot eliminated lectures and instead assigned students to listen to podcasts of his lectures. He suspected that few students would actually view or listen to the podcasts, and that the few who did would be "usually multitasking or running about while doing so." Jackson indicates that the podcast technology did indeed reduce learning because of student multitasking. A similar recent innovation in high school science courses is called "flipping," where teachers prepare videos for students to watch outside of class. Students are then expected to pursue the topics in more depth in class. Based on the evidence in Distracted, I'd venture that high school students are more prone to multitask while watching the videos than are college students.

Jackson's theory is that students fall short of their intellectual potential due to their failure to exercise self-discipline. She suspects that the control of attention is the driver behind willpower, writing "Here again we see how attention is the conductor of the orchestra of you…." She quotes psychiatry professor Leanne Tamm: "Kids are always told to pay attention, but they don't know what that means."

Her concluding paragraph opens with a challenge to our culture: "We are on the cusp of an astonishing time, and on the edge of darkness." I found the book stimulating and insightful, and was impressed with the author's depth of research. I recommend it to everyone who is interested in the effects of technology on our culture.

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The Inquisition of Climate Science

By James Lawrence Powell,Columbia University Press, 2011, 232 pp, $27.95, ISBN 978-0-231-15718-6 (cloth); ISBN 978-0-231-52784-2 (ebook)

In fifteen short chapters, this book provides a stout defense of the consensus view of climate scientists that global warming is genuine and that human-caused carbon emissions are responsible. In technically careful but vivid prose, Powell makes his points with sharp wit (and sharp elbows for the skeptics that he brands as "deniers").

In preparing to read and review this book, I read Spencer Weart's *The Discovery of Global Warming* (Harvard University Press, 2003), which had sat unread on my bookshelf for far too long. That book and Powell's provide a powerful one-two intellectual punch on the subject of global climate and human impact. Weart's book is mainly a narrative of the development of modern climate science, while *The Inquisition of Climate Science* concentrates on the protracted battles between climate scientists and their detractors. Powell doesn't hesitate to name names on both sides. The book's dedication is to "James E. Hansen, Michael E. Mann, Benjamin D. Santer, and the late Stephen H. Schneider – SCIENTISTS OF COURAGE AND INTEGRITY" (capitalized in the original). On the side of the skeptics, a diverse group of individuals (scientists, industry consultants, writers, and politicians) receive Powell's greatest scrutiny and criticism. These include physicists Freeman Dyson and Frederick Seitz, MIT meteorologist Richard Lindzen, Bjorn Lomborg, best-selling author Michael Crichton, S. Fred Singer, former

Apollo astronaut and US Senator Harrison Schmitt, Patrick Michaels, US Senator James Inhofe, and last but not least Viscount Monckton of Brenchley.

In the book's preface, Powell writes, "What are my credentials? I am not a climate researcher. I like to think that may be an advantage, as I have no axe to grind, no position to defend. I do have a PhD in geochemistry from MIT. I have received research grants and written scientific articles and books. President Ronald Reagan and George H. W. Bush each appointed me to the National Science Board, where I served for twelve years. That experience informed me about how science works at the level of national policy. Ultimately, of course, any book has to speak for itself."

This reader found that the book spoke for itself very well indeed. Whereas Weart's book is a scholarly historical narrative, Powell's book is righteously indignant. Before reading these two books, I was sympathetic to the consensus scientific view, and Weart's book convinced me. As I began Powell's book, I wondered about the appropriateness of a title that recalls Galileo's clash with Church authority, and I was struck by Powell's sometimes strident tone. However, he musters the technical evidence very well and argues clearly from it. By the time I finished *The Inquisition of Climate Science*, I was cheering him on. We are in James Lawrence Powell's debt, for he has taken on the climate-change skeptics in a hard-hitting but technically sound manner. He has done a fine job of fighting fire with fire – something that too few with advanced scientific training are willing to do. I heartily recommend this book.

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