TEACHERS CLEARINGHOUSE FOR SCIENCE AND SOCIETY EDUCATION NEWSLETTER

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The Meaning of Sustainability

by Albert A. Bartlett

Background on Sustainability

In the 1960s and 1970s, it became apparent to many thoughtful individuals that global populations, rates of resource use and environmental degradation were all increasing so rapidly that these increases would soon encounter the limits imposed by the finite productivity of the global ecosphere and the geological availability of mineral and fossil fuel resources.

Perhaps most prominent among the publications that introduced the reality of limits in hard quantitative terms was the book *Limits to Growth* (1) which, in 1972, reported the results of computer simulations of the global economy that were carried out by a systems analysis group at MIT. The simulation recorded five parameters for the global economy (population, agricultural production, natural resources, industrial production and pollution) for the period of time from 1900 to 1970 and then projected the computer-generated values of these parameters for the period from 1970 to 2100. For a wide range of input assumptions, the projections predicted a major collapse of world population in the mid-twenty first century. The computed results seemed to show that sustainability of life as we know it may not be an option.

Limits to Growth evoked admiration from scientists and environmentalists who were comfortable with quantitative analysis. The study evoked consternation from less quantitative types who tend not to believe in limits. *Limits to Growth* precipitated immediate and urgent rebuttals from the global economic community which proclaimed that human ingenuity can overcome all shortages so that, in effect, there are no limits. (2, 3) The book *Limits to Growth* got people thinking about sustainability.

The Definition of Sustainability

We must be clear on the meaning of sustainability before we make any more use the term. A very commonly used definition of sustainability is implied in the following definition of sustainable development which is found in the report of the Brundtland Commission of the United Nations (4):

> **Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.**

We must note two important things. First, “future generations” (plural) implies “for a very long time,” where long means long compared to a human lifetime.” Second, the arithmetic of steady growth shows that steady growth of populations or of rates of resource consumption for modest periods of time leads to sizes of these quantities that become so large as to be impossible. The combination of these two observations leads us to the First Law of Sustainability (5):

> **Population growth and/or growth in the rates of consumption of resources cannot be sustained.**

The First Law is based on arithmetic so it is absolute. Science is not democratic, so the First Law of Sustainability is not debatable; it can not be modified or repealed by professional societies, by congresses or by parliaments. The First Law implies that the term “Sustainable Growth” is an oxymoron. This is true when this term is used by an untutored person on the street, by an economics professor, or by the President of the United States. (6)

The Brundtland Definition of Sustainability

The Brundtland definition of sustainability is appealing because it has both virtue and vagueness. It is virtuous to

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Future of Space Exploration at AMNH

"Beyond Planet Earth: The Future of Space Exploration" is the newest special exhibit at the American Museum of Natural history in New York City, and curator Michael Shara spoke to educators about it at a special meeting at the museum on 9 December 2011. He spoke of looking forward into the next 500 years of space exploration, with an emphasis on the next 50. He did this in terms of four destinations within our solar system: the Moon, asteroids, Mars, and the Jovian satellite Europa.

Shara's vision of the role of the Moon in future space exploration is very different from that of the past. First, people will get there not by rockets but by a "space elevator" cable, which he would construct by tethering the International Space Station to the Moon, then extending the cable down toward the Earth just above its atmosphere (to eliminate friction). A gondola suspended from the Earth end of the cable would appear to move at 1000 miles per hour, because that is the speed of the Earth's surface rotation, Shara said, but achieving that speed from Earth to link up with the gondola would be much less than achieving the Earth-orbital speed of 17,500 miles per hour as is presently required. (Similar advantages would also apply to returning to Earth from the Moon.)

The Moon would also serve as a base for exploration elsewhere in the solar system, and the exhibit has a full-scale model of an inflated hut that would serve as one of the moonbase dwellings. This base would also peer into space with a rotating liquid mirror telescope. Shara also envisioned mining the isotope helium-3 on the moon, to be used in providing energy from its fusion to form helium-4 and protons. He added that the Chinese are presently on a path to repeat the American sequence of lunar flights and landings.

Because the mass of many asteroids is insufficient to enable a spacecraft to orbit them, the exhibit points out that spacecraft will need to hover over them. Shara pointed out the importance of identifying and tracking asteroids in order to avoid the fate of the dinosaurs.

A walkthrough of a replicated Martian surface in the exhibit shows what an inhospitable place it presently is; but, as Carl Sagan pointed out long ago, it can be terraformed. The exhibit envisions doing this in the table below.

Shara added that until the Martian atmosphere is thickened to be 35% that of Earth, an Ace bandage spacesuit would afford the necessary protection there.

Only a small part at the end of the exhibit is devoted to the final destination it considers, Europa. But Shara expects that it too will be explored in the next 50 years. The next goals after that would be the exoplanets identified by the Kepler satellite, but Shara stated that he expects no aliens in the Milky Way, because we've seen no evidence of their attempted exploration.

time	1 year	10 years	100 years	1000 years
% Earth oxygen	0.004	0.01	0.6	24
temperature (^{o}F)	-76	-58	32	32
% Earth pressure	0.6	2	94	104

The TEACHERS CLEARINGHOUSE FOR SCIENCE AND SOCIETY EDUCATION, INC., was founded at The New Lincoln School on 11 March 1982 by Irma S. Jarcho, John L. Roeder, and the late Nancy S. Van Vranken. Its purpose is to channel information on science and society education to interested readers. To this end it publishes this *Newsletter* three times a year. Thanks to funds from tax-deductible contributions, the Clearinghouse is happy to be able to offer its services for a one-time nominal charge. In order to continue offering its services for a nominal charge, it also solicits underwriting of its publications by interested corporate sponsors. All correspondence should be addressed to the editor-in-chief at 194 Washington Road, Princeton, NJ 08540-6447 or via e-mail at <JLRoeder@aol.com>. The Clearinghouse is sponsored by the Association of Teachers in Independent Schools, Inc., and is affiliated with the Triangle Coalition for Science and Technology Education.

PCAST targets postsecondary STEM Ed

In its *Prepare and Inspire* report two years ago, the President's Council of Advisors on Science and Technology (PCAST) addressed the need for improved education in science, technology, engineering, and mathematics (STEM) at the K-12 level. Now, in a new report, *Engage to Excel: Producing One Million Additional College Graduates With Degrees in Science, Technology, Engineering, and Mathematics*, they target postsecondary STEM education. The reason is that maintaining the historic U.S. preeminence in science and technology requires a million more STEM professionals over the next decade than would otherwise be produced – a 34% increase over current rates of 300,000 STEM bachelor and associate degrees per year.

PCAST states that three quarters of this need could be filled by increasing the retention of those with initial intentions of earning a STEM degree, currently less than 40%, by 40 to 50%. They add that the three most prevalent reasons that college students drop STEM majors are 1) uninspiring introductory courses (a point made by non-science majors when they took these courses, according to Sheila Tobias in her research for *They're Not Dumb, They're Different*, covered in our Spring 1992 issue), 2) difficulty with required math, and 3) an unwelcoming atmosphere.

Because the first two years of college are the most critical for recruiting and retaining STEM majors, they are the focus of this report, leading to three "imperatives":

1) "Improve the first two years of STEM education in college."
2) "Provide all students with the tools to excel."
3) "Diversify pathways to STEM degrees."

The title of the report was so chosen because excelling in STEM fields requires the engagement of all concerned – students, teachers, and leaders in academia, industry, and government.

To achieve its three imperatives, the report makes five overarching recommendations, each with a set of actions, each with its set of implementation actions, responsible government agencies, and estimated costs. The five recommendations are as follows:

1. *Catalyze widespread adoption of empirically validated teaching practices*. We have learned at the precollege level that engaging students improves their learning, and there have been some noteworthy implementations of teaching at the college level that equally engages students. But since this transformation needs to become much more widespread, the first implementation action is to "Establish discipline-focused programs funded by Federal research agencies, academic institutions, disciplinary societies, and foundations to train current and future faculty in evidence-based teaching practices." Though the envisioned reformed teaching will not necessarily be more costly, making the transition to it requires time and effort that could be costly. Reaching 10-20% of the 230,000 STEM faculty in the U.S. in five years should be possible at a cost of $10-15 million per year.

2. *Advocate and provide support for replacing standard laboratory courses with discovery-based research courses*. "Traditional introductory laboratory courses generally do not capture the creativity of STEM disciplines," the report states. "They often involve repeating classical experiments to reproduce known results, rather than engaging students in experiments with the possibility of true discovery," while "Engineering curricula in the first two years have long made use of design courses that engage student creativity."

3. *Launch a national experiment in postsecondary math education to address the math preparation gap*. The math preparation gap is the result of an insufficient number of high school graduates with sufficient math skills, with many of these graduates persuaded by their introductory math courses that all STEM fields are dull. "Reducing or eliminating the mathematics preparation gap is one of the most urgent challenges – and promising opportunities – in preparing the workforce of the 21st century," the report emphasizes. Elsewhere it calls out to "reduce or remove the bottleneck" which is "currently keeping many students from pursuing STEM majors," and it does so by any means imaginable in buttressing the first implementation action for this recommendation to "Support a national experiment in mathematics undergraduate education at NSF, the Department of Labor, and the Department of Education."

4. *Encourage partnerships among stakeholders to diversify pathways to STEM careers*. The phrase "by any means imaginable" is operable here as well, as is evident from the fact that this recommendation carries with it four implementation actions.

5. *Create a Presidential Council on STEM Education with leadership from the academic and business communities to provide strategic leadership for transformative and sustainable change in STEM undergraduate educa-*

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NGA cites benefit of STEM education

- STEM job holders earn 11% more than their counterparts with the same degrees in other jobs.
- The top ten bachelor degree majors with highest median earnings are all in STEM fields.
- The average wage of $77,880 for STEM occupations in May 2009 was greater than the average wage of $43,460 for non-STEM occupations.
- STEM jobs increased in number three times faster than non-STEM jobs for the past 10 years and are expected to continue increasing two times faster.
- The 2010 unemployment rate for STEM workers was 5.3%, 10% for all others.

These are the reasons the National Governors Association (NGA) gives for the importance of students in their states to take courses in science, technology, engineering, and mathematics (STEM) in *Building a Science, Technology, Engineering and Math Education Agenda,* which begins with the following observation:

> Increasing the number of students versed in STEM and growing the number of graduates pursuing STEM careers or advanced studies are critical to the economic prosperity of every state and the nation. A labor force without a rich supply of STEM-skilled individuals will face stagnant or even declining wealth by failing to compete in the global economy, where discovery, innovation, and rapid adaption are necessary elements for success. (p. 9)

Two goals of the "STEM Agenda" are cited:

1) "expand the number of students prepared to enter post-secondary study and pursue careers in the areas of science, technology, engineering, and mathematics."
2) "boost the proficiency of all students in basic STEM knowledge." (p. 11)

". . . both goals are intended to enhance the global competitiveness of the U.S. economy and help individuals achieve economic security in their careers." (p. 11) (STEM proficiency is noted to be important for all students, because it facilitates problem solving and critical thinking.)

Yet, in spite of the aforementioned employment advantages of a STEM background, the NGA laments that STEM fields comprise little more than 10% of the bachelor's degrees currently awarded in the U.S., while they comprise more than half the bachelor's degrees in Japan, China, and Singapore.

The NGA report attributes this deficiency of STEM graduates in the U.S. to the following five factors:

- Lack of rigorous K–12 math and science standards.
- Lack of qualified instructors.
- Lack of preparation for postsecondary STEM study.
- Failure to motivate student interest in math and science.
- Failure of the postsecondary system to meet STEM job demands.

But the NGA is not content just to put out a call for action. It knows that the states are responsible for forthcoming action and closes by describing the steps that states have already taken and will be taking in the future to do the following:

- Adopt rigorous math and science standards and improved assessments;
- Place and retain more qualified teachers in the classroom;
- Provide more rigorous preparation for STEM students;
- Use informal learning to expand math and science beyond the classroom; and
- Establish goals for postsecondary institutions to meet STEM job needs.

The National Governors Association report was designed to inform the public and persuade them of the importance of STEM. It is available online at <http://www.nga.org/files/live/sites/NGA/files/pdf/1112STEMGUIDE.PDF;jsessionid=CC905C5294F348DC62BD60C135BC12F2>.

T&E Testing to begin 2014

Of interest to teachers of STS is the mention in the NGA report that, although the National Assessment of Educational Progress (NAEP) presently includes only the S and M of STEM fields, T&E will be added in 2014. Three categories will be evaluated: 1) Technology and Society; 2) Design and Systems; and 3) Information and Communication Technology.

On communicating the science of climate change to the public

Our Fall 2010 issue contained a report on a panel addressing the subject, "When Scientists Should Step In: Media, Politics, and Science," at the previous summer's meeting of the American Association of Physics Teachers. Since then, two articles in the October 2011 issue of *Physics Today* give pointers on how scientists should communicate with the public when they do "step in" to voice what they know about how their area of scientific expertise relates to public issues. This is done in the context of communicating to the public about a science-related topic of increasing public controversy – climate change.

Richard C. J. Somerville and Susan Joy Hassol begin their article on "Communicating the science of climate change" by citing the results of a May 2011 public-opinion study by a team from Yale and George Mason Universities: "only 64% of American s think the world is warming (down from a high of 71% . . . in November 2008)" – with 12% "alarmed," 27% "concerned," and 25% "cautions." "And," they add, "only 47% of all respondents believe that global warming, if it exists, is caused mostly by human activity." Moreover, an even lower percentage of the public is aware that "at least 97% of climate researchers most actively publishing in the field agree that climate change is occurring and that it is primarily human-induced."

Somerville and Hassol attribute these figures to a variety of causes – including concern about the impact addressing climate change will have on our fragile economy, "well-organized and well-funded disinformation campaign[s]" whose motivations range from ideological to financial (one consequence being the public's imperceptions of the strong scientific consensus), "widespread scientific illiteracy," and "the way the media handle the topic." "They often portray climate change as a controversy, presenting the opposing sides as equally credible," they lament, adding that "the current crisis in journalism has also resulted in fewer experienced reporters with the requisite expertise."

But, of all the causes of lack of public belief in climate change, Somerville and Hassol note that "Not least important is how scientists communicate – or fail to do so." They point out that "Effective communication is usually not a lecture but a conversation that involves what people really care about. People generally care less about basic science than about how climate change will affect them and what can be done about it. Furthermore," they add, "climate change is often framed as an environmental issue, when it should more appropriately be framed as an issue threatening the economy and affecting humanity's most basic needs, food, water, safety, and security."

As examples of disinformation campaigns, Somerville and Hassol cite the way opponents pounced on errors (since corrected) in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change in 2007 and "the online publication in 2009 of stolen emails written by prominent climate scientists [which] promptly led to publicized accusations of data tampering and other wrongdoing." They also fault scientists for trying to communicate with the public in the same way they do to each other, "beginning with background information, moving to supporting details, and finally coming to their results and conclusions." But, Somerville and Hassol counsel, they should begin with the bottom line in communicating with the public and "craft simple, clear messages and repeat them often."

Somerville and Hassol also criticize scientists for speaking in "code." Key words have a different meaning to the public than to other scientists, they point out, and they provide a table of the public meaning of scientific terms, with suggestions of other words that would be better choices to convey the scientists' intended meaning to the public (see table, next page).

Somerville and Hassol also caution that using the terms "belief" and "consensus" in connection with climate change run the risk of conveying the meaning that "makes some in the public conclude that global warming is just a matter of opinion." And "when scientists say human activity 'contributes' to global warming, that sounds like it could be a small contribution, when in fact it is the primary cause." Somerville and Hassol go on to point out that "when climate scientists say that warming is 'inevitable,' it can give the impression that nothing can be done." Rather, they need to emphasize "that society faces choices. Although it is true that some additional warming cannot be avoided, the amount of future warming is still largely in our hands. . . . we can improve the chances that the public will hear and accept the science if we include positive messages about our ability to solve the problem."

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climate change

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Steven Sherwood examines the public's attitude toward climate change in relationship to public acceptance of "Science controversies past and present," the past controversies being the heliocentric model of the universe presented by Copernicus in 1543 and the general theory of relativity presented by Einstein in 1916. "All three provocative ideas," Sherwood writes, "have been in [Thomas] Kuhn's words, 'destructive of an entire fabric of thought,' and have shattered notions that make us feel safe. That kind of change can turn people away from reason and toward emotion, especially when the ideas are pressed on them with great force."

The first identification of global warming from greenhouse gases was by John Tyndall in 1864, and Svante Arrhenius followed this by an 1896 prediction of the increase in global temperature that would come from burning coal. Confirmatory tests by Guy Callendar in the 1930s lead Sherwood to write that "It took both Copernicanism and greenhouse warming roughly a century to go from initial proposal to broad acceptance by the relevant scientific communities" (the corresponding interval for heliocentrism was the 89 years between the publication of Copernicus' *De Revolutionibus* in 1543 and Galileo's *Dialogue Concerning the Two Chief World Systems* in 1632), Sherwood writes, adding that "It remains to be seen how long it will take greenhouse warming to achieve a clear public consensus; one hopes it will not take another century."

Yet, as if it can be a source of consolation, Sherwood recognizes that "The ugly nature of the current climate debate, with its increasingly frequent characterization of scientists as opportunists, totalitarians, or downright criminals, is also, unfortunately, not new. Copernicus (posthumously) and his prominent followers through Isaac Newton were all accused of being heretics or atheists. Einstein was derided by his political opponents through the 1920s and 1930s as a Communist . . . or simply as a fraud."

scientific term	public meaning	better choice
enhance	improve	intensify, increase
aerosol	spray can	tiny atmospheric particle
positive trend	good trend	upward trend
positive feedback	good response, praise	vicious cycle, self-reinforcing cycle
theory	hunch, speculation	scientific understanding
uncertainty	ignorance	range
error	mistake, wrong, incorrect	difference from exact true number
bias	distortion, political motive	offset from an observation
sign	indication, astrological sign	plus or minus sign
values	ethics, monetary value	numbers, quantity
manipulation	illicit tampering	scientific data processing
scheme	devious plot	systematic plan
anomaly	abnormal occurrence	change from long-term average

FORTHCOMING SCIENCE & SOCIETY EDUCATION MEETINGS

27-29 Mar 12, EEGlobal, the 2012 Energy Efficiency Global Forum, The Peabody Resort, Orlando, FL. Contact Alliance to Save Energy, (202)-857-0666, <info@ase.org>.

PCAST

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tion. The purpose of this recommendation is to oversee implementation of the other four.

Engage to Excel is available online at <http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_feb.pdf>.

Socolow Revisits "Wedges"

When Robert Socolow and Steven Pacala published their original "wedge" strategy to stabilize emissions of carbon dioxide in order to cap its atmospheric concentration at less than twice its pre-industrial level of 280 ppm in the 13 August 2004 issue of *Science*, they proposed achieving it through seven "wedges" to form a "stabilization triangle," each wedge representing a reduction of 25 gigatons of carbon over 50 years. When Socolow spoke to Princeton University alumni on the same topic on 8 April 2008, since no action had been taken to implement the wedge strategy in the preceding four years, the number of required wedges had increased to eight.

Almost four years after revisiting his wedge strategy, Socolow has visited it yet again. In an online paper, "Wedges Reaffirmed," presented jointly by the *Bulletin of Atomic Scientists* and Climate Central, he writes that

> Today, *nine* wedges are required to fill the stabilization triangle, instead of seven. A two-segment global carbon-dioxide emissions trajectory that starts now instead of seven years ago – flat for 50 years, then falling nearly to zero over the following 50 years – adds another 50 parts per million to the equilibrium concentration. The delayed trajectory produces nearly half a degree Celsius . . . of extra rise in the average surface temperature of the Earth. . . . Between 2001 and 2008, the emissions rate climbed by more than a quarter.

Mindful that there now appears to be greater denial that climate change is a result of human activity and that many place a greater priority on economic recovery, regardless of its impact on climate change, Socolow writes that

> Over the past seven years, I wish we had been more forthcoming with three messages: We should have conceded, prominently, that the news about climate change is unwelcome, that today's climate science is incomplete, and that every "solution" carries risk. I don't know for sure that such candor would have produced a less polarized public discourse. But I bet it would have. Our audiences would have been reassured that we and they are on the same team – that we are not holding anything back and have the same hopes and fears.

But while Socolow feels that his paper "contains the sobering message that the job ahead is daunting," he also feels that "humanity is not hopeless" and that "it is not too late to bring these messages forward." Admitting that "environmental science has brought unwelcome news – that the actions of our species are capable of changing the planet at global scale," he states that "it is counterproductive for advocates of prompt action on climate change to pretend that the new knowledge has only positive consequences, such as the stimulation of green jobs and elegant new technology." More realistically, he writes that

> Global prosperity now depends on our species' success at a totally unfamiliar assignment: to "fit" our many billions of people on this small planet, with its finite resources and finite capacity to withstand pollution. The job will be very hard and will require sustained focus.

He adds that

> . . . we should anticipate robust resistance to the message that we are fouling our own nest with fossil fuel emissions and deforestation. Armed with insights from psychology and history, communicators of the climate change threat will more deeply understand the hostility to their message.

Socolow continues by stating that "It would be productive for advocates of prompt action also to concede that the message from climate science is not only unwelcome but also incomplete. . . . I think it should be possible to convey that Earth systems science is an evolving human enterprise where discordant views are the norm, and then to explain why certain issues have proved hard to resolve. My working assumption is that candor creates trust." He concludes this section of his paper with a wish that

> some museum would prepare a climate exhibit with two adjacent displays that show two worlds with the same greenhouse gas concentrations at some future date (say, 50 years from now). One display would show a world in which human beings have been lucky and the worst manifestations of climate change have not yet arrived; in the other, we have been unlucky and at least a few of the more high-consequence outcomes are already on the scene. With the help of such an exhibit, the public would understand that neither those who proclaim with certainty that the world is facing imminent disaster nor those who seek to convince us that negligible suffering lies ahead can defend their case without going beyond today's climate science.

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Global prosperity now depends on our species' success at a totally unfamiliar assignment: to "fit" our many billions of people on this small planet, with its finite resources and finite capacity to withstand pollution. The job will be very hard and will require sustained focus.

Fueling the Car of Tomorrow

Our greatest dependence on oil is for transportation and space heating, primarily the former. We continually talk about reducing that dependence so that we are not beholden to politically unstable regions of the world. Another reason would be to prepare for the eventual depletion of the world's oil reserves. Still we want to preserve the mobility to which we have become accustomed. How appropriate is it that The University of Detroit Mercy's College of Engineering and Science (in our nation's automotive capital) should have developed a curriculum titled *Fueling the Car of Tomorrow*!

This curriculum, which can be downloaded online at <http://eng-sci.dmercy.edu/precollege/alt_fuel_curriculum/>, consists of a "series of hands-on activities intended to teach high school students about the future of the automobile through the eyes of scientists and engineers." These seventeen activities can be infused into high school biology, chemistry, or engineering courses or constitute a stand-alone pre-engineering course. Eight of the activities relate especially to engineering, and five each to chemistry and to biology.

The focus of these activities is primarily the internal combustion engine and its modifications designed to accommodate alternative fuels to gasoline. The combustion process and its products are addressed, also how the efficiency of the internal combustion engine varies with the speed of the vehicle. Students then make and measure the properties of ethanol from sugar and yeast and biodiesel from methanol, sodium hydroxide, and vegetable oil. They investigate how ethanol can be made from starch and cellulose (in the form of toilet paper) as well as from sugar, given the greater abundance of the former. And they also investigate the role of bacteria, both to produce ethanol and to produce enzymes (in this case, to decompose hydrogen peroxide).

Only three of the final five activities do not deal with combustible fuels but, rather, with the role of hydrogen fuel and electricity (hydrogen is made in the laboratory from zinc and hydrochloric acid, the mechanical power and electrical energy produced by batteries is measured, and a hybrid vehicle is compared with a conventional vehicle in a computer simulation). The final activity, "Which Fuel is Best? Compares gasoline, ethanol, biodiesel, electricity (from coal), and hydrogen (from solar) on the basis of efficiency, cost, materials used, and carbon dioxide generated.

Curricula available from Project Look Sharp

Project Look Sharp at Ithaca College is a source of a variety of curricula of interest to teachers of science, technology, and society topics. They can be purchased or downloaded without charge from the Project's website, <www.projectlooksharp.org>. Printed lessons typically include a Teacher's Guide, Student Handout, Student Worksheets, and Student Readings; they are supplemented by PowerPoint presentations and videos.

Project Look Sharp's five environmental curricula are described as follows:

<u>1. Chemicals in the Environment</u>. This five-lesson curriculum for middle school through college is described in a 185-page curriculum guide. The lesson titles are toxic chemicals, Rachel Carson (two lessons), reactor safety, and depleted uranium.

<u>2. Endangered Species</u>. This five-lesson curriculum for middle school through college is described in a 185-page curriculum guide. The lesson titles are history, humans and animals, the Northern Rockies gray wolf, the rainforest, frogs and atrazine.

<u>3. Resource Depletion</u>. This five-lesson curriculum for middle school through college is described in a 185-page curriculum guide. The lesson titles are history, damming rivers, Arctic oil drilling, the Exxon *Valdez*, and water rights.

<u>4. Global Warming</u>. This eight-lesson curriculum for high school through college is described in a 383-page curriculum guide. The lesson titles are framing the debate, conclusions from data, bias in reporting, causes, consequences, the precautionary principle, carbon footprints, and global warming in media.

<u>5. Sustainability</u>. This is a nineteen lesson curriculum for high school through college. The lessons focus on the sustainable use of resources used to provide our food.

Curriculum kits from Project Look Sharp are also available in U.S. History, Health, Global Studies, Psychology and Aging Studies, and General Media Literacy.

AIP and AVS: "Energy Transition to a Sustainable Future"

The American Institute of Physics and the American Vacuum Society (AVS) organized an Industrial Physics Forum on "Energy Transition to a Sustainable Future," held during the AVS International Symposium in Nashville, TN, in November 2011. It began with a session on "Energy Security and Energy Policy" and closed with a session on "Materials for a Sustainable Future." Other topics included new developments in safety and efficiency regarding electric energy and transportation.

The opening session on energy security and policy was addressed by five speakers: William Hogan of Harvard University, Edward Steinfeld of MIT, Ellen Williams of BP, Aristides Patrinos of Synthetic Genomics, and Omkaram Nalamasu of Applied Materials. Hogan set the scene by recounting the role of fossil fuel use in the U.S. since the Arab Oil Embargo. Steinfeld set forth four stages of bringing a new development in energy to commercial fruition – 1) creating options, 2) demonstrating feasibility, 3) early adoption, and 4) improvements in use. Each stage requires increasingly higher levels of investment, Steinfeld noted, and the U.S. leads the world in stage #1; but, he lamented, the U.S. has lagged behind China in stages #2 through #4.

Williams reported on efforts by BP to offset the emissions from burning the fossil fuels it is known for. One of these is biofuels, but producing them in a way that does not require fossil fuels, as is the case for fertilizing corn. BP research seeks to develop synthetic enzymes that can extract ethanol from woodier plants that grow year round and require little fertilizer. BP is also researching ways to sequester carbon dioxide emissions underground, a process that can add underground pressure to facilitate the extraction of oil from BP oilfields. Patrinos reported on research to synthesize organisms that could produce biofuels more efficiently than naturally-occurring organisms – *e.g.*, synthetic algae, which could also have the advantage of being able to thrive in dirty, salty environments that cannot be used to produce food for humans. Nalamasu reported on efforts to make LEDs cheaper so that they can replace compact fluorescent bulbs and therefore eliminate the environmental problem posed by the compact fluorescent's mercury vapor and further reduce the present 22% of U.S. electricity presently used for lighting.

The first of three speakers on the role of electric energy, Harold McFarlane of Idaho National Laboratory pointed up the advantages and disadvantages of nuclear energy and discussed new designs for safer nuclear reactors. John Kassakian of MIT followed by listing the advantages of installing "smart" features in the electric grid. Lastly, Zhenguo "Gary" Yang from Pacific Northwest National Laboratory (Richland, WA) described the latest in battery technologies: lithium-ion (light but low in energy density), sodium sulfur, and vanadium redox (high storage capacity and charge rate but low energy density). Yang also cited the lithium-air battery (light with high energy density but poor charge-discharge properties).

Also reporting on the lithium-air battery was Sally Swanson of IBM, where a team is working to improve the battery's performance and thereby increase the range of electric transportation. Another effort to make more efficient use of energy in transportation was the thermoelectric generator designed to generate electricity from the high temperature of an automobile's exhaust gases, as described by Gregory Meisner of General Motors.

At the closing session on "Materials for a Sustainable Future," Todd Allen of the University of Wisconsin-Madison pointed up the importance of the choice of the right materials in nuclear reactor design.

(*Editor's Note*: This article was extracted from coverage of talks at the Industrial Physics Forum provided by Charles Day and Jermey Matthews of the American Institute of Physics.)

Socolow on Wedges

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Lastly, Socolow advocates dealing with the inherent risk in any approach to dealing with climate change in an iterative process, by evaluating the effects of policies in short-term intervals and taking into account the results of new research and development during the most recent interval in deciding what to do in the next one.

(*Editor's Note*: Socolow's paper, "Wedges Reaffirmed," is available online at <http://www.climatecentral.org/blogs/wedges-reaffirmed/>. Our coverage of the original Socolow and Pacala paper appeared in our Fall 2004 issue, our coverage of Socolow's talk upgrading the number of wedges to eight in our Spring 2008 issue.)

Science addresses food security

The 1996 World Food Summit defined food security to be "a situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preference for an active and healthy life." Food security is the topic of a special section in the 12 February 2010 issue of *Science*, and its major review, written by a team of ten led by H. Charles J. Godfray, notes that the greater affluence expected in a population whose growth is decelerating will add to the demand for food whose production places the greatest pressures on an environment that is already threatened by climate change. "A threefold challenge now faces the world: Match the rapidly changing demand for food from a larger and more affluent population to its supply; do so in ways that are environmentally and socially sustainable; and ensure that the world's poorest people are no longer hungry," they write.

To feed the expected world population of 9 billion in 2050 is expected to require between 70% and 100% more food – the figure of 70% is cited by the Declaration of the World Summit on Food Security in a second review by Mark Tester and Peter Langridge – and this is going to have to be produced on no more land than is under cultivation today (other land is being lost to urban development or needs to be preserved for the sake of biodiversity and our natural environment). Moreover, more land will be needed for housing and feeding an increased number of livestock – already, increased wealth of consumers, particularly in China and India, has increased the demand for meat and dairy products, leading to a 1.5-fold worldwide increase in cattle, sheep and goats, 2.5-fold increase in pigs, and 4.5-fold increase in chickens in the last 50 years, with a third of global grain production fed to them.

"The Green Revolution succeeded by using conventional breeding to develop F_1 hybrid varieties of maize and semidwarf, disease-resistant varieties of wheat and rice . . . . the importance of greater water-and nutrient-use efficiency, as well as tolerance of abiotic stress, is also likely to increase," Godfray writes. "Modern genetic techniques and a better understanding of crop physiology allow for a more directed approach to selection across multiple traits." Here Godfray strikes a theme that is echoed by many other contributors to this special section on food security: the need for genetic modification techniques to be accepted worldwide if the world's future food security is to be assured. Acknowledging the opposition to genetic modification, on basic principles by some and as a symbol of corporate greed by others, he recognizes that it cannot play its required role in providing food security until it gains public trust and acceptance. Tester and Langridge echo this as follows:

> . . . more is required than can be provided by traditional breeding approaches . . . . GM technologies permit the generation of novel variation beyond that which is available in naturally occurring (or even deliberately mutated) populations. . . . Nevertheless, the widespread application of GM technologies will remain limited while regulatory demands impose high costs on releasing GM crops. Although it is likely that most of the important contributions to crop improvement in the coming 5 to 10 years will continue to be from non-GM approaches, we consider that transgenic technologies will inevitably be deployed for most major crops in the future.

Godfray also writes about what genetic modification can achieve in the future beyond its present achievements. Current genetically modified crops have been developed by inserting single genes to incorporate single traits, but the next level will incorporate combinations of traits or polygenic traits by incorporating multiple genes. One such polygenic trait would be nitrogen fixation, which is one of the goals for engineering crops for the future, in order to eliminate the nitrate pollution and nitrous oxide emissions that plague present agricultural practice. Other goals for genetically modifying crops to provide future food security include increased yield and more nutritional yield, resistance to disease, resistance to pests, tolerance of drought and salinity, reduced methane emission from livestock, asexual reproduction in hybrids (to improve their seed quality), and conversion of annuals to perennials.

Other ways to enhance food security include reducing food waste, precision agriculture, and modifying diets. Waste is the present fate of 30-40% of food worldwide, partly because of inadequate storage facilities, but also because of concern about cosmetic appearance and adherence to premature "use by" dates. "Precision agriculture, or information-based management of agricultural production systems, emerged in the mid-1980s as a way to apply the right treatment in the right place at the right time," write Robin Gibbers and Viacheslav Adamchuck. Global navigation satellite systems, geographic information systems, and other sensors (electromagnetic, optical, and chemical) connected to computes can profile a field for such parameters as diseases, weeds, pests, soil moisture, and soil condition (including pH), then direct the application of needed treatment by automatically-guided vehi-

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give the impression that one is thinking of the wellbeing of future generations, but the definition itself is vague; it gives no specifics or hints about the nature of a sustainable society or about how we must conduct our society in order to become sustainable. This vagueness of definition opens the door for people to use the term "sustainability" to mean anything they want it to mean. It's straight from Alice in Wonderland where Humpty Dumpty proclaims (7), "When I use a word, it means just what I choose it to mean, neither more nor less." With the freedom supplied by the vagueness, anyone can become an expert on sustainability.

Unfortunately, the Brundtland definition contains a flaw. It focuses first on the needs of the present, which have nothing to do with sustainability, and secondarily it mentions the needs of future generations which are vital for sustainability. This sets the stage for intergenerational conflict in which the present wins and future generations lose. We need to rephrase the Brundtland definition as follows:

> **Sustainable development is development that does not compromise the ability of future generations to meet their own needs.**

Peak Petroleum Production and Global Climate Change

Today we face two major global threats to our way of life: the two threats are related and both are predictable consequences of a single cause; overpopulation. The first threat is the peaking of the production (tons per year) of fossil fuels, particularly petroleum. The second threat is the rapidly developing global climate change. As these threats develop, each will have a profound effect on life as we know it. To understand the first threat we need to know about the Hubbert Curve.

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cles. Diets rich in food with low (food input/food output) ratios can enhance food security, and Gretchen Vogel notes that this ratio is particularly low for insects – only 1/2, as opposed to 1/8 for a cow. But Erik Stokstad points out that eating less beef would not benefit the Asians who eat largely rice and wheat, because cows eat corn and soybeans. In fact, since people eating less beef would probably eat more pasta, *less* wheat would be available to Asians. However, feeding less corn and soybeans to fewer cows would benefit Latin Americans and Africans.

This brings us to Gebisa Ejeta, who writes "Sub-Saharan Africa remains the only region in the world where hunger and poverty prevail" in a contribution titled "African Green Revolution Needn't Be a Mirage." Indeed, Godfray has informed us that in the last 50 years per capita food production has increased by a factor of 2 in Asia, 1.6 in Latin America, but has barely kept pace in Africa. Ejeta, who received a World Food Prize for genetically engineering a sorghum strain resistant to the parasite *Striga Hermonthica*, notes that much needs to be done to do for the critical African crops of sorghum, millet, maize, and cassava what the Asian Green Revolution did for wheat and rice.

A final admonition regarding food security comes from a team of sixteen headed by N. V. Federoff in a contribution titled "Radically Rethinking Agriculture for the 21st Century." Noting that we are expecting to have to feed three billion more people by 2050, using the same amount of arable land we have today, with the added challenge of climate change and water scarcity, they write that "photosynthesis has a temperature optimum in the range of 20°C to 25°C for our major temperate crops," because "plants develop faster as temperature increases, leaving less time to accumulate the carbohydrates, fats, and proteins that constitute the bulk of fruits and grains." Rather than focus on developing crop varieties to produce greater yields in today's agricultural environment, Federoff, *et al.*, urge us to develop varieties that will produce greater yields in the agricultural environment of the future – with increased temperature, decreased water in some places, flooding in others, rising salinity, and different pathogens and pests. They also note that the successful record of efficacy and safety in growing genetically modified crops the past 13 years indicates that the present system of required approvals should be re-evaluated to become less complex and costly, thus opening the field to university researchers, who would produce genetically modified varieties for new crop species, for which the seed demand is not large enough to warrant corporate investment.

(*Editor's Note*: In addition to the work by the authors cited, this article also drew from work written by Christopher Barrett and Elizabeth Pennisi.)

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The Hubbert Curve

Back in the 1950s the geophysicist M. King Hubbert noted that a couple of centuries ago the production (in tons per year) of a finite non-renewable resource, such as petroleum, was essentially zero. He reasoned that production would rise to one or more maxima after which it would decline back to zero in another century or two. No matter how erratic the production turns out to be, the curve of production (tons per year) vs. time (years) can be approximated by the Gaussian Error Curve which starts at zero, rises to a maximum and then returns to zero. The area under the curve from zero to infinity is equal to the ultimate size R of the recoverable resource measured in tons. This curve is known at the Hubbert Curve. The important parameter of the curve is the date of the maximum. In the case of petroleum production in the U.S., the peak occurred in 1971, just as Hubbert had predicted years earlier.

The mathematical exercise of fitting a Gaussian Curve to the world petroleum production data shows that if the world's ultimate recoverable quantity of conventional petroleum is 2000 billion barrels, then the peak of world petroleum production could be expected around the year 2004 and the peak moves to a later date at the rate of 5.5 days for every billion barrels that is added to the estimated world supply. (8, 9) In the case of world petroleum today (2012), there is debate among petroleum experts as to whether or not the world peak may have already passed. (10)

The passing of the world peak of petroleum production will be a major milestone for human life on Earth because it will mean that the tons per year of petroleum being produced world-wide will start to decline in its inevitable but erratic descent toward zero. At the same time the world population is projected to be increasing and the world per capita demand for petroleum can also be expected to be increasing. Supplies are decreasing but demand is increasing.

Almost all aspects of our industrial society depend on petroleum, so that, as Richard Heinberg has pointed out, peak petroleum will be quickly followed by Peak Everything. (11) In particular, modern agriculture is completely dependent on petroleum, so the peak of world petroleum production will be followed by the peak of world food production. We will then be facing the specter of declining world food production while at the same time the world population is expected to continue to grow. This is a recipe for famine and conflict.

The Transition From Production Controlled by Demand to Production Controlled by Supply

Most discussions of sustainability, especially scientific discussions, tell repeatedly of experts who advocate major programs to increase supplies ("Drill baby, drill!") to meet the demands of growing populations. In this scenario, production is governed largely by demand. The more you need, the more you can have. But now, as the peak of global production of petroleum is near, the world is making the transition from the left side of the Hubbert Curve to the right side. On the left side the quantity produced each year is determined largely by demand while on the right side quantity produced each year is falling so that the quantity produced will be governed mainly by the availability of supplies. As we pass the peak, Nature changes the game. On the left side of the peak, resource shortages are met by increasing production, so the cost of a barrel of petroleum tends over time to rise only slowly. On the right side of the peak, production (barrels per year) is constrained by the availability of supplies of petroleum so that shortages develop and prices rise rapidly.

The discipline of economics has long been accustomed to dealing with life on the rising left side of the Hubbert Curve for most critical resources. On the rising left side we have worked hard to increase resource production in order to meet the growing demand. The big question is, will economics be able to adapt to the completely changed conditions on the right side of the Hubbert Curve where production is determined, not by what we want, but rather by what is available? Will we continue to try to apply left side economics to the right side of the Hubbert Curve?

Global Climate Change

With regard to the second major threat, global climate change, we can note that (12)

> **If any fraction of the observed global climate change can be attributed to the actions of humans, this is positive proof that the human population, living as we do, has already exceeded the carrying capacity of the Earth.**

This condition is unsustainable. This observation provides a direct identification of overpopulation as the main cause of global climate change. Strangely few, if any, of the experts on global climate change have spoken out to

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call public attention to the obvious and clear cause and effect connection between overpopulation and global climate change.

The Cause and Effect Connection Between Overpopulation and Global Climate Change

To the first approximation, the magnitude of the effect of humans in producing global climate change is proportional to the product of the size of the global population P and the average per capita annual consumption of resources, A (tons per (person-year)). The product of P times A is the total annual consumption of resources (tons per year). Already this product appears to have exceeded the carrying capacity of the Earth and the world is briefly in overshoot.

If we are serious about reducing the causes of global climate change, we must reduce both P and A simultaneously and rapidly throughout the world.

This defines the task before us. Reduction of P brings us in conflict with the business community that sees more people as more customers. Reduction of P brings us in conflict with various religious groups that oppose any reduction of births and that regard unrestricted reproduction as a basic human right. The reduction in A must be done equitably, recognizing that today (2012) the average annual per capita consumption of resources A, varies by one or two orders of magnitude between our well-to-do western societies and the world's poorest societies.

The Problem Stated

The problem is apparent at once. Reducing either P or A is completely contrary to the foundations of our religious and economic systems. We are given the impression by "experts" that both P and A must increase continuously if we are to have a "healthy society." How small must P become to be sustainable? David Pimentel, a global agricultural scientist at Cornell University has estimated that a sustainable world population, living at the dietary level of the average American, is about 2 billion people. (13) The world population in late 2011 is estimated to have reached 7 billion people and was growing at the rate of approximately 1% per year! The annual increase of world population in 2012 is thus something like 70 million per year.

Stopping population growth and stopping the growth of rates of consumption of resources are both necessary, but are not sufficient, conditions for sustainability.

The Insufficiency of Popular Prescriptions for Achieving Sustainability

Thousands of individuals and groups are working worldwide on hundreds of aspects of "sustainability." When you look at this work you quickly conclude that all of the usual sustainability prescriptions are valuable, but when you add them all up their sum is much less than what is needed. The reason? All of these efforts fail to address overpopulation! These usual sustainability endeavors include all manner of big research projects and thousands of smaller efforts such as promoting the use of more efficient light bulbs, more efficient automobiles, more efficient homes, expanding and improving the efficiency of the national electric power transmission grid, *etc.*

Back to the Fundamentals: Malthus

Malthus observed some 200 years ago that population growth has the mathematical power to overcome the limited potential of increasing food supplies. By implication, the meaning of the message of Malthus is that, given sufficient time, population growth has the mathematical power to overcome or negate the limited advances that result from all of the technical achievements of our scientific and engineering establishments.

And if you're wondering where do you get the greatest reduction in greenhouse gas emissions per dollar spent, it is interesting to note that one probably gets more reduction per dollar spent if you spend that dollar on family planning as compared to spending it on any of the "engineering type" solutions that are so popular and widespread. It has been estimated that a dollar spent on family planning will yield about five or more times the reduction of the emission of global greenhouse gases than you get when that dollar is spent on engineering "solutions" that are aimed at reducing the emission of greenhouse gases. (14)

Growth as the Centerpiece of Our Economy

In our custom of taking care of ourselves before we think of the future, we are supported by the overwhelming devotion of our society to endless growth which is often called "Sustainable Growth." This oxymoronic concept is the centerpiece of our entire society, in which

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almost all leaders in our business, governing, and economic communities ignore or deny the existence of limits. The universality of the economic belief that there are no limits to growth gives the present generation reason to believe that there will always be plenty for future generations so that, as a consequence, we need not inconvenience ourselves now by accepting restrictions on our consumption or reductions in our population growth rates. As has been prominently asserted (15),

The American way of life is not negotiable!

Nuclear Fission and Fusion

In what follows I am assuming that there will be no major scientific or technological breakthroughs in the energy sector in the next century or so. I am uncertain about the role conventional nuclear fission power will play during the next hundred years. In the U.S. we have failed to provide the promised long-term storage for spent nuclear fuel and there seems to be little support in Washington, DC, to find an answer to the problems of what to do with the existing and predictable future quantities of high-level nuclear waste. Nevada has said that it does not want the Yucca Flats nuclear waste depository located in its borders. It could be expected that, if asked, the people in the other 49 states would say that they do not want the nuclear waste to be stored in their states, either. Unless some way can be found around this impasse, the future of nuclear power in the U.S. does not seem to be very bright. Yet if the lights don't come on when one turns on the switch, people will quickly develop strong support for electrical power from nuclear fission.

Conventional nuclear plants are extremely expensive to construct and to operate and they are very complex. They are subject to occasional accidents, which frequently turn out to be very serious. The finite nature of the supply of uranium suggests that nuclear power is not sustainable. So I don't include nuclear fission as a big player in my view of the distant future.

I have even less hope that there will be the successful development and widespread application of nuclear fusion within the next century or two. Fusion research has been continuing since the end of World War II with the hope that fusion will produce large quantities of low-cost electricity. Judging from the size of today's experimental fusion facilities, any plant using fusion to generate electricity will be very large, very complex and very expensive. Fusion still has a long way to go before it can be expected to meet the demands of the electricity market, which requires reliable electric power 24 hours a day and 365 days a year. The uncertainties are so large that I feel that it would be unwise to count on the widespread availability of fusion-generated electricity on any proposed timetable. Therefore, I leave fission and fusion out of the following discussion of sustainability.

Sustainability of the Solar Society

In the long run, a century or more from now, if our society survives the catastrophic collapse predicted by *Limits to Growth,* the surviving society will be powered solely by solar energy, which includes wind, waterpower, and tidal energy. All of the easily available fossil fuels will have been used to the point where more extraction is uneconomic. Geothermal energy may provide a small fraction of the energy needed by the surviving society. This sounds pretty austere, but the solar society was anticipated with optimism by the famous American inventor Thomas A. Edison many years ago (16):

I'd put my money on the sun and solar energy. What a source of power! I hope we don't have to wait until oil and coal run out before we tackle that.

Sustained Availability

But it is not all doom and gloom. The concept of "Sustained Availability" gives us some freedom to make limited use of fuel and mineral resources during the transition period between the present and the distant future.

Do you remember from calculus that the integral from zero to infinity of $\exp(-kt)$ is finite and has the value $1/k$? This mathematical fact has a useful consequence. Suppose that P is the annual production of a resource in tons per year and that P varies with time according to the equation

$$P = P(0) \exp(-kt)$$

where t is the time in years, $P(0)$ is the present rate of production and k is the fractional change in P per year.

$$k = -(dP/P)/dt$$

For a declining curve, dP is negative. The graph of production in tons per year *vs.* time will be a declining exponential, of the same form as the decay curve for a sample of a radioactive material. The area under the complete curve of tons per year *vs.* years from zero (the present

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time) to infinity is the total amount of the resource (tons) that is consumed in all of the future. This can be set equal to the estimated size *R* of the total remaining resource in tons to give a special value of *k* for which the total resource consumption between now and infinity on the declining exponential curve is equal to the present size *R* of the resource. In other words, a special value of *k* can be found for the reserves of a resource so that the production of the resource declines steadily but *R* lasts forever!

What is the particular value of the constant *k* which will allow the resource to last forever? This can be answered by example. It has been stated that world petroleum will last 40 years at present rates of consumption. In this case the particular value of *k* to make world petroleum last forever is ($k = 1/40 = 0.025$). So if the global use of petroleum is made to decline 2.5% per year the petroleum will last forever! This decay curve has a "half life" of 28 years.

It's important to note that

> **at every point on the decaying production curve, the life expectancy of the then remaining resource will be 40 years at the then current rate of production.**

This has been called "Sustained Availability" (SA). The concept and the options available to a producing country that is following SA to divide production between domestic consumption and export were all examined in mathematical detail in 1986. (17)

More recently, and completely independent of this earlier work, the concept of SA, without the mathematics, has been reinvented and applied to world petroleum production. In the petroleum business, the present rate of production divided by the size of the estimated remaining resource $P(0)/R$ at a given time is called the "Depletion Rate." This is the fraction of the remaining resource that is produced this year; it is the reciprocal of the life expectancy of the resource "at present rates of consumption." World petroleum today (2012) is estimated to last about "40 years at present rates of consumption." The depletion rate is then 2.5% per year.

In 2004 the geologist Colin Campbell of Ireland and the physicist Kjell Aleklett of Uppsala University in Sweden proposed "The Uppsala Protocol" which called for oil producing countries to agree voluntarily to an accord (18):

> **No country shall produce oil at above its current Depletion Rate, such being defined as annual production as a percentage of the estimated amount left to produce.**

Thus, qualitatively Campbell and Aleklett independently re-invented the concept of Sustained Availability that had been published eighteen years earlier.

The concept of Sustained Availability (the Uppsala Protocol) can be applied to the finite reserves of any non-renewable fuel or mineral resource. The rate of decline, *k*, can be adjusted at any time based on new evaluations of the life expectancy of the resource "at present rates of consumption."

This is pretty good. We can use finite resources, such as petroleum, on declining curves in a way that allows future generations to access the resources just as the present generation does but in declining amounts each year. This path for resource production has the unique feature, noted above, that at every point on the declining exponential curve, the life expectancy of the remaining petroleum at the then present rate of consumption will be 40 years!

We now have a "bridge" between our present society with its lavish use of non-renewable energy and the society of the future which will have to live pretty much exclusively on solar energy.

Sustainability: Living Solely on Solar Energy

Here are some scattered thoughts on the central challenge of sustainability: living solely on solar energy. To understand the challenge of sustainability we might first ask what societies in this world today are closest to sustainability? I think we would have to answer that the most sustainable societies today are the primitive societies such as those in remote regions in Africa, Asia, Australia, *etc.* If our society crumbles, these primitive societies will probably go on living their hard and difficult lives being little touched by the collapse of the civilized world.

But as we strive for sustainability, our goal can't be to go back to a primitive way of life. People would simply not accept this. But there is an important lesson here; increasing the technological complexity of our society is probably not the path to follow if we want to move to a

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more sustainable society. So let's not go back thousands of years; let's look at things 200 years ago. The North American society of 200 years ago got along using mainly solar energy. First, and most important, the population was much, much smaller than today's population. Second, the society was an agrarian society with most of the population employed directly or indirectly in agriculture. Draft animals, windmills, and small amounts of water power provided essentially all of the non-human energy used on the farm. The draft animals provided most of the fertilizers that were used. We can see approximately this sort of living today in the Amish communities of western Pennsylvania and eastern Ohio. I suspect that the Amish communities are the closest to sustainability of any of today's American communities.

The Amish communities are mainly agrarian. The people are guided by religious beliefs: in general they use little or no electricity or petroleum and they use little in the way of engineering and technology. Their children are educated perhaps through the 8th grade, which is sufficient for their agricultural work and for their interactions with the world around them. They are very successful in their agricultural pursuits. Their life is simple and austere and their communities contribute very little in the way of global warming gases. As individuals, they have a very small ecological footprint. On the other side of the sustainability ledger, they tend to have a high fertility rate, which is certainly unsustainable.

Now we can see the fundamental question of sustainability:

> **Can we transform our society to a solar-based society which will probably have to be mainly an agrarian society, while keeping and sharing throughout the world the benefits of modern medicine and technology?**

The first observation is that to do this we will have to have a much smaller population than the 7 billion plus that we have today (2012).

Sustainability and Science, Engineering, and Technology

A major consequence of our much heralded science, engineering and technology has been to allow more people to live in regions that once supported only smaller populations. Ever since the age of hunters and gatherers, the population has grown slowly and humans have gradually invented science, engineering, and technology to meet the needs of the growing populations. When the needs were not met, growing populations and civilizations were in trouble. Archaeologists today study the ruins of societies that failed and disappeared. A factor of the demise of these failed societies was the inability of the societies to provide sufficient food for their populations. The societies that persisted did so because they used science and technology to increase agricultural production and to allow urbanization and the rise of cities.

Science, engineering and technology have made today's big cities possible, so that in 2012 something like 82% of Americans live in cities. All over the world people are leaving their poor but marginally sustainable rural life to crowd into the world's massive and increasingly unmanageable cities.

Cities have near zero ecological productivity. In the ecological sense, our cities are deserts and wastelands! They are the human equivalent of the cattle feedlots (and other "high efficiency" facilities for the production of pigs and chickens) that one sees throughout America. In the feedlots the animals are confined: Petroleum is used to haul food to the animals and then more petroleum is used to haul away the waste products. So it is in our cities. The people are confined. Petroleum is used to haul in food and energy and to haul out waste. The human cities and the cattle feedlots are both made possible by science, engineering, technology and by abundant low-cost energy. By making cities possible, science, engineering and technology have supported and encouraged population growth, which is the exactly the opposite of what is required for sustainability.

Sustainability and Scientists, Engineers, and Technologists

As we contemplate how we should deal with the threat of global warming, it is distressing to read a statement by "a professor…who studies international climate policy…" saying that "The way we reduce emissions is through technology." (19) Why is it that engineers, scientists, and technologists almost never recommend stopping population growth as the solution to the problems of reducing global greenhouse gas emissions? Is this solution too obvious?

By ignoring overpopulation, scientists, engineers and technologists put society in a deep hole, yet they seem to forget the old adage:

When you find yourself in a hole - stop digging!

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Throughout the world, our mega-technologists (albeit with a deep sense of responsibility and public service) recommend that we work hard to use science, engineering, and technology to accommodate the growth of populations. Providing food for the expected population increase is presented as a great challenge, even though meeting the challenge will make the population problems worse. Here is a popular national newspaper columnist writing on the problems of overpopulation in the U.S. (20):

> **The United States has its population challenges at home – building the infrastructure from schools to roads to food supply – for a predicted 100 million more people [in the U.S.] by 2040.**

The prevailing reaction of our leaders seems to be to speed up our digging. If we raise taxes and spend heavily and build the public infrastructure needed to accommodate the predicted population growth, then the people will appear. We have trapped ourselves in a self-fulfilling prediction.

> **Can it be that scientists, engineers and technologists are impeding the movement of our society toward sustainability?**

Science, engineering, and technology have made it possible for populations to grow so large that by our largeness we are threatening the global ecosphere. Is this what we want from our science and technology?

The Role of Science, Engineering, and Technology in a Sustainable Society

There *is* a role for science, engineering, and technology in a sustainable society. This is because the sustainable society will operate from electricity with large amounts coming from solar cells and wind turbines, with smaller amounts coming from hydroelectric and geothermal sources. Science, engineering, and technology will be needed to improve the efficiency of the generation, transmission, and use of the electrical energy.

Sustainability and Politics

We deplore the scientific illiteracy of members of Congress because many members don't understand the implications of the large scale of things created by our science, engineering, and technology. Should the members of Congress be criticized for their scientific illiteracy because they don't recognize the problems that are developing so rapidly, or should we criticize ourselves for not recognizing that the overpopulation created by all of our actions has caused these predictable problems? Carl Sagan observed that (21)

> **We've arranged a global civilization in which most crucial elements – transportation, communications, and all other industries; agriculture, medicine, education, entertainment, protecting the environment; and even the key democratic institution of voting – profoundly depend on science and technology. We have also arranged things so that almost no one understands science and technology. This is a prescription for disaster. We might get away with it for a while, but sooner or later this combustible mixture of ignorance and power is going to blow up in our faces.**

Sustainability and Geoengineering

One of the most alarming technological trends today is the eagerness with which technologists and many nonscientists, in the name of sustainability, are endorsing megaprojects of geoengineering that are intended to allow the continued growth of our growth-based society. For instance, we see proposals to mess with the Earth's atmosphere globally by a program of continuous injection of particulates in the upper atmosphere to scatter sunlight away from the Earth in order to reduce global warming. These technologists who offer geoengineering as a solution to the problem of global warming seem to ignore Eric Sevareid's Law (22):

> **The chief cause of problems is solutions.**

Has there been a comprehensive evaluation of the many problems that will result if we start a global project of injecting small particles into the upper atmosphere? And what about the problems that we don't anticipate in advance?

Sustainability and Desertec

A megascale high-tech "environmentally friendly" project called Desertec is currently gaining support in Europe. It is proposed to cover large parts of the Sahara Desert in Africa with solar collectors which will be used to generate electricity that will then be sent to Europe via electrical transmission lines and cables under the Mediterranean. This might work in a peaceful world, but long lonely transmission lines are tempting targets for terrorists, as are undersea cables. (23)

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People have forgotten that with the opening of the first World War almost 100 years ago, the first thing the British did was to send out naval raiding parties to destroy German undersea cables and remote relay stations that provided communications between Germany and its African colonies. At the same time the Germans were sending out naval raiding parties to attack and destroy British undersea cables and relay stations that kept Britain in communication with its world-wide empire. (24) Our mega-technologists today seem to forget that

> **Those who don't know history are destined to repeat it.** (25)

Sustainability and Smart Growth

Planners sometimes promote "Smart Growth" as the solution to the problem of sustainability. Smart Growth applies to new developments which are built to accommodate growth. It calls for development on a human scale with places of work, shopping and recreation all being located within walking or bicycling distances from the residences. This is very pleasant indeed. But we must note that

> **Dumb growth destroys the environment.**
> **Smart growth destroys the environment.**
> **The difference is that smart growth**
> **destroys the environment with good taste.**
> **So it's like buying a ticket on the TITANIC.**
> **If you're smart you go first class**
> **If you're dumb you go steerage.**
> **Either way the result is the same.**

Sustainability and Localization

"Peak Petroleum" will cause rapid increases of transportation costs and thus make it more difficult to move fresh food half way around the world to the shelves in our supermarkets. Sustainability will require that the bulk of our food be produced locally near its point of consumption. We have the opposite of this in the world today in which items of food are transported to the wealthy countries from all parts of the world. World trade agreements will be reduced in importance because of a reduction of international trade.

Sustainability and Education

Throughout the country, colleges and universities are introducing courses and educational programs in topics such as "Sustainability Studies." (26) It would be interesting to know how many, if any, of these programs stress the fundamental requirement of the First Law of Sustainability and point out that stopping population growth is a necessary (but not a sufficient) condition for sustainability.

Academic research proposals that contain the word "sustainability" abound and many receive generous support. But do these programs actually advance significantly the cause of sustainability or do they serve mainly to advance narrower goals? A simple test will answer this question for any particular program: Does the program acknowledge that overpopulation is the root cause of our present problems and then go on to address overpopulation in a significant way? If the answer is "No," then, no matter what the proponents of the program may say, the program is not likely to contribute in a significant way to the achievement of sustainability. There's more money and glamour in the high-tech research programs than there is in working to make family planning assistance available to all who want it so that population sizes can be reduced to sustainable levels.

Sustainability and War

Modern warfare is extremely dependent on fossil fuels and minerals; hence, war can't be a part of a sustainable society. The world in 2012 seems to have a deep commitment to perpetual war. In today's wasteful and destructive environment of unceasing hostility we can have little or no hope of achieving global sustainability. In seeking to abolish war we must remember that overpopulation is a major factor that drives people to make war.

The Gift That Keeps on Giving

Fertility reduction is the gift that keeps on giving. One avoided birth today will result in many more avoided births in the succession of future generations. The People's Republic of China has boasted that its (very coercive) "One child per family" policy has avoided over 300 million births (27) and that as a consequence, China claims that it has done more to reduce its emission of global greenhouse gases than any other country has done.

What We Need to Do

As a start, here are twelve things that are urgent: In our classrooms and in our lives as scientists,

1) We must acknowledge that overpopulation is the world's most serious and threatening problem and that this problem requires immediate and urgent attention.

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2) We must teach about the arithmetic and consequences of growth as they apply to our present rates of consumption of resources and to our current national and global conditions of overpopulation.

3) We must seek to educate elected officials at all governmental levels about the severe present problems of overpopulation in our own local communities, in the United States and the world. We treasure our democracy but we must remember the words of Isaac Asimov (28): "Democracy cannot survive overpopulation."

4) We must break down the mental and other blocks that keep most of our environmental organizations, large and small, from addressing overpopulation on the local and national levels.

5) We need to get all of our mainline scientific associations and societies to act on the recognition that overpopulation is a threat to the stable societies. Science can thrive only in a stable society. The long-term survival of science is threatened by overpopulation.

6) We should seek to get the U.S. and other governments to support major programs of family planning in the U.S. and throughout the world. These programs should make high quality family planning assistance available worldwide at no cost to all individuals who request it. The goal of the family planning program should be that every child is a wanted child. Rapid population decrease is essential to achieving sustainability.

7) We must expend great efforts worldwide in the education and emancipation of women, giving women freedom to make their own reproductive, economic, and political decisions.

8) We should work to guide production of fossil fuels and mineral resources in accord with the concept of "Sustained Availability" (The Uppsala Protocol), thinking of it as a program of Equal Opportunity for Future Generations.

9) We must continue our efforts to use science and technology to greatly improve the efficiency with which we use energy and mineral resources within the framework of Sustained Availability.

10) We must continue research on the development of alternative fuels, being careful to see that these alternative fuels are not competing with the development of food supplies as is the case in 2012 with production of ethanol in the U.S.

11) We must encourage the transition from our present inefficient mega-agriculture (29) to localized agriculture that operates solely from solar power and from human and animal labor.

12) We must seek to re-orient science, technology and engineering away from their present roles that support population growth and redirect them to work for more modest, less glamorous and less complex roles that can improve the quality of life for human beings. The model might be that which is found in the book *Small is Beautiful* by E.F. Schumacher. (30)

As one can see, the creation of a sustainable society will be both difficult and challenging.

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News from Triangle Coalition

Time Well Spent: Eight Powerful Practices of Successful, Expanded-Time Schools

Today there are at least 1,000 schools across the U.S. that offer an expanded schedule. As interest in expanded learning time grows, so does a corresponding concern for how schools can ensure that adding time will actually translate into a better education for every student. The National Center on Time & Learning has recently released a new report to address this issue. *Time Well Spent: Eight Powerful Practices of Successful, Expanded-Time Schools*, outlines specific practices that can lead to dramatic increases in student achievement and preparation for success in college and the workforce. The report offers an in-depth examination of 30 expanded-time schools serving high-poverty populations with impressive track records of student success, and demonstrates how these schools leverage their additional time in order to implement other critical reforms. The report focuses on how high-performing, expanded-time schools use time, and makes eight recommendations, based on the practices of the schools studied:

1. Make every minute count -- maximize added time;

2. Prioritize increased hours that are tailored to the school and their students;

3. Individualize added time for each student based on diverse needs;

4. Build a positive school culture of high expectations and mutual accountability;

5. Provide new experiences for students to make their education more well-rounded;

6. Prepare students for the future by encouraging college readiness and career goals;

7. Strengthen instruction by providing increased time for teacher professional development; and

8. Evaluate how well goals are met by assessing and analyzing data.

Time Well Spent: Eight Powerful Practices of Successful, Expanded-Time Schools is available online at <http://www.timeandlearning.org/TimeWellSpent_LO_RES_FINAL.pdf>.

(*Editor's Note*: The preceding item was excerpted from the Triangle Coalition Electronic Bulletin for 27 October 2011, reprinted with permission.)

Report Compares U.S. Education Systems with Other G-8 Countries

A new report from the National Center for Education Statistics (NCES) compares educational systems in the United States with systems in other G-8 countries. This 2011 edition of a biennial series of compendia reports describes key education outcomes and contexts of education in the Group of Eight (G-8) countries: Canada, France, Germany, Italy, Japan, the Russian Federation, the United Kingdom, and the United States. The report is organized into five topical areas: population and school enrollment, academic performance, contexts for learning, expenditures for education, and educational attainment and income. Results are drawn from the Organization for Economic Cooperation and Development's (OECD) ongoing Indicators of Education Systems (INES) program, as well as the Program for International Student Assessment (PISA), which is also coordinated by the OECD. Findings include:

- The United States awarded the lowest percentage (15 percent) of first university degrees in science, mathematics, and engineering-related fields among all the G-8 countries in 2008. In the other G-8 countries, the percentages ranged from 22 percent in Canada and Italy to 29 percent in Germany.
- In science literacy, the performance pattern of 15-year-old males and females was not consistent across the G-8 countries. The only measurable differences were in 2009 in the United States (14-point advantage for males, on average) and Canada (5-point advantage for males, on average), and in 2006 and 2009 in the United Kingdom (10- and 9-point advantage for males, respectively, on average).
- In 2007, the total expenditures per student and the portion of these expenditures devoted to core education services were higher in the United States than in all other G-8 countries with data reported at the combined primary and secondary education levels and the higher education level.

This compendium is a product of the National Center for Education Statistics at the Institute of Education Sci-

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ences, part of the U.S. Department of Education. The full report can be viewed online at <http://nces.ed.gov/pubs2012/2012007.pdf>.

(*Editor's Note*: The preceding item was excerpted from the Triangle Coalition Electronic Bulletin for 17 November 2011, reprinted with permission.)

NGA Releases STEM Education Guide

The National Governors Association (NGA) recently released a report, *Building A Science, Technology, Engineering, and Math Education Agenda*, focused on strengthening STEM education. The National Governors Association (NGA) first addressed STEM in its 2007 report, *Building a Science, Technology, Engineering and Math Agenda.* This report updates those recommendations in light of recent state progress to improve education standards and other efforts to advance STEM education. In addition, this report incorporates recent data from studies that make the economic case for pursuing a STEM agenda even more compelling than before.

The report's six brief chapters cover the following issues:

- Goals of the STEM agenda, focusing on specific measures.
- Why STEM is important in terms of jobs, prosperity, and future economic success.
- Where the current system is preventing the graduation of more high school and college students with STEM skills.
- What is being done and can be done to counter these trends.
- Concludes with a look at the work ahead.

Governors, state education policy staff, and state education leaders can use this guide to further the implementation of STEM agendas. For more information on NGA's STEM work, visit <www.nga.org/cms/stem>. The report is available online at <http://www.nga.org/files/live/sites/NGA/files/pdf/1112STEMGUIDE.PDF;jsessionid=CC905C5294F348DC62BD60C135BC12F2>.

(*Editor's Note*: The preceding item was excerpted from the Triangle Coalition STEM Education Bulletin for 12 January 2012, reprinted with permission. See separate story, page 4 of this issue.)

NSF Releases 2012 Science and Engineering Indicators

The United States remains the global leader in supporting science and technology (S&T) research and development, but only by a slim margin that could soon be overtaken by rapidly increasing Asian investments. So suggest trends released this week in the report, *Science and Engineering Indicators 2012,* by the National Science Board (NSB). The report outlines the overall status of the science, engineering and technology workforce, education efforts and economic activity in the United States and abroad.

According to the report, the largest global S&T gains occurred in the so-called "Asia-10″ – China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan and Thailand – as those countries integrate S&T into economic growth. While the U.S. share of global R&D dropped from 38 percent to 31 percent between 1999 and 2009, it grew from 24 percent to 35 percent in Asia during the same time. In China alone, R&D growth increased a stunning 28 percent in a single year (2008-2009), propelling it past Japan and into second place behind the United States.

In 2009, President Obama released *A Strategy for American Innovation,* which recognized the importance of science and engineering as drivers of innovation and identified a strong fundamental research base as critical to innovation, economic growth and competitiveness. "Maintaining our role as the world's engine of scientific discovery and technological innovation [is] absolutely essential to our future," the President said.

NSF has launched a number of new initiatives designed to better position the U.S. globally and at home by enhancing international collaborations, improving education and establishing new partnerships between NSF-supported researchers and those in industry, for example. Among these initiatives are Science Across Virtual Institutes (SAVI); The NSF Innovation Corps (I-Corps) program; NSF investment in advanced manufacturing; and Science, Engineering and Education for Sustainability (SEES).

Review the complete *Science and Engineering Indicators 2012* at <http://www.nsf.gov/statistics/indicators/>.

(*Editor's Note*: The preceding item was excerpted from the Triangle Coalition STEM Education Bulletin for 19 January 2012, reprinted with permission.)

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Triangle Coalition Members Commit to Secure 100K Excellent STEM Teachers

A national movement to recruit, prepare, and retain 100,000 science, technology, engineering, and math (STEM) teachers in 10 years has gained momentum in recent months. 100Kin10 was convened in 2011 by Carnegie Corporation of New York and Opportunity Equation in response to President Obama's call to expand the nation's STEM teaching force. With the addition of 34 new partners, the 100Kin10 movement now boasts more than 115 educational and corporate partners committed to using their resources and talent to bring excellent STEM teachers to American classrooms. To date, 14 funders have committed more than $22 million to support partner organizations in reaching this goal.

In order to become a 100Kin10 partner, organizations must be nominated and go through a rigorous review process which examines each nominee's capacity to advance the movement's goal. Triangle Coalition members involved include the Kenan Fellows Program for Curriculum and Leadership Development, the National Center for Technological Literacy (NCTL), the National Council of Teachers of Mathematics (NCTM), and the National Science Teachers Association (NSTA).

Dr. Valerie Brown-Schild, Director of the Kenan Fellows Program, one of the new partner organizations, says the core competencies of 100Kin10 and its partners strongly align with those of the Kenan Fellows Program. The program has committed to match at least 50 North Carolina teachers annually with STEM leaders in industry and academia for a summer of research and intensive professional advancement. According to Dr. Brown-Schild, involvement in 100Kin10 will provide opportunities for the program to address the national need for more STEM teachers; network with other organizations working towards the same goal; and access resources to which they otherwise might not have access.

The 100Kin10 partners also include science centers and museums, including the National Center for Technological Literacy at the Museum of Science, Boston. "We are pleased to be included on the 100Kin10 STEM teacher initiative," reports Ioannis Miaoulis, president and director of the Museum of Science, Boston and NCTL founder. "Science centers and museums can play a key role in STEM education. While often mistaken as simply field trip destinations, science centers are much more engaged in formal K-12 education than most people appreciate. At the NCTL, we develop formal classroom standards-based, teacher-tested K-12 science and engineering curricula and offer corresponding teacher professional development opportunities across the country."

To learn more about the 100Kin10 and view a complete list of partners and their commitments, visit <http://www.100kin10.org>.

Quality Counts Report Gives the U.S. Education System a Grade of C

Last week, *Education Week* released its annual Quality Counts report evaluating the nation's education system and grading it overall as a C. The report tracks six distinct areas of policy and performance and is the most comprehensive ongoing assessment of the state of American education. In addition to the comprehensive national evaluation, the report also includes state-by-state report cards that measure states' efforts to improve public education. This 16th annual edition, *The Global Challenge—Education in a Competitive World,* takes a critical look at the nation's place among the world's public education systems and the challenges of competing in a global environment. The report discusses the use of international insights by state officials in shaping their own state policies and programs as well.

When breaking down the results by state, Maryland, for the fourth year in a row, comes out as the overall top-ranked state with a grade of B+. Strong finishers Massachusetts, New York, and Virginia follow close behind, each receiving a B. Nearly half the states, however, receive grades of C or lower.

The report finds that in the U.S., mathematics and science are the subjects most strongly influenced by international standards and examples. Key findings related to math and science include:

- When developing or revising their own academic standards, states are most likely to seek international guidance in mathematics and science, two subjects often linked to economic competitiveness and technological innovation.
- In math, 23 states looked to other nations to inform their standards; 13 states did so for science.
- For math and science, Singapore was most frequently cited as an exemplar, mentioned by 18 states. Other international systems used as mod-

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els included: Japan (by 11 states), Finland (10), Canada (8), England (7), Hong Kong (6), and New Zealand (5).

More Key Findings:

- **Most states look beyond the U.S. borders** to inform their own educational reforms, policies, and programs.
- **Effects of the economic downturn linger** in American education, a year and a half after the official end of the recession.
- **Since the recession, teacher pay has risen**, relative to the earnings of workers from comparable occupations. However, uncertainty about the post-stimulus outlook remains.

NESTA Polls Teachers on Climate Change Education

The National Earth Science Teachers Association (NESTA) released the executive summary of its 2011 informal online survey on climate change education. The survey included 61 questions about a range of topics including climate change education in K-12 classrooms, teacher preparation and professional development, the educational resources teachers use, and the outside pressures and challenges they face in teaching about climate change. The respondents included 555 K-12 educators in the United States who currently teach about climate change.

NESTA found that 89% of respondents believe global warming is a reality (compared to 63% of adults in the general public), with the highest levels of agreement coming from teachers in Western states, younger teachers, urban teachers, and females. Only 6% indicated that they did not believe global warming is happening (compared to 19% of the public). On average, only 13% of respondents attribute climate change to mainly natural causes (compared to 35% of the public). Responses varied by region, as teachers in the Western and Northeastern United States expressed significantly more concern about global warming than Southern teachers.

Climate change educators make extensive use of educational resources from professional societies, federal agencies, and universities, and to a lesser extent resources from other non-profits and for profit organizations. Teachers also expressed a strong preference for professional development opportunities in their local area, as well as for research experiences with a scientist or research lab. Webinars, self-paced learning, and lectures and science cafes ranked as the least desired options for professional development.

About one third of teachers reported that students, parents, administrators, or community members have argued with them that climate change is not happening or that it is not the result of human activity. 38% of respondents agreed that "students have misconceptions about climate change that are hard to address." Furthermore, 36% of teachers said that they have been strongly encouraged to teach "both sides" of climate change.

As the NESTA survey shows, educators often face outside pressure when trying to teach climate change, which is accepted by the scientific community but controversial among the public. In response to this issue, the National Center for Science Education (NCSE) just launched a new initiative aimed at defending the teaching of climate change.

NCSE executive director Eugenie C. Scott explains, "We consider climate change a critical issue in our own mission to protect the integrity of science education. Climate affects everyone, and the decisions we make today will affect generations to come. We need to teach kids now about the realities of global warming and climate change, so that they're prepared to make informed, intelligent decisions in the future."

GAO Calls for Greater Coordination between STEM Programs

This week, the U.S. Government Accountability Office (GAO) released the findings of its study of federal STEM education programs. With so many STEM education programs conducted across various federal agencies, the study was conducted to address concerns about the overall effectiveness and efficiency of these programs.

GAO examined the number of federally funded STEM education programs; possible overlap and opportunities for coordination among programs; and the extent to which STEM education programs measured effectiveness. This study has similar goals to STEM education inventory published by the White House Office of Science and Technology Policy (OSTP) last December. As OSTP is currently developing a comprehensive five-year strategic plan for the coordination of the federal STEM

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education portfolio, GAO makes recommendations for OSTP to include in that plan.

As a result of its study, GAO recommends that OSTP work with the federal agencies to better align their activities with a government-wide strategy, develop a plan for sustained coordination, identify programs for potential consolidation or elimination, and assist agencies in determining how to better evaluate their programs.

GAO finds that in FY2010, 13 federal agencies invested over $3 billion in 209 programs designed to increase knowledge of STEM fields and attainment of STEM degrees. More than half of these programs were administered by Department of Health and Human Services, the Department of Energy, and the National Science Foundation. Almost a third of the programs had obligations of $1 million or less, while some had obligations of over $100 million.

The study also revealed that while eighty-three percent of the programs overlapped to some degree, they were not necessarily found to be duplicative. However, the programs are similar enough that they must be well coordinated and guided by a robust strategic plan. Currently, though, less than half of the STEM education programs indicated that they coordinated with those that were similar in other agencies. Furthermore, the study also revealed limited use of performance measures and evaluations within the agencies which hinders the ability of decision makers to assess the effectiveness of individual programs as well as the overall STEM education effort.

Current efforts by OSTP to inventory federal STEM education activities and develop a 5-year strategic plan present an opportunity to enhance coordination, align government-wide efforts, and improve efficiency of limited resources by identifying opportunities for program consolidation and reducing administrative costs.

(*Editor's Note*: The preceding four items were excerpted from the Triangle Coalition STEM Education Bulletin for 26 January 2012, reprinted with permission.)

Survey Uncovers Inventive Perception Among Untapped Young Americans

Invention and innovation are essential to remaining globally competitive, and a new survey shows an untapped group of potential inventors in the U.S. The 2011 Lemelson-MIT Invention Index, released 19 January, indicates that American women ages 16 – 25 possess many characteristics necessary to become inventors, such as creativity, interest in science and math, desire to develop altruistic inventions, and preference for working in groups or with mentors – yet they still do not see themselves as inventive. Young men in the same age group echo these characteristics, highlighting the need to cultivate young adults' interest in science and math, while educating and inspiring them about the impact they can have on others through invention.

The annual Lemelson-MIT Invention Index, which gauges Americans' perceptions about invention and innovation, surveyed 1,000 Americans ages 16 – 25. Nearly three quarters of the young women and men indicate they are creative, the characteristic they most associate with inventors; however, fewer than 27 percent of women and 39 percent of men describe themselves as inventive.

Further demonstrating inventive traits, young women show a strong affinity for math and science with 42 percent rating these as their favorite subjects; over half of male respondents agree. Thirty-five percent of young women also say they have a family member working in a field related to science, technology, math, or engineering. While the results reveal young women's innate interest in inventive fields, recent statistics show while more women are entering college and obtaining degrees, less than ten percent earn them in technical majors such as computer and information sciences, engineering, or math. This proportionately small group indicates a need to educate women about translating their skills and academic interests into inventive careers.

Chad Mirkin, a member of the President's Council of Advisors on Science and Technology and 2009 recipient of the $500,000 Lemelson-MIT Prize, remarked, "This country needs innovative new programs to stimulate the interest of young men and women in STEM and to challenge them to use their intellect and creativity to invent solutions to some of the world's most pressing problems. Women have an enormous amount to offer in this regard, but aren't currently pursuing science or technology fields at a high enough rate."

The Lemelson-MIT Invention Index also reveals that young women and men do not see the U.S. as leading the way in invention; as the majority view Japan as the leader and rank the U.S. as second.

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To improve the U.S. standing, young women cite access to governmental funding and including invention projects during school as the best ways to encourage aspiring inventors. Men agree, noting that providing places to develop inventions is another way to encourage hopeful inventors. The availability of invention tools and education has the potential to boost the quantity of inventive professionals, according to survey respondents. To learn more, visit <http://mit.edu/invent/index.html>.

(*Editor's Note*: The preceding item was excerpted from the Triangle Coalition STEM Education Bulletin for 2 February 2012, reprinted with permission.)

PCAST Releases Undergraduate STEM Education Report

At a public briefing on Tuesday, the President's Council of Advisors on Science and Technology (PCAST) released its second report on STEM education. This report focused on undergraduate education and is entitled "Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics." The report provides a strategy for improving STEM education during the first two years of college in order to dramatically increase the graduation rates of students with STEM degrees.

Fewer than 40 percent of students who enter college as STEM majors complete college with a STEM degree. Increasing retention of STEM majors to just 50 percent would alone help generate approximately three quarters of the targeted 1 million additional STEM degrees in the next decade, the report says. PCAST lays out a strategy to achieve this which takes into account reasons students abandon STEM courses in the first two years, lagging math skills, and diversifying pathways to encourage women and minorities.

In addition to its call to create a Presidential Council on STEM Education, PCAST makes the following recommendations:

1. Catalyze widespread adoption of empirically validated teaching practices.
2. Advocate and provide support for replacing standards laboratory courses with discovery-based research courses.
3. Launch a national experiment in postsecondary mathematics education to address the math preparation gap.
4. Encourage partnerships among stakeholders to diversify pathways to STEM careers.

The report is available online at <http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_feb.pdf>.

(*Editor's Note*: The preceding item was excerpted from the Triangle Coalition STEM Education Bulletin for 9 February 2012, reprinted with permission. See separate story, page 3, this issue.)

STEM Education Highlighted in President's Budget Request

In his FY 2013 budget request, President Obama is proposing an increased investment in education, especially in the areas of science, technology, engineering, and mathematics (STEM). He elaborated on his plans for improving STEM education at the White House Science Fair last week, where he renewed his commitment to train 100,000 excellent STEM educators, and made an additional promise to produce 1 million more STEM graduates in the next ten years.

The President is requesting to increase the U.S. Department of Education's (DoEd) overall budget by 2.5 percent, to $69.8 billion. As in the previous two years, the budget proposes consolidating 38 of DoEd's smaller programs into 11 broader ones. Details on specific STEM education programs are discussed below.

The National Science Foundation (NSF) saw a 3.6% increase for STEM education investments in the request, which would bring its budget up to $1.2 billion. Of that amount, K-12 programs at NSF would receive $262.84 million, an increase of 7.4% over 2012. NASA's Education budget, on the other hand, received a 26% cut, which would bring it down from $136 million in 2012 to $100 million in 2013. (NASA Education received $145 million in 2011.)

In his budget, President Obama identified three overarching priorities for improving STEM education:

- increasing STEM literacy so that more students are motivated to pursue STEM subjects;
- improving the quality of math and science teaching;

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- and expanding STEM education and career opportunities for underrepresented groups, including women and minorities.

Key STEM components in the FY 2013 Budget Request include:

- **$150 million for the Effective Teaching and Learning STEM program (DoEd)** – which would replace the current Mathematics and Science Partnerships (MSP) program at the DoEd. Funds would be awarded through competitive grants, rather than the current formula structure, to support professional development for STEM teachers, especially in high-need areas.

- **$80 million for STEM teacher training (DoEd)** – through a set aside from the Effective Teachers and Leaders State Grants to support the President's goal of preparing 100,000 effective STEM teachers over the next ten years. This program would support competitive awards to expand pathways into STEM teaching fields.

- **$190 million for a new Presidential Teaching Fellows program (DoEd)** – replacing the current TEACH grants, this program would grant scholarships to talented students to attend "high-performing" teacher preparation programs and then work in high-need schools and subjects, including STEM.

- **$150 million for Investing in Innovation (i3) program (DoEd)** – which prioritizes STEM, and would also host the Advanced Research Projects Agency-Education (ARPA-ED) program, a new research program for developing educational technology solutions in STEM and other high-need areas.

- **$30 million in the DoEd Fund for the Improvement of Education, combined with $30 million from NSF** – for an "evidence-based grant competition" similar to the i3 program that would support and improve the use of quality, effective K-12 STEM practices within these two agencies and across the Federal Government.

- **$20 million for the NSF Widening Implementation and Demonstration of Evidence-based Reforms (WIDER)** – a program that was new in FY 2012 when it received $8 million. WIDER supports the improvement of instructional practices of faculty teaching undergraduate STEM courses.

As this proposal is only a list of requests from the Administration, Congress will now begin its process of negotiating and passing a budget for FY 2013.

(*Editor's Note*: The preceding item was excerpted from the Triangle Coalition STEM Education Bulletin for 16 February 2012, reprinted with permission.)

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RECOMMENDED SCIENCE AND SOCIETY EDUCATIONAL RESOURCES

1. Bruce Parker, "The tide predictions for D-Day," *Phys. Today*, **64**(9), 35-40 (Sep 2011).

Not only the tide but also the phase of the Moon was critical in determining the time of D-Day in World War II. This article describes how the tides were predicted by performing a frequency analysis of tidal data recorded in the past and extrapolating it into the future. Before the advent of computers, this was done by machines whose pulleys were gauged to represent the frequencies in the tidal "spectrum."

2. Owen Gingerich, "The great Martian catastrophe and how Kepler fixed it," *Phys. Today*, **64**(9), 50-54 (Sep 2011).

The section on "Kepler's Laws" in the video series, *Mechanical Universe*, points out that Kepler wisely chose to "wage war on Mars" in arriving at his First Law. Although the eccentricity of Mars's orbit was key to identifying planetary orbits as ellipses, Kepler would never have won his "war" had he not realized that the Earth did not orbit the Sun in a circle at constant speed. The key to winning the "war on Mars" was properly plotting the orbit of the Earth. Though this is explained in *Mechanical Universe*, if the explanation there goes by too fast, Gingerich in this article gives you all the information you need in a format that you can digest at your own pace.

3. Jeremy F. Price, Diane Silva Pimentel, Katherine L. McNeill, Michael Barnett, and Eric Strauss, "Science in the 21st Century: More Than Just the Facts," *Sci. Teach.*, **78**(7), 36-41 (Oct 11).

As reported in our Fall 2011 issue, the National Science Teachers Association (NSTA) adopted a position statement on Quality Science Education and 21st Century Skills last June, and they devoted the October 2011 issue of their high school publication to this topic. The position statement cites the work of the Partnership for 21st Century Skills, first described by this *Newsletter* in its Winter/Spring 2009 issue, and that of the National Research Council, which cites the importance of adaptability, complex social and communication skills, nonroutine problem-solving skills, self-management and self-development, and systems thinking. These five skills are the focus of this article, as developed through the authors' urban ecology curriculum, which emphasizes "the local and community-based nature of science." The authors have also developed "two frameworks – *Four Ways of Knowing Science* [understanding, doing, talking, and acting on science] and *Action Planning* – "that teachers can use to help student meet the challenges of the 21st century."

4. Karina Clemmons and Colleen Sheehy, "Science, Technology, and YA Lit," *Sci. Teach.*, **78**(7), 42-45 (Oct 11).

"This article provides three engaging projects science teachers can use to help students develop environmental consciousness and global awareness – both important 21st -century skills – using YA [young adult] lit and technology." All are built around young adult novels related to environmental consciousness, with one "grounded in the Buck Institute for Education's project-based learning (PBL) framework," described in our Winter/Spring 2011 issue. A list of twenty suitable novels of this type is also included.

5. Harold Pratt, *The NSTA Guide to* A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (NSTA, 2012). 36 pp. ISBN 978-1-936959-77-8. Free download from NSTA Store: http://www.nsta.org/store/product_detail.aspx?id+10.2505/9781936959778

This *Guide* is designed not to replace the *Framework* but to facilitate studying it. Organized into 13 chapters paralleling the 13 chapters of the *Framework*, its chapters provide the following for each of the *Framework*'s chapters: an overview of the *Framework* chapter, analysis of differences and similarities between the *Framework* and the older *National Science Education Standards*, and things that science education personnel can do to understand the *Framework* and its impact. Among the differences noted between the *Framework* and *Standards*: The *Framework* includes what has been learned about the learning process in the past 15 years, introduces the inclusion of engineering and technology, and shifts from inquiry to practices, including those of engineering. The *Guide* notes that the *Framework* core idea of Engineering Design is already being addressed by teachers who have students do projects and that the core idea of Links Among Engineering, Science, and Society has overlap with the *Standard* for Science in Personal and Societal Perspectives. Among changes in content from the

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Framework: a new physical science core idea, "Waves and Their Applications in Technologies for Information Transfer," and a broadened range of topics in the earth and space sciences but with fewer core ideas and greater stress on the role of human impact.

6. Rodger W. Bybee, "Scientific and Engineering Practices in K-12 Classrooms," *Sci. Teach.*, **78**(9), 34-40 (Dec 11).

In this article the executive director emeritus of Biological Science Curriculum Study "present[s] the science and engineering practices from the recently released *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*." Boxes present in full the eight "Scientific and Engineering Practices" in Chapter 3 of the *Framework*, and the text of the article addresses the two questions, "Why practices and why not inquiry?" and "Why science *and* engineering?" Bybee points out that science education reform in the 1960s used the "*processes* of science as a replacement for the *methods* of science" – to shift "emphasis from students' memorizing five steps in the scientific method to learning specific and fundamental processes such as observing, clarifying, measuring, inferring, and predicting." He continues to note that "During the period 1960-1990, interest and support grew for *scientific inquiry* as an approach to science teaching that emphasized . . . using the skills and abilities of inquiry to learn those concepts" but that "scientific inquiry has not been implemented as widely as expected." Meanwhile, *Taking Science to School*, one of the reports instrumental in leading to the current *Framework*, "describes four proficiencies that link the content and practices of science." Thus, Bybee states, in the *Framework* "Scientific inquiry is one form of scientific practice," and the larger set of scientific practices is a means "of expanding and enriching the teaching and learning of science." In addressing the second question, Bybee notes that "In the 1960s, technology and engineering were marginalized in the U.S. science curriculum." The present inclusion of science *and* engineering is designed to remedy that marginalization.

7. Geoff Keith, Bruce Biewald, Ezra Hausman, Kenji Takahashi, Tommy Vitolo, Tyler Cummings, and Patrick Knight, *Toward a Sustainable Future for the U.S. Power Sector: Beyond Business as Usual 2011* (Civil Society Institute, 2011, available online at <http://www.civilsocietyinstitute.org/media/pdfs/Toward_a_Sustainable_Future_11-16-11.pdf>).

This study, conducted by Synapse Energy Economics for the Civil Society Institute, contrasts a Business As Usual (BAU) Scenario with a Transition Scenario through 2050. Given recent tragedies at Fukushima and coal mines, coupled with declining costs for photovoltaic cells, they project the following contrast, based on economic analyses that take into account ten distinct regions of the U.S.:

electric energy source/emission	Business As Usual	Transition
total	increase at 0.9%/yr to 5590 TWh/yr	decrease at 0.1%/yr to 3760 Twh/yr
coal-fired generation	increase 26% to 2340 Twh/yr	decrease to zero
natural gas-fired generation	increase to 1840 Twh/yr	increase to 1230 Twh/yr
nuclear generation	increase to 870 Twh/yr	decrease to 618 Twh/yr
wind generation	increase to 189 Twh/yr	increase to 611 Twh/yr
photovoltaic generation	increase to 24 Twh/yr	increase to 842 Twh/yr
carbon dioxide emissions	increased 28%	decreased 81%

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REVIEWS OF SCIENCE AND SOCIETY EDUCATIONAL RESOURCES

Naomi Oreskes and Erik M. Conway, *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming* (Bloomsbury, New York, 2010), 355 pp. $27.00. ISBN 978-1-59691-610-4.

When I first learned about this book, it brought to mind David Michaels's *Doubt is Their Product*, reviewed in our Winter/Spring 2009 issue. Indeed, both books begin in the same way, describing how the tobacco industry tried to defend its product in light of Surgeon General pronouncements that it caused lung cancer and other health problems. But whereas Michaels continues by describing other industry efforts to discredit scientific challenges to the safety of their products, Oreskes and Conway focus on the perpetrators of these challenges to science. They followed what they call "a characteristic pattern in science; first there is scattered evidence of a phenomenon, published in specialist journals or reports, and then someone begins to connect the dots." (p. 69) When they "connected the dots," they found four men to be instrumental in leading challenges to scientific evidence of health consequences of smoking and second-hand smoke and atmospheric consequences of nuclear warfare and emissions of chlorofluorocarbons and the oxides of nitrogen, sulfur, and carbon: Frederick Seitz, Robert Jastrow, William Nierenberg, and Fred Singer.

It turns out that all four men were scientists who had in their earlier years scored impressive records as scientists. A well-known solid state physicist, Seitz had been President of the National Academy of Sciences and The Rockefeller University. Jastrow had been the founding Director of the Goddard Institute for Space Studies (and the lead professor at the Summer Institute in Space Physics, which I attended in 1962). Nierenberg had been Director of the Scripps Institution of Oceanography before joining the transition team for President Ronald Reagan. And Singer was also a former President of the National Academy of Sciences. Oreskes and Conway describe them in their introduction as follows:

> Seitz, Singer, Nierenberg, and Jastrow had all served in high levels of science administration, where they had come to know admirals and generals, congressmen and senators, even presidents. They had also dealt extensively with the media, so they knew how to get press coverage for their views, and how to pressure the media when they didn't. They used their scientific credentials to present themselves as authorities, and they used their authority to try to discredit any science they didn't like. (p. 8)

The only member of this quartet to be involved in challenging the science supporting the health effects of smoking was Seitz, whose Rockefeller University had benefited from money from the tobacco industry for "health research." Now retired, "from 1979 to 1985" he "directed a program for R.J. Reynolds Tobacco Company that distributed $45 million to scientists around the country for biomedical research that could generate evidence and cultivate experts to be used in court to defend the 'product.'" (p. 5) By 1985 the tobacco industry was looking for a younger person to aid its efforts, but Seitz lost no time finding a new cause: nuclear superiority, enabled by the Reagan Strategic Defense Initiative. There was plenty to challenge here: the CIA's estimate of Soviet nuclear capability, the claim of a "nuclear winter" resulting from a nuclear war, and the arguments of the Union of Concerned Scientists (UCS) against anti-ballistic missile systems. Jastrow's response to the UCS was to enlist Seitz and Nierenberg in forming the George C. Marshall Institute as a platform from which they could issue their pronouncements.

Singer joined Nierenberg in playing a significant role to challenge the science in the next issue considered by Oreskes and Conway: acid rain. When there was disagreement between the U.S. and Canada about the atmospheric transport of nitrogen and sulfur oxides in both directions across their joint border, the Reagan Administration – rather than rely on a 1981 National Academy of Sciences report that cautioned about the risks of continuing the same emissions from power plants or a similar 1982 report from the Environmental Protection Administration (EPA) – sought a new acid rain peer review panel. It chose Nierenberg (a member of the Reagan transition team) to chair it and "suggested" that Singer be a member. Once a strong environmentalist, Singer had now become concerned about the cost effectiveness of environmental remediation, and he brought these views to what otherwise was a panel supportive of the Canadian view, even after some of Nierenberg's original nominees were rejected by the White House. Because Singer was alone in his views on the panel, they were consigned to an appendix. But between the receipt and release of the report by the White House, Nierenberg made changes in the Executive Summary requested by the White House

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Office of Science and Technology Policy – and neither these changes nor Singer's appendix were submitted to the rest of the panel for approval. The result was to soften the sense of urgency to take action, which led to Congressional delay, and efforts by panel members to have the record set straight went for naught.

Singer, who served as chief scientist in the US Department of Transportation under Reagan in 1987, was particularly vociferous in challenging concern about stratospheric ozone depletion; and when he couldn't get his views published in *Science*, he went to the *Wall Street Journal* and *National Review*. After Reagan left the presidency, Singer continued his efforts, even to the extent of criticizing the Nobel Committee when Sherwood Roland, Mario Molina, and Paul Crutzen were awarded the 1995 Nobel Prize in Chemistry for their work that chlorofluorocarbon emissions had triggered ozone depletion in the stratosphere, a situation which would endanger life on Earth by enhanced exposure to solar ultraviolet light.

Both Seitz and Singer were implicated in challenging the pronouncement that secondhand smoke could cause cancer – a conclusion of studies that showed lung cancer rates among nonsmoking wives depending on how much their husbands smoked. Singer's work was the basis of *Bad Science: A Resource Book* – "a how to handbook for fact fighters." (p. 144) Oreskes and Conway describe "bad science" as

> science that is obviously fraudulent – when data have been invented, fudged, or manipulated . . . where data have been cherry-picked – when some data have been deliberately left out – or it's impossible for the reader to understand the steps that were taken to produce or analyze the data. It's a set of claims that can't be tested, claims that are based on samples that are too small . . . . when proponents of a position jump to conclusions on insufficient or inconsistent data. (p. 153)

But peer review insures that scientific publications follow the criteria of good science, and Oreskes and Conway point out that the EPA report on passive smoking was peer-reviewed twice, with the peer reviewers finding the initial conclusions too weak, especially as they regarded the effects on children. They also point out that secondhand smoke "was a man-made risk that was being imposed without consent." (p. 161) In support of the British organization, Freedom Organization for the Right to Enjoy Smoking Tobacco (FOREST), Fred Seitz's cousin Russell opined in *Forbes* that the solution should be for the U.S. Government to develop a smokeless cigarette – "spend taxpayer money figuring out how to safely deliver nicotine – an addictive and toxic substance – to the American people." (p. 165)

After the Soviet Union collapsed and there was no longer a need to argue for nuclear superiority, the three cofounders of the George C. Marshall Institute needed a new mission and found it in attacking environmental "alarmists," particularly James Hansen, whose testimony to Congress about the effects of carbon dioxide emissions on global warming in the hot summer of 1988 were attracting a lot of notice. To counteract Hansen, Jastrow, Seitz, and Nierenberg authored a 1989 book, published by their Institute, which attributed global warming to the Sun and "cherry picked" one of Hansen's graphs, which did not show good agreement between model-predicted temperatures and actual temperatures because the effect of volcanoes had not yet been included. The Marshall Institute also arranged for Nierenberg to brief the Office of Cabinet Affairs, the Office of Policy Development, the Council of Economic Advisers, and the Office of Management and Budget. They also took an expanded version of their arguments to the 1992 World Petroleum Congress.

Meanwhile, Singer did his "dirty work" by taking advantage of the terminal illness of Roger Revelle by enlisting Revelle to coauthor a paper with a smaller prediction of global temperature increase in the next century than Revelle would have liked. Although it was published without peer review in the journal of the Washington Cosmos Club, it was used against the 1992 presidential campaign of Al Gore, who had been mentored by Revelle.

"Seitz, Jastrow, Nierenberg, and Singer had access to power – all the way to the White House – by virtue of their positions as physicists who had won the Cold War," Oreskes and Conway write. "They used this power to support their political agenda, even though it meant attacking science and their fellow scientists. . . ." (p. 213) But the authors also express concern about the way the mass media had become complicit with the "professional deniers" by giving them equal space in their stories as if covering a scientific issue were the same as reporting on a debatable political issue, thus giving the public the impression that science, like politics, is two-sided.

". . . if science is about studying the world as it actually is – rather than as we wish it to be – then science will always have the potential to unsettle the status quo," the

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authors continue (p. 236). "Lately science has shown us that contemporary industrial civilization is not sustainable," they add (p. 237). "Maintaining our standard of living *will* require finding new ways to produce our energy and less ecologically damaging ways to produce our food. . . . the crux of the issue . . . [is] that unrestricted commercial activity was doing damage – real, lasting, pervasive damage . . . . free enterprise can bring real costs – profound costs – that the free market does not reflect. . . . Those who find this hard to accept attack the messenger, which is science."

In articulating their "New View of Science" in their Epilogue, Oreskes and Conway write that "Doing something has costs . . . and if you aren't confident those costs will be repaid in future benefits, you're better off leaving things alone. Moreover, acting to prevent future harm generally means giving up benefits in the present: certain benefits, to be weighed against uncertain gains." The idea "that science could provide certainty . . . was most clearly articulated by the late-nineteenth-century positivists," but that was only a dream. (p. 267) Because we cannot do all of our science, Oreskes and Conway state, we need to trust the science done by scientists and its dependence on peer-reviewed observations and measurements, and we must not be dissuaded by "contrarians" like Seitz, Jastrow, Nierenberg, and Singer, whose message may be more appealing but not voiced through the established procedures of science.

\- John L. Roeder

World Leaders

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dents ask "Why do I need to know *that*?" he regards it as *his* fault.

Muller also spent time talking about his take on "the scientific method." To him, it is all about challenging the work of others and being receptive to challenges to one's own work. One of his biggest success stories, which he related, was that of a young woman who challenged a physicist at Livermore's National Ignition Facility (whose mission is to achieve inertially contained nuclear fusion) on his claims for what would be needed to provide California's electrical energy from photovoltaic cells. Another student who "made his day" was one who complained that he couldn't figure out what Muller's politics were – physics shouldn't be political, he said. What he is interested in doing is to teach physics that will enable his students to apply it to whatever they do in life.

(*Editor's Note*: Muller's development of "Physics for Future Presidents" as the successor to "Physics for Poets" is profiled in our review of *Science and the Educated Person* in our Winter/Spring 2011 issue.)

Infusion Tips

The late Dick Brinckerhoff suggested the following criteria for ways to infuse societal topics into our science courses: items should be a) challenging, b) relevant, c) brief, and d) require a value judgment. Consider the following:

According to the Science Times of *The New York Times* of 6 March 2012, the journals *Science* and *Nature* have withheld since last fall publication of papers describing experiments which transformed the H5N1 bird flu virus into mutant forms that spread among mammals.

Noting that the reduced cost of equipment for doing genetics experiments has enabled more amateur biologists to do them, *The Times* calls attention to the do-it-yourself biology movement, one of whose websites, <DIYbiology.org>, now has more than 2000 members. Publication of the withheld papers could enable one of these members to recreate the mutated H5N1 virus. Nevertheless, a panel of scientists convened by the World Health Organization has recommended that these papers be published.

Do you agree or disagree with the World Health Organization recommendation? Why or why not?

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The Transition Scenario also uses 76% less water than BAU and withdraws 90% less cooling water.

8. Bill Bigelow, "Scholastic Inc. Pushing Coal," *Rethinking Schools*, **25**(4), 30-33 (Summer 2011).

This article describes how protests and media coverage led Scholastic to abandon a partnership it had formed with the American Coal Foundation to publish a fourth grade curriculum which presented an imbalanced picture of coal by not calling attention to any of its disadvantages.

TEACHERS CLEARINGHOUSE FOR SCIENCE AND SOCIETY EDUCATION, INC.
194 Washington Road
Princeton, NJ 08540-6447

Teach Physics as if Your Students will become World Leaders

Richard Muller initially resisted teaching the "Physics for Poets" course at the University of California at Berkeley – until he realized that physics was something that should be taught to everyone, not just students who would become the physicists of the future. Students majoring in other fields are smart, too, he realized, albeit in a different way. And if you think your students are dummies, they can tell – so don't talk down to them. Teach every student as if she/he would become a future world leader, and teach them the physics they will need to know in that position.

Thus was born "Physics for Future Presidents," as Muller described it to the American Association of Physics Teachers at their February 2012 meeting in Ontario, CA. He told the Association that the day after 9/11 he devoted his class to a discussion of the physics of what happened – the energy released, he pointed out, was greater than that released by North Korea's nuclear bomb. Likewise, after the Japanese tsunami he wanted his students to become Fukushima experts. Teaching students what world leaders need to know to make important decisions for the world makes for informed citizens, and it has caused the enrollment of what used to be "Physics for Poets" to increase and to be voted the best course on the Berkeley campus. Muller said that if stu-

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