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Science and Technology for the Twenty-First Century: This Special Edition *MIT Faculty Newsletter*, addressed to President Obama, his administration, and the U.S. Congress, includes articles on climate change; nuclear disarmament; the needs of science; infrastructure; energy; public health; the green initiative; the financial crisis; sustainability; the World Wide Web; and the environment and energy policy.

The Role of Oceans in Climate Change

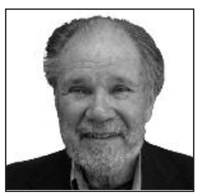

Paola M. Rizzoli Peter H. Stone

THE CRUCIAL ISSUES OF climate change and global warming involve all the components of the earth system, atmosphere, oceans, land, biosphere, and cryosphere. The oceans are among the most poorly known and understood, because of the enormous difficulty of probing the deep layers which are still basically void of observations, and the sparseness of data in the southern ocean. There are numerous ways in which the oceans affect the Earth's climate, but we will discuss only those two that, in our opinion, are of the utmost importance.

The first crucial role played by the oceans involves the mixing of heat anomalies into the deep layers. Within the context of global warming scenarios, strong mixing of surface heat anomalies will retard surface warming rates (Hansen et al., 1985). Mixing is primarily per-

continued on page 18

A New Method for Negotiating Arms Control Agreements



Aron M. Bernstein

AS A PHYSICIST WITH A long-standing interest in arms control and a member of the National Board of the Council for a Livable World, I have been gratified by President Obama's repeatedly stated commitment to work towards eliminating nuclear proliferation and creating a nuclear-free world, highlighted by his Prague speech of April 5. I am also encouraged by his rapid progress in improving U.S.-Russian relations, including working towards a revised Start Treaty by the end of the year, which includes significant reductions in nuclear weapons and delivery systems. Of course, now comes the even harder work of implementing those policies!

The example of President Clinton, who came to office with the goal of reducing the world's nuclear arsenals, but failed to carry through, offers us a sobering

continued on page 19

A New Commitment to Science and Technology R&D

Editorial

Editorial Sub-Committee

THE OBAMA ADMINISTRATION has refreshing support for a renewal of investment in science and engineering. The appointments of Steven Chu, John Holdren, and Jane Lubchenko represent excellent choices. The immediate commitment of significant amounts of the American Recovery and Reinvestment Act stimulus funds to NIH, NSF, DOE, and other research and development (R&D) agencies is encouraging. The new administration has eliminated barriers to stem cell research, expanded opportunities for international cooperation among scientists, and promised that science would not be subverted for political gains. We applaud all of these efforts.

This is the first of a series of issues in which the *Faculty Newsletter* is publishing diverse articles from MIT faculty members on areas of R&D in science,

continued on page 3

contents

Vol. XXI No. 5 Summer 2009

	01	**The Role of Oceans in Climate Change** Paola Malanotte-Rizzoli and Peter H. Stone
	01	**A New Method for Negotiating Arms Control Agreements** Aron M. Bernstein
Editorial	01	**A New Commitment to Science and Technology R&D**
Numbers	03	**Budget of the United States Government (2005-2010) Outlays By Selected Agencies**
	04	**The Science We Need and the Needs of Science** Mark Kastner
Numbers	05	**Budget of the United States Government (2009-2014) Outlays By Selected Agencies**
	06	**System at a Crossroads: Rethinking Infrastructure and Mobility** Fred Moavenzadeh and Kyle Frazier
	08	**Energy Transitions and Transformations** Stephen R. Connors and David H. Marks
	10	**Society's Nervous System: A Key to Effective Government, Energy Efficiency, and Public Health** Alex Pentland
	11	**An Alternate Green Initiative** Leon R. Glicksman
	12	**Rotten Apples or a Rotting Barrel: How Not to Understand the Current Financial Crisis** Susan S. Silbey
	13	**The Way to Sustainability** Leon Trilling
	14	**Making the Web Work for Science** Hal Abelson and John Wilbanks
	16	**A Note to Secretary of Energy Steven Chu** David Gordon Wilson
Numbers	20	**Budget of the United States Government (1962-2010) Percentage Distribution of Outlays by Selected Agencies**

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A New Commitment to R&D
continued from page 1

engineering, and economics that are key to socioeconomic progress and raising the global standard of living. In this issue, we cover a range of issues including environmental science, nuclear disarmament, transportation infrastructure, cleaner energy, and more. The next issue will carry articles on biomedical research, chemistry and chemical engineering, science education, and social aspects of globalization.

The articles are not intended to represent an "MIT point of view" or a consistent policy formulation, but rather the clear views and visions of a variety of knowledgeable and concerned faculty. Undoubtedly, other faculty would have other points of emphasis, and will disagree on some of the points. We hope that the articles stimulate further discussion and dialogue and help launch a new period of optimism and excitement among our students and colleagues throughout the nation.

Science and technology have had enormous societal impacts over the past century. Advances in agriculture, transportation, computation, telecommunications, medicine, and pharmaceuticals have been primary driving forces behind the rising quality of life and increased prosperity for many. However, our world is facing important challenges such as the possibility of catastrophic climate changes with the resulting need to find cleaner energy sources. Although R&D in science and technology cannot, by itself, solve global issues, it is an absolutely necessary component of the solutions.

We encourage all scientists and engineers to use this window of opportunity to take part in discussions on how science and technology can enhance human conditions for future generations. Please send all submissions to ***fnl@mit.edu*** or contact any member of the *Newsletter* Editorial Board.

Editorial Sub-Committee

Numbers

Budget of the United States Government (2005-2010) Outlays By Selected Agencies (in millions of dollars)

Department or Other Unit	2005	2006	2007	2008	2009 Estimate	2010 Estimate
Agriculture	85,309	93,534	84,428	90,796	116,243	132,861
Defense – Military	474,372	499,357	528,593	594,686	655,018	685,096
Education	72,858	93,429	66,372	65,960	49,684	100,542
Energy	21,271	19,649	20,116	21,400	29,322	46,302
Homeland Security	38,713	69,098	39,172	40,684	49,183	49,258
Housing & Urban Development	42,453	42,435	45,561	49,088	65,132	54,762
National Institutes of Health	28,495	28,461	29,030	29,312	30,545	30,996
Transportation	56,596	60,139	61,697	64,944	79,723	90,517
Veterans Affairs	69,844	69,807	72,820	84,786	96,477	108,756
Environmental Protection Agency	7,913	8,321	8,259	7,939	8,421	10,760
NASA	15,602	15,125	15,861	17,833	19,574	18,444
National Science Foundation	5,434	5,542	5,529	5,847	6,687	8,143
Total Outlays	**2,472,205**	**2,655,435**	**2,728,940**	**2,982,881**	**3,997,842**	**3,591,076**

Source: U.S. Government Printing Office: ***www.gpoaccess.gov/usbudget/fy10/browse.html***

The Science We Need and the Needs of Science

Marc Kastner

THE WORLD URGENTLY REQUIRES breakthroughs in science and engineering to meet two goals – renewable energy and global health. Without a reduction of CO_2 emissions, the people of the world are undertaking a dangerous experiment – creating a new global environment and waiting to see whether they can survive in it. On the positive side, renewable energy technology could not only reduce CO_2 emissions, but could also provide new industries to help the economy recover. Turning to global health, there have been spectacular advances in understanding the science of life and in medical technology. Now the convergence of the life sciences with the physical sciences and engineering offers the promise for more rapid progress in curing disease.

It is very unlikely that scientific and technological advances alone will solve these problems, but it is equally unlikely that they will be solved without such advances. Consider renewable energy. Some have argued that if we simply implement currently available technologies we can stop the increase of CO_2 in the atmosphere. However, if one looks closely at current technologies, every one of them has deficiencies that require new science and engineering to overcome. Here are some examples: We cannot yet build batteries with sufficient energy storage to propel a good-size automobile 200 miles. New battery materials will be needed to make this possible. Available solar cells are ready to offset electricity needs, and their cost is decreasing because of the increasing scale of production. However, their large-scale incorporation into electricity production will require cost reductions from new materials and geometries that are more dramatic than expected from simply scaling up manufacturing.

It is hard to believe that the United States, let alone China and India, will simply stop burning coal, the world's most abundant and inexpensive fossil fuel, and we will therefore need to find a way to capture and permanently store the resulting CO_2. The U.S. Department of Energy, Office of Fossil Energy, expects that the CO_2 will be permanently sequestered deep underground in rock or saline aquifers. However, we do not know whether enough CO_2 can be injected; whether it will stay underground or come out, and if it comes out, whether it will come out slowly or catastrophically; whether it will react with water and rock forming stable compounds or will pollute underground aquifers. To answer these questions requires a deeper understanding of the geochemistry and geophysics of CO_2. These examples are from a recent report by a subcommittee of the Basic Energy Sciences Advisory Committee of the U.S. Department of Energy (*www.sc.doe.gov/BES/reports/abstracts.html*). None of the technologies that reduce CO_2 emissions are without political obstacles, which may be even greater than the scientific and engineering ones. However, the politics will be even more difficult if the science is not well understood.

The life sciences have undergone two revolutions. The first began with the discovery of the structure of DNA by Watson and Crick in 1953 that gave birth to modern molecular and cellular biology. The second is the genomic revolution – the decoding of the entire DNA sequences of organisms. I am told that the cost of sequencing is decreasing at a more rapid rate than the cost of making transistors is decreasing according to Moore's law, making it likely that sequencing will influence medical practice at an accelerating pace. These two revolutions have expanded our knowledge and understanding of biology and medicine at an astonishing rate, and many new diagnostic tests and drugs have been developed based on this science, improving lives for millions of people. In parallel there has been astonishing progress in medical technology. Collaborations among physical scientists, engineers, and doctors have given us CAT scans, Magnetic Resonance Imaging, and a wide variety of therapeutic devices. Many of us believe that the convergence of the life sciences with the physical sciences and engineering is a third revolution.

Consider renewable energy. Some have argued that if we simply implement currently available technologies we can stop the increase of CO_2 in the atmosphere. However, if one looks closely at current technologies, every one of them has deficiencies that require new science and engineering to overcome.

In some sense, the genomic revolution may be just the first example of this convergence, since it relies so heavily on technology and mathematics. There is little doubt that investments in this convergence will lead to advances in knowledge that will translate into better detection, diagnosis, and treatment of diseases, and mankind will benefit from investment in this kind of research. MIT President Susan Hockfield recently wrote in *Science* (*www.sciencemag.org/cgi/content/full/323/5918/1147*) about the third revolution. Global health will not improve without political and societal change, but the third revolution is sure to help.

These two areas of science are ones in which there will be great practical benefits, but one cannot have strong science in these areas without a scientific enterprise that is uniformly well supported. It is especially important not to neglect fundamental, curiosity-driven, disciplinary research. For this reason, it is important to pursue the goal of the America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science (COMPETES) Act, to double the budgets of the National Science Foundation and the Department of Energy Office of Science.

The stimulus package passed by Congress and signed by the President promises a short-term pulse of funds for science and engineering. This will provide much needed new equipment and may keep students and postdocs from leaving their labs for a year or two, hopefully until the job market improves. However, such short-term funding can be dangerous. Indeed, the doubling of the NIH budgets in the 1990s was wonderful, but its aftermath, four or five years of flat budgets, has been very painful. Young people, who, with great expectations, became graduate students in the life sciences at the beginning of the doubling, joined the ranks of untenured faculty members at a time when it became extremely difficult to secure NIH funding. We must be careful not to make commitments during the stimulus that we cannot sustain when it ends. The pressure to cut research funding will be intense when the economy recovers, because the federal deficits will be enormous. We must urge the President and Congress to provide sustained if modest growth in our research budgets in order to make the scientific and engineering breakthroughs the world so badly needs.

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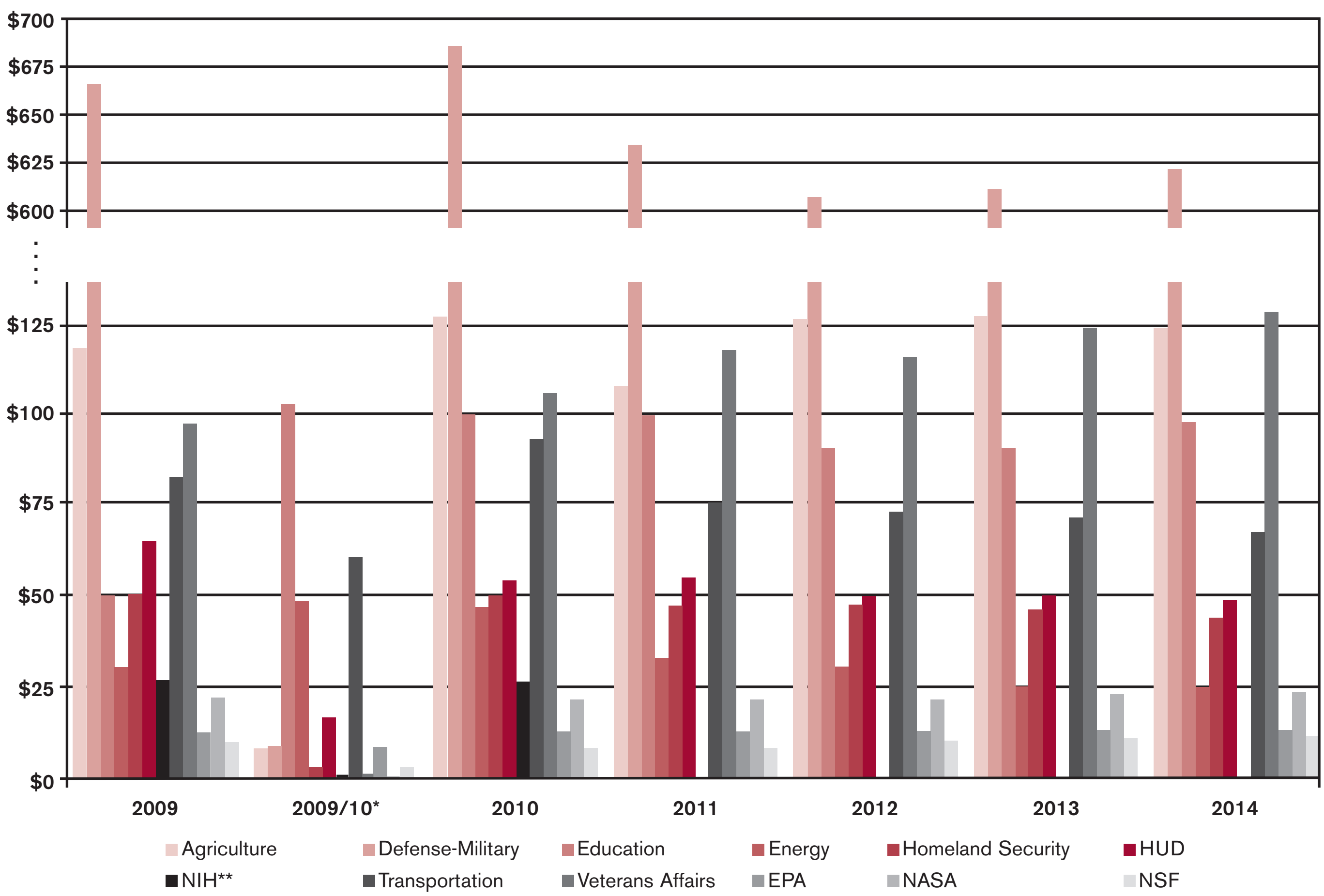
Numbers

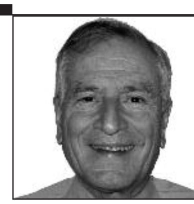
Budget of the United States Government (2009-2014)
Outlays By Selected Agencies (in millions of dollars)

Source: U.S. Government Printing Office: *www.gpoaccess.gov/usbudget/fy10/browse.html*



*Recovery Act
**Data N/A for 2011-2014

System at a Crossroads: Rethinking Infrastructure and Mobility*




Fred Moavenzadeh Kyle Frazier

THE U.S. INFRASTRUCTURE SYSTEM is at a crossroads, and a new approach – encompassing research as well as practice – is needed to move the system forward. Performance indicators like the number of hours that drivers spend on congested highways or that delayed travelers spend in overburdened airports are trending upwards, while the estimated backlog of deferred maintenance and repair spending is likewise on the rise. Overall, the infrastructure system – actually a collection of interdependent though not always integrated systems – is simply not consistently and efficiently delivering the services, primarily mobility, that society and the economy demand from it. The creative and thoughtful application of new "enabling technologies" to infrastructure systems – especially from the fields of information and communications – offers the potential to make substantial systemic gains, but a broadening and reorientation of research is needed to provide the knowledge and tools to seize these opportunities.

The difficulty of orchestrating a comprehensive response to this problem is compounded by the structure of the infrastructure enterprises, which are extensively fragmented along multiple dimensions. Authority is held by a mixture of local, state, federal, and regional – or metropolitan – agencies. It is divided according to modes (e.g., air, rail, highway, marine, and pipelines in transportation) and often it is further split among entities responsible for guide-ways and infrastructure, vehicles and rolling stock, system operations, and other functions. Information traditionally has not flowed easily across these boundaries, and decision-making typically allocates resources to achieve localized optimization with poor understanding or little regard for effects on long-term improvements in the larger system. Provision of mobility – and enhancement of its quality – is an issue requiring a comprehensive approach and participation of the many service providers and other stakeholders. Our failure as a nation to adopt such a coordinated and inclusive approach has been a major factor contributing, over the last several decades, not just to a lack of real progress, but also to an actual worsening of service provision by the systems at large.

More and more stakeholders are becoming aware of the shortcomings of the system, but too often the proposed remedy is to increase spending without rethinking the underlying strategy. This flawed thinking was evident earlier this year in the public discourse that surrounded the economic stimulus; much focus was placed on the condition and capacity of physical infrastructure systems, including many anecdotal examples of poorly maintained, deficient, or even failing assets. Physical infrastructure, however, exists to provide services like mobility to society, and there has been considerably less talk explicitly about improving these services than there has been about simply building or rebuilding infrastructure. To assume that investment in fixing roads and bridges will solve or even significantly lessen our mobility problems is to underestimate dangerously the scope and complexity of the true mobility challenge. The crux of this task is adapting and, where necessary, expanding or replacing legacy systems to meet the challenges of the twenty-first century; to do so will require considering not only the physical elements of the system but also the institutions, policies, organizations, and other factors that constitute the infrastructure system and influence the level of mobility it makes possible.

To be sure, there have been a range of limited initiatives to modify various aspects of infrastructure over the past two decades, including some efforts to craft viable public-private partnerships and work on intelligent systems, but there has remained a deficit of political will to make the high-level decisions necessary to overcome infrastructure's web of interrelated capacity, efficiency, and revenue problems and facilitate widespread improvement to mobility and modernization of the systems that deliver it. The challenges that the system faces are complex, and it seems not unreasonable to suggest that a paradigm shift in the approach is needed to successfully overcome them. When faced with such a challenge, this nation has in the past turned to science and technology, and these fields must undoubtedly be called upon again to modernize the systems and meet our mobility needs in this new century. We must not, however, rely on these disciplines exclusively.

Conventional wisdom tells us that, as a nation, we should invest more in research and development in infrastructure, but the nature of this investment will be vital to its success. Federal and state governments, industry groups, and other organizations have spent vast sums of money on research for decades, yielding mostly modest successes and incremental improvements, though the results have been decidedly unbalanced across infrastructures. For example, major advances in information technology have revolutionized communication and the infrastructure that supports it, but no parallel to this exists in other forms of infrastructure. Valuable though the countless incremental innovations in infrastructure have been, they have proven unable to keep pace with the rapid rate of change in the economy, demographics, and other external factors that shape the demand for infrastructure services and have failed to forestall continued worsening of congestion and other performance indicators. Recognizing the limitations of current approaches and devising improved R&D investment strategies to overcome them is imperative.

As suggested above, critically evaluating the mobility challenge and the full spectrum of possible research contributions is essential to moving the nation towards a more sustainable and better-performing infrastructure paradigm. We must ask ourselves what is working, what is not, and what priorities are likely to generate the sought-after outcomes most effectively. What might modern infrastructure systems, able to deliver mobility sustainably, look like? Looking to the history as well as the current state of our existing systems can provide insights. For example, the U.S. transportation system has developed – mostly haphazardly – over the past two centuries. It moves both people and goods and includes multiple modes of travel, notably air, maritime, rail, highways, public transit systems, and pipelines. To improve this system, we must look not only to the technologies and operations of the individual physical systems but also to the effects of the institutional and organizational structures that provide governance and management. Institutional jurisdiction is fragmented in multiple dimensions – along modal, geographic, and functional lines – and coordination among these is difficult to achieve.

The nation's Northeast corridor – connecting major metropolitan areas like Boston, New York City, and Washington, DC – is an illustrative example. The corridor includes a mix of railways, sea lanes, highways, and air traffic routes that connect the cities, as well as a multitude of options for local travel within individual metropolitan areas. Governance and management of these systems involves the federal government, multiple states, and countless local or regional authorities, each with its own resources, goals, and incentives. Much of the infrastructure is operating against the margins of capacity constraints and has been kept in operation longer than designers intended. Congestion has been a problem for years, but the constraints and complexities of the fragmented system have made significant improvements very difficult to achieve. Altering the ways in which the various modal and geographic authorities interact may be an important element in improving the overall system performance, but overcoming the many barriers – political and otherwise – to such changes is no straightforward task.

Recent technological developments have given us tools that may facilitate new inter-organizational interactions and coordination, make new management approaches feasible, and ultimately enable fundamental systemic changes to improve mobility. Information and communications technologies have advanced rapidly for several decades and have transformed other industries. Their uptake in infrastructure systems, however, has been relatively unbalanced, and in certain infrastructure systems, such as transportation, very slow. Some transportation stakeholders have successfully applied various information and communication technologies to improve their own operations and management systems, and a few initiatives – like the U.S. Department of Transportation's Integrated Corridor Management Systems – are seeking to leverage technology to enhance the performance of individual subsystems in limited geographic areas. These are important first steps, but the scope of application must be broadened significantly. Applying new technology within organizations and subsystems is valuable, but addressing infrastructure's problems comprehensively means exploring the opportunities for using information and communication technologies to enable new strategies across many organizations and, indeed, systemwide. Maximizing the potential benefits requires looking for the best ways to align technologies, management strategies, and institutional structures. The nature of these interactions and the policies necessary to implement and optimize them are not well known, creating an opportunity for trans-disciplinary research to make a real contribution to mobility improvement.

As a nation, we must come to grips with the mobility challenge and re-orient the infrastructure enterprises to meet this challenge with holistic and sustainable solutions. This challenge is not unlike that which we are facing in the healthcare sector, and the response must be similarly comprehensive: not only using technology to improve what is already done, but also searching for ways in which it can support a new, better paradigm involving change in much more than technological systems. Investing strategically in mobility research will provide the knowledge, technologies, and ideas necessary to accomplish this task in the context of infrastructure, but we must ensure that our investments are shaped by the challenges of the future and not the problems of the past.

**Mobility, in this article, refers to all modes of infrastructure: mobility of people, goods and services, power and energy, water, and information. For examples, however, the article draws primarily from transportation.*

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Energy Transitions and Transformations

Stephen R. Connors

David H. Marks

This brief "op-ed" outlines some of the energy challenges and solutions that we have been conducting research on for over the past eight years – both at home and abroad – that simultaneously address the "substantial and sustained" reductions in both greenhouse gas as called for by world leaders (e.g., 80% by 2050) as well as other environmental threats, and energy security especially as it pertains to imported fossil fuels.

Note that this is not just a supply oriented technology view, nor just ways of increasing efficiency to reduce demand. Rather, we focus on integrated strategies that can provide substantial emissions reductions at large scale and in time. Thus a great deal of emphasis is focused on matching the dynamics of energy demands and supplies, and the role of large-scale demonstrations to gain consumer and industry confidence regarding innovative management options.

This piece focuses on key aspects of how we might transform the domestic U.S. energy market and the need for energy security, robust availability, and markets to bring about efficient use.

THE UNITED STATES, AS WELL AS many regions of the world, needs to protect itself economically and environmentally by substantially reducing fossil fuel consumption, especially imported fuels subject to increasingly volatile world energy markets. A strategy to transform a nation's or region's energy supply and demand infrastructure can be separated into three complementary components:

Aggressive End-Use Efficiency – Move aggressively to improve the efficiency of energy services, especially with new technologies that substitute information for energy (e.g., smart houses, grids, roads, etc.). An aggressive end-use efficiency strategy reduces the demand for energy and extends the usefulness of the energy delivery infrastructure.

Diversify Domestically – Greatly diversify the energy resources tapped by the energy sector to meet domestic energy needs. A large component of this diversification is a shift away from reliance on global fuel markets/supply-chains, to domestic energy resources comprised of both renewable and conventional carbon-free supplies.

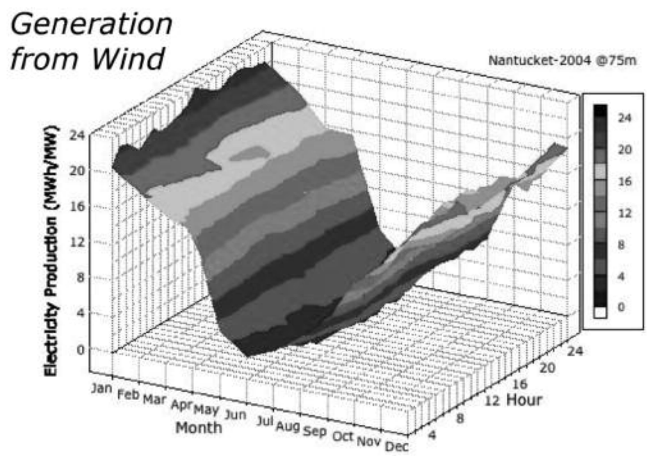
Modernize Energy Networks – Modernize energy infrastructures by which those energy resources/supplies are transformed and delivered to consumers. This has near-, medium-, and long-term components as we consider investments in the high-voltage grid to accept remote wind and/or clean coal, and the development of smart, local, microgrids capable of handling dynamic loads (demand response) and distributed generation and electricity storage. Analogous investments to improve the logistics of alternative fuel production and distribution will also be required.

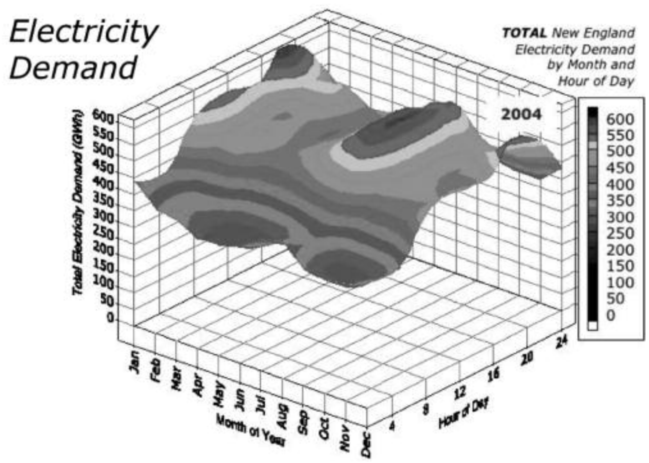
Key to the design and implementation of such a strategy is a *detailed understanding of local and regional dynamics*, or situational aspects, of energy supply and demand (see figures next page). How national and state policies develop both new technologies and the business models required for their rapid deployment at all levels is a *major design challenge*. This includes the electrification of transportation, the co-development of electric vehicles and fleets, smart grids enabling V2G (vehicle-to-grid), and also new clean generation to charge those vehicles. Economic stimulus benefits, and the need to rapidly develop the *human capital* necessary for this transformation, provide a substantial opportunity for the nation to move forward.

How national and state policies develop both new technologies and the business models required for their rapid deployment at all levels is a major design challenge. This includes the electrification of transportation, the co-development of electric vehicles and fleets, smart grids enabling V2G (vehicle-to-grid), and also new clean generation to charge those vehicles.

Demonstrations, Pilots, and Priming the Energy Industry for the Future

Near-term initiatives the new administra-





tion should consider include policies which simultaneously create business opportunities and jobs in the near term, and "prime the pump" for a low-carbon energy (not just electricity) future. Clearly the "Aggressive End-use Efficiency" component above provides the best early opportunities. This includes incentives to companies to retrofit buildings for lower energy consumption, but should also consider policies that provide a new foundation of construction activities promoting the renewal of the nation's building stock, thereby insulating the construction business from frequent boom-bust cycles.

For the "Diversify Domestically" component, business and job creation is concentrated more at the levels of new projects/facilities, and will exhibit the dynamics seen in the wind industry over the past decade with the intermittent Production Tax Credit – all along the supply-chain – unless more steady and consistent policies are implemented. While state and federal policies supporting wind and solar have resulted in a large number of projects, investments, and the growth of the industry, to achieve the level of investments and growth envisioned to reduce greenhouse gases by 50-80% by mid-century, these policies need to be sustained and expanded.

As indicated in the U.S. Dept. of Energy's 2008 *20% Wind Energy by 2030* vision report, we are only now beginning to look at the power grid investment requirements required to achieve "big wind." The two surface plots of daily and seasonal New England electricity demand and offshore wind resources dynamics show the long-term challenges of matching electricity supplies and demands. Not shown, are both the short- and long-term variability and uncertainty of multiple renewable resources that need to be factored into future energy systems design.

This is only one need of the future grid, and so "Modernizing Energy Networks" also balances network-wide investments which coordinate both growth and aging of the existing grid with new topologies to integrate remote wind and solar, remote carbon-capture and storage fossil, as well as highly dynamic distributed generation on lower voltage systems. While these may have limited job impacts in the near term, grid-by-grid analyses to identify network modernization (e.g., smart grid) strategies and investments need to begin in earnest now.

All together this level of effort clearly goes beyond a (large) handful of demonstration or pilot projects. In our work of the last several years, we have increasingly identified the need for "priming projects" or "integration demonstrations" which not only move the technologies forward, but develop the human capital and industry familiarity in siting, building, and operating these new technologies.

There are some significant "public goods" investments that governments also need to consider to develop and sustain this new energy industry. Education and training is one obvious need. Game changing and integration R&D is another. Often overlooked is the need to systematically collect geographically specific and high-resolution renewable resource data, so we can understand how much we can rely upon specific renewables, and to identify deployment thresholds we may encounter as they enter the energy system. Finally, there is also a need to develop "local and regional visions" that inform local communities of the economic and environmental benefits of large-scale penetration of renewables, smart grids, and to a lesser extent efficiency, to both combat NIMBY as well as to develop the local institutions essential to both create and sustain the jobs of a new energy future.

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Society's Nervous System: A Key to Effective Government, Energy Efficiency, and Public Health

Alex Pentland

MOBILE PHONES – AND THE twenty-first century networking infrastructure supporting them – are one of the few remaining bright spots in today's economic climate. Just as mobile phones have become an indispensable part of our daily lives, they have also emerged as a genuine catalyst for global economic growth.

Worldwide, there are now more than four billion mobile phone subscribers and every day two million new subscribers get phones. At this pace, one billion additional subscribers will be connected to the global economy by the end of next year. Studies have proven that connecting people with wireless networks plays a major role in the development of poor and underserved communities, just as the Internet has done for more wealthy groups. For the first time in history, the majority of humanity is linked and has a voice.

The most important changes, however, may come from the fact that these same mobile phones are location-aware sensor platforms and their wireless networks support sensors in cars, buses, and homes. As a consequence, our mobile wireless infrastructure can be used to understand the patterns of human behavior, monitor our environments, and plan the development of our society. This functionality is mostly latent at this point, but already these devices are being used to measure population flows into cities and slums, to map the movement of populations during emergencies, to identify neighborhoods where social services are inadequate, and to manage automobile traffic congestion. The ability of mobile phone networks to identify unusual patterns of movement and communication is also how public health officials and disaster relief teams are scanning for outbreaks of diseases like SARS and emergencies such as tidal waves.

Like some world-spanning living organism, wireless traffic systems, security sensors, and especially mobile telephone networks are combining to become intelligent, reactive systems with sensors

The most important changes, however, may come from the fact that these same mobile phones are location-aware sensor platforms and their wireless networks support sensors in cars, buses, and homes. As a consequence, our mobile wireless infrastructure can be used to understand the patterns of human behavior, monitor our environments, and plan the development of our society.

serving as their eyes and ears. It seems that the human race suddenly has the beginnings of a working nervous system. For society, the hope is that we can use this new in-depth understanding of individual behavior to increase the efficiency and responsiveness of industry and government. For individuals, the attraction is the possibility of a world where everything is arranged for your convenience – your health checkup is magically scheduled just as you begin to get sick, the bus comes just as you get to the bus stop, and there is never a line of waiting people at city hall.

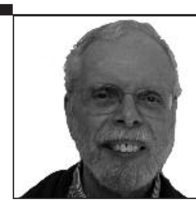
Unfortunately, this new nervous system is still separate from humanity's brain. Like a newborn infant, the local reflexes are beginning to work but they are unconnected to the main centers of information and communication. To realize the promise of this social nervous system, mobile networks must merge seamlessly with Internet computing to allow uniform, first-class, anywhere-any device access to the full potential of the world's computing, communications, and sensory resources. The idea of "cloud computing" should begin with mobile wireless sensor and communication networks, and not with physically static computing and Internet resources.

To realize the full potential of integrating mobile devices, wireless sensors, and Internet computing, there are three challenges that must be faced by government, industry, and universities:

(1) We must create open standards and policies that allow users to create and use mobile applications that access the full power of the Internet as easily as today's Web applications. Funding is needed for research in "mobile cloud computing," and for translation of these new tools to commercial reality.

continued on page 17

An Alternate Green Initiative



Leon R. Glicksman

ALTHOUGH CONSIDERABLE RESEARCH is underway to develop energy supply technologies that limit environmental damage, the dearth of large-scale affordable solutions for clean energy supplies that will be available in the near term presents serious concerns. The problem is compounded by the worldwide increase in energy consumption. As the developed world continues its modest energy growth, it is being overtaken by the explosive energy consumption of China, India, and other developing countries. Not only is the attention of the public and the press focused on the supply side, but federal and industrial research and development funding is heavily weighted toward supply-side solutions. It seems more reasonable to take a balanced approach to the energy problem, putting as much attention on means to reduce energy consumption as on means to generate additional energy. This requires a substantial rethinking of America's R&D policy.

In the transportation sector, improvement of fuel economy for vehicles is finally receiving serious consideration in the U.S. Although it will certainly help reduce our reliance on liquid fossil fuels, it is not sufficient, by itself, to halt overall global warming. The largest single energy consumption sector is not transportation, rather, it is buildings. Residential and commercial buildings together consume 40 percent of our primary energy and more than two-thirds of our electricity.

Several organizations have established ambitious goals for the efficiency levels of future buildings. The American Institute of Architects has a goal of achieving, by the year 2010, a minimum 50 percent reduction from the current level of consumption of fossil fuels used to construct and operate new and renovated buildings. Some government bodies have stated goals of achieving zero net energy buildings in the next few decades. Modest improvements in energy efficiency, 20 to 30 percent reductions, can be achieved by application of current products and technology in a straightforward fashion. Techniques to lower residential heating energy consumption in northern climates by 80 percent or more have been shown to be available for new construction with acceptable life cycle costs. However, solutions to achieve similar efficiencies in commercial buildings and for homes in hot and humid climates are not yet at hand; and require substantial R&D efforts.

For the past decade, R&D support for this sector has been chronically ignored. The new administration in Washington has promised to reverse this. So what should a new research program of energy efficiency look like? The building sector compromises so many actors and contributions from so many technical disciplines that it is hard to single out a short list of the best bets. That leads to the first conclusion: the government can not get in the business of picking winners, certainly not specific technical niches. Achieving substantial levels of energy efficiency requires a combination of technologies. If there is something approaching a silver bullet, it is integrated design and operation – architects, developers, engineers, construction firms, and energy consultants working together from conceptual design through finished construction and integrated operation.

Research on integration is needed across disciplines – how to combine future developments in materials, controls, and thermal science into an optimum combination. Such an approach not only will ensure that the major building elements such as the building skin or envelope, heating and cooling systems, ventilation, and lighting are well matched, but it will also result in substantial economies. Possible elements include windows that capture and distribute daylight deep into the building interior, thermodynamic cycles that double heating and cooling system efficiencies, and thin insulations based on nanotechnology that can be easily retrofitted on the inside of exterior walls.

The largest single energy consumption sector is not transportation, rather, it is buildings. Residential and commercial buildings together consume 40 percent of our primary energy and more than two-thirds of our electricity.

continued on page 17

Rotten Apples or a Rotting Barrel: How Not to Understand the Current Financial Crisis

Susan S. Silbey

WHAT CAUSED THE FINANCIAL crisis? Certain observers blame poor choices by victims and irresponsible decision-making by market actors – and say more regulation isn't the answer because the problem is not the unregulated market. This excuse is often heard after organizational failures, and it misses the point by accusing the bad apples and not the rotting barrel.

Holman Jenkins Jr. writes in the December 17 *Wall Street Journal* that investors with Madoff were incompetent consumers. They failed to behave as the responsible and rational actors economic theory assumes they will be; they trusted rather than investigated the person with whom they invested. The daily reports about hedge funds earning reliable profits of 20 to 30 percent annually were irrelevant and did not feed the fraud. The front page of the December 18 *New York Times* quotes Professor Lucian Bebchuk of Harvard Law School as saying that Merrill Lynch managers were "responding to distorted incentives." Those are the very same incentives many law and economic scholars claim are the only ground of rational action. If the unconstrained pursuit of self-interest and economic reward that has led to the complete financialization of all production, distribution, and management turns out to be just one big global Ponzi scheme, it is not, according to neo-liberal ideologues, a flaw in the theory of the market but simply the result of bad or incompetent market actors.

Should we remember that the theory of the market – as the most efficient mechanism for coordinating action – rests on the assumption that bad actions will nonetheless lead to good outcomes?

Crises of corporate and professional responsibility have been endemic to American capitalism, and if the current financial crisis is of an unprecedented magnitude, it is different only in degree but unfortunately not in form. With each chapter – from the robber barons of the nineteenth century, the Tea Pot Dome scandals and the stock market crash of 1920s, through Watergate, the Savings and Loan crisis, and Iran Contra in the 1970s and '80s, to Enron and World Com in the 1990s, to the current financial disaster – the response has been unimaginatively the same: some few weak or greedy, uninformed or misguided individuals made poor choices. Those bad apples made the barrel rot.

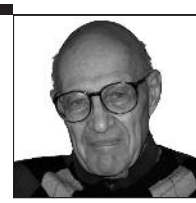
Just as we have the American myth of Horatio Alger battling all odds to lift himself up by his own bootstraps, we have a companion myth concerning poor choices and ethical lapses. The stories of Enron, the drug trials for Actonel, and the Schon affair at Bell Labs, for example, have already been narrated as stories of a few rotten apples in basically good barrels. In a similar manner, we will soon see more and more stories about Merrill Lynch, Citigroup, AIG, and General Motors describing how one or another person made a bad decision or acted unwisely. We are unlikely to read stories about rotting barrels, only about rotten apples.

The story about a rotting barrel would require an analysis of how the progeny of Milton Friedman and Friedrich Hayek propagated modern *laissez-faire* economics and sold it worldwide through the Washington Consensus, the World Bank, and Wall Street, successfully challenging the legitimacy of government (and just about all institutions other than the family) while legitimating a massive transfer of wealth from the working and middle classes to super-rich financiers who eventually rotted in that very same barrel. This less familiar story about a rotting barrel would also require us to ask how the theory of the efficient market managed to justify annual bonuses exceeding the annual profits to shareholders. Might we soon hear a story about how this financial downturn is merely an expected once-a-century readjustment for longer-term capitalist stability? I guess those shareholders – pension and mutual funds, states, banks around the world – were just irresponsible, that is bad consumers, unprepared for this market correction. In other words, because the cause of our crisis, in the popular account, is not a rotten barrel but a few bad apples, we need not look any further to explain how this financial pyramid imploded.

I keep thinking, however, that if the apples keep rotting, there must be something wrong with the way they are grown or with the barrel. More than 60 years ago, the sociologist Edwin Sutherland published his much lauded work on white-collar crime in which he observed that American corporations constituted the largest category of criminal recidivists. This counter-intuitive observation illustrated Sutherland's theory in which he described criminal behavior as normal learned behavior in subcultures where there is an excess of circulating definitions

continued on page 17

The Way to Sustainability


Leon Trilling

NO OBJECTIVE IS MORE URGENT, more complex, or more encompassing than the passage from a world addicted to material growth to one built on the notion of sustainability over time.

The history of human communities is a set of rides up logistic curves. They start with the limited exploitation of a niche and the creation of an appropriate social and cultural structure. As the carrying capacity of the niche is reached or exceeded due to exhaustion of resources or outside interference, the community either collapses or painfully adapts to seek a higher carrying capacity.

Up to the nineteenth century, these activities caused small repairable perturbations in the natural order. By the end of that century, a few nation-states and entrepreneurs, using new technology and the market system, competed for wealth and power across the entire planet. Their labors led to a much larger population of richer, healthier, and more diverse people; but they also reduced natural redundancies, exhausted some resources, and brought about ever more deadly wars and more disruptive economic crises.

While early warnings of danger were ignored, it has been recognized since 1968 (Club of Rome) that the party cannot go on much longer. We are here because our technology used up too many resources and produced more pollution than we knew how to get rid of, in the service of a competition for power by people who believed that continuing material growth was essential to their well being.

To approach sustainability, we must create a leaner technology, invent local and global institutions to control that technology, reduce to a tolerable level the inequities suffered by many peoples as a result of the power competition, and build substantial popular support for a sustainable world.

Many traditional tasks of technology were performed by specialists who viewed their assignment narrowly with limited concern for the possible effects of their work on the environment. Unforeseen consequences were seen as externalities. If necessary, a fix was performed after the fact.

As some of those consequences became more serious and as their victims became more articulate, the way engineering was performed began to change. Devices or processes were seen as operating in a large encompassing system, and it was the performance of that system which had to be optimized over the life span of the devices, including their disposal.

An effort was made to measure the physical, biological, and medical consequences on the entire system so that standards of performance could be set. This new design procedure called for the teamwork of specialists from diverse fields, including the economic, political, and social sciences. And by focusing on the entire system from the start, the designers were able to consider a wide range of options to solve a functional problem.

At the same time, public agencies, gradually and reluctantly at first, undertook to set and enforce performance and environmental impact standards. Enterprises at first resisted this trend because internalizing externalities might increase their costs in a competitive context. Articulate popular support for the new "greener" engineering in the European Union and then in the U.S. seems to have settled the policy of environmental regulation so that the issue now is "how" or "how much." In fact, national governments have invented and are putting in place novel incentives such as "cap and trade."

The effects of industrialization on the environment transcend national boundaries and must be addressed on a worldwide basis. The resulting political negotiations must account for differences in culture, wealth, political power structure, and level of development. They are therefore very complex and move ahead slowly. They are backed up by an international scientific program that provides generally accepted background data as a basis for establishing standards and building popular support.

Such support is essential in the long run, so it is interesting to speculate on the dynamics that affect it. For example, what can the mutually supportive fields of cognitive science, psycho-economics, game theory, and role-playing experiments tell us about how attitudes toward risk, tension between self-preservation instinct and social empathy, trust in others, and past cultural experience are likely to affect private and public choices between material growth and sustainability.

A better sense of these dynamics may help guide the public discourse on how best to manage the transition. I suspect that the tension between the traditional worldview absorbed at home and the incompatible science-oriented view offered somewhat imperfectly in school must be relieved to facilitate it.

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Making the Web Work for Science

Hal Abelson

John Wilbanks

THE WORLD WIDE WEB was created for science. Tim Berners-Lee's invention of the Web (1989) was motivated by the need to manage information about experiments in high-energy physics. Today, anyone with a Net connection and a browser can find obscure music with a few mouse clicks, or custom-design a new pair of shoes, or auction the paintings in their attic to an audience of millions. Yet in comparison, science has been affected very little. To be sure, scientists have embraced some aspects of the Web, like putting databases and journals into digital formats. But the overall effect has been to support business as usual. There's been nothing in science like the transformational impact of the Web on news, shopping, or entertainment.

Are you looking to buy a Canon Powershot A590 digital camera? Type "Powershot A590" into Google and click on "shopping," and you'll see pages of stores offering the camera for sale, conveniently ordered by price, with buyer recommendations and links that you simply click on to purchase.

In contrast, imagine that you're a malaria researcher investigating glycophoren A as a drug target. A Google search under "malaria glycophoren A drug target" brings up 1300 documents, with no overall summary to guide you; and that's only the free literature, not the closed-access journal publications. Suppose you wade through those papers and find an interesting result you'd like to replicate. Can you click on a link to order the cell lines? Hardly. Getting those samples requires contacting the researchers, negotiating a materials transfer agreement with their institution, a negotiation that could easily take months, if you can get the materials at all. A study in 2002 (Campbell, et. al.) found that 47% of academic geneticists had been rejected in their efforts to get data or materials from other academics.

If we lack a game-changing Web of Science, it's not for lack of vision or technology. As far back as the '80s, Bob Futrelle at Northeastern University was prototyping computer programs where you could ask about molecular biology research results, and back would come graphs of experiments – illustrations extracted from the pages of journal publications – together with machine-generated textual interpretations of the graphs. A single query could in principle let you view and compare the graphical results of dozens of experiments, mined from the literature. As Futrelle wrote (1992), "If future electronic documents are to be truly useful, we must devise ways to automatically turn them into knowledge bases."

One of the best steps the new administration can take to promote the progress of science is to remove barriers to realizing the Web's potential as a tool for scientific research. Here, an important message for policy makers is "First, do no harm."

Twenty years later, there are still no tools like this in common use as research aids. MIT computer engineers could implement them, but the MIT Libraries couldn't deploy them because the licenses the Libraries sign with academic journal publishers specifically prohibit data mining of papers and reuse of figures.

To liberate science from prohibitions on turning documents into knowledge bases, we need more mandates for open-access publishing like the one from the National Institute of Health (NIH), and more institutional open-access policies like the one the MIT faculty unanimously adopted at their March faculty meeting.

One of the best steps the new administration can take to promote the progress of science is to remove barriers to realizing the Web's potential as a tool for scientific research. Here, an important message for policy makers is "First, do no harm." The "Fair Copyright in Research Works Act" (HR 6845), now before the House Judiciary Committee, would repeal the NIH mandate and forbid government agencies from making any similar mandates. This bill is downright destructive to scientific progress, and it should be scuttled. Quite the opposite should occur. NSF and other agencies should be directed to follow NIH's lead in ensuring that the results of publicly funded research are publicly available

Open access to publications is only a first step. Imagine being able to treat the more than a thousand molecular-biology databases, together with the published literature in molecular biology, as a unified system where you can pose questions and get precise answers. A researcher interested in potential drug targets for Alzheimer's disease might want a list of genes involved in signal transduction that are related to pyramidal neurons. Typing that into Google results in tens of thousands of hits, primarily titles of papers, with no real sense of what they have to do with the question. To get instead an actual list of genes requires software that can interpret the statements in the papers and combine information from different databases that use different vocabularies. One approach to that kind of massive-scale data integration relies on document markup (metadata) and the methods of the Semantic Web research effort that Berners-Lee now leads at MIT CSAIL (Computer Science and Artificial Intelligence Laboratory). CSAIL also hosts Science Commons, part of the independent public-interest organization Creative Commons, which is using this approach to create an open knowledge base of annotated biomedical abstracts, integrated with major neuroscience databases.

So a second priority for the administration should be to promote tools and standards that facilitate data mining and integration across research results. The NSF's Office of Cyberinfrastruture articulated such a program in 2007, but it was never fully implemented. It's time to do so.

Can we go further? How about the "fantasy" of researchers ordering biological materials by simply clicking on links in published papers? That's doable, provided institutions can pre-negotiate standard agreements so that requests for materials can be automated.

Can we go further? How about the "fantasy" of researchers ordering biological materials by simply clicking on links in published papers? That's doable, provided institutions can pre-negotiate standard agreements so that requests for materials can be automated. This is another area where Science Commons is working, collaborating with the Association of University Technology Managers (AUTM) to formulate those agreements, and with plasmid depositories like Addgene that can provide distribution and manufacturing. That infrastructure is already deployed through the Kauffman Foundation's Bridge Network for research and technology transfer. Even so, effecting real change will require confronting a university culture where scientists often respond to a first-to-publish reward system by withholding data and materials.

Amazon, Wikipedia, eBay, and YouTube show how the Web can transform culture and commerce. Science research is a lot harder than contributing to a collaborative encyclopedia or uploading videos. But if policy makers can focus on removing the obstacles to making the Web work for science, the payoff in innovation would be huge.

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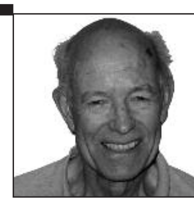
A Note to Energy Secretary Steven Chu



David Gordon Wilson

THIS IS A NOTE FROM an academic colleague with something in common with you: we are both fascinated by what science and engineering could do to improve the world, while also realizing that environmental/energy policy has a vital role. Reviews of your distinguished career have stated that you believe that a tax on gasoline or fossil fuels in general or on carbon emissions could be necessary. My students and I at MIT have been working on these aspects for many years, and we want to steer you in a slightly different direction – but one with dramatically better consequences.

The problem is that taxes of this type have at least three major disadvantages. They are regressive, hurting poor people more than the rich; they are inflationary, because they increase the price of almost everything that makes up the cost-of-living index; and they put huge sums at the disposal of Congress and the administration to squander on "bridges to nowhere" and similar boondoggles.

Please consider a way to achieve the same objectives with no government interference, with the minimum of government expenditure, and with huge benefits elsewhere. We need to give everyone strong incentives to reduce consumption of fossil fuels and emissions of pollutants. All three of the disadvantages cited above can be avoided by the following. Appropriate fees that increase quarterly should be charged for measurable emissions and for purchasing fossil fuels. For instance, gas could be increased by 25 cents per gallon every three months. The fee monies should be immediately deposited in an impregnable trust fund. At the end of every month the fund should be reduced to zero by dividing the total sum by the number of legal adult citizens (perhaps age 17 and over) in the country, and by depositing the resulting precisely equal amounts in the bank accounts of every such citizen, rich and poor. (Everyone would be required to have a bank account. The banking industry would be delighted.) Thus the poor would get back more than their additional spending even if they did not change their way of life because consumption of almost everything, and the associated fees, increase with income, whereas the amount rebated is the same for all.

Everyone, rich and poor, and businesses of every size, would have increasingly strong incentives to reduce emissions and the use of fossil fuels, and to develop alternatives. As the purchase price of oil and coal gradually rose, other technologies would become attractive for industry to produce and for consumers to purchase. The calculation of the cost-of-living (COL) index should be required to include (as reductions in the COL) the amounts returned to consumers in addition to the increased costs of anything involving emissions and the use of fossil fuel.

We would thus have a policy that is fair to rich and poor (that in fact would serve to ameliorate the appalling disparity in tax treatment of the past years); that would give strong incentives to the formation of new enterprises and to increasing employment; that would reduce emissions and the use of fossil fuels in an optimum, speedy, way; that does not involve taxes (because the government would receive no funds from the fees), and in addition would have strong disincentives to illegal immigration (because "illegals" would have to pay the higher prices but would not get the rebate). It would cost the government very little to introduce and manage (the prevention of cheating and the prosecution of violators would be the principal requirements). A "white paper" on the steps needed is included on the Website: ***lessgovletsgo.org***.

We know that despite FDR's valiant efforts to stop the Great Depression, it was in fact ended precipitously by the Japanese attack on Pearl Harbor and the resulting declarations of war. If you put into place the policies recommended above, you would be declaring war on global warming, and could stop our present depression. And the U.S. would again emerge victorious, as the green leader among nations.

Please give it your blessing and campaign to get it adopted by your colleagues in the Obama administration. Point out that otherwise we are condemned to repeat the experience of the 1970s when the price of oil first rose, and all kinds of green enterprises were started, and then the price collapsed. All these innovative companies went out of business and their employees were dumped. We cannot let that happen again.

We are looking forward to your role in the country's future.

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Society's Nervous System
Pentland, from page 10

Current legal statutes are lagging far behind our ability to collect and process data about people . . . .

(2) The mobile networks are as much a sensor net as a communications net: the location of and state of mobile devices, environmental monitors, and civic infrastructure (medical, traffic, power, etc.) and similar sensors should be as easily accessible and useful as digital documents are today. To accomplish this, we need a dramatic increase in research into the use of these new sensor networks for civic, environmental, and commercial applications. In particular, basic research focused on using these sensor systems to understand the patterns of human behavior is essential because this understanding will form the bedrock of effective social systems.

(3) To avoid abuse of these new data sources, we must have a "new deal on data" that ensures accountability and data ownership. Current legal statutes are lagging far behind our ability to collect and process data about people; clearly our notions of privacy and ownership of data need to evolve in order to adapt to these new capabilities. Perhaps the first step is to give people ownership of their data, creating what economists know as a "fair market" for the information that will drive this new social nervous system.

If we can successfully address these three challenges, then we will see current systems evolve into an effective nervous system for our society, one that will repay our investment many-fold in terms of better civic services, a greener way of life, and a safer, more healthy population.

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An Alternate Green Initiative
Glicksman, from page 11

Integration includes the development of virtual building technology that allows specialists in materials or thermal science to effectively transfer their innovative concepts and advanced knowledge to groups with modest technical training such as designers and developers. Understanding and promoting integration is also required across different levels of scale; from planning individual zero net energy buildings through urban master plans.

In the near term there are energy efficient building solutions that not only pay for themselves; they reduce global warming while producing net economic gains. Why has the rate of adoption been so limited? There are difficult policy issues that must be examined by theoretical studies as well as large-scale experiments.

An aggressive R&D program in the building sector would forestall a substantial portion of the demand for new power stations and give more time to develop environmentally friendly energy-supply concepts. Not only are there a host of opportunities to apply today's efficiency knowledge, but advanced technologies – drawing on basic research by scientists and engineers in solid-state lighting, thermodynamics, turbulent flows, and nanotechnology – could allow us to economically reduce building energy demand by far more than 50 percent from today's level. To accelerate those developments, governmental and industrial R&D efforts need to be substantially refocused and expanded, which would have the added benefit of enhancing the educational opportunities for the next generation of leaders in the building-efficiency field.

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Rotten Apples or a Rotting Barrel
Silbey, from page 12

favorable to violation of norms or law over definitions unfavorable to the violation of law. He called this the principle of differential association. If we want to understand how the barrel rots, Sutherland suggested, we must look to the discourses and interactions that constructed and organize the barrel. The principal lesson Sutherland offers is that all behavior, deviant as well as normative, is learned in interaction with others. That learning includes the motivations, drives and rationalizations, as well as techniques, which can be complex, especially in financial transactions. Sutherland's work emphasized the importance of cultural context and social organization rather than exclusive focus on individual choice making. In other words, while we might want to acknowledge human agency and decision-making at the heart of economic or any other social action, we blind ourselves to the structure of those choices – incentives and content – if we focus too closely on the individual and ignore the larger culturally validated opportunities and motives that channel that choice-making activity.

Rather than thinking about this financial crisis as the consequence of an episode or series of problematic individuals, organizations, or professions, we might think about it as the outcome of learned behavior. We might then ask how our culture supports or challenges different kinds of behavior, how that culture is learned, and what are its lessons and messages. Then, we might imagine moving from a narrative of a few bad apples, or many bad apples, to a story about how the apples are grown, how they enter the barrel, and finally how different organizations of the barrel – free markets or regulated markets, effective government or privatized governance, shareholder power or corporate autonomy – might keep them fresh or encourage rot.

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The Role of Oceans in Climate Change
Malanotte-Rizzoli and Stone, from page 1

formed by small-scale oceanic processes, generally decomposed into multiple components: diapycnal and isopycnal diffusion (i.e., diffusion across and along constant density surfaces); mesoscale and submesoscale eddies, with scales < ~ 100 Km.; and convection. Diapycnal diffusion in particular is crucial in determining the ocean's circulation, since it is the diapycnal mixing of heat and salinity from the ocean's surface to its depths that gives rise to the density gradients which drive the large-scale circulation and its horizontal heat transports (Munk and Wunsch, 1998).

Vertical mixing by the other diffusion processes is strongest in high latitudes (Huang et al., 2003 a, b). There the strong cooling of surface waters favors static instability of the water column and a vertical alignment of the isopycnal surfaces. The former leads to penetrative convection; the latter to isopycnal diffusion being predominantly vertical and large amounts of potential energy becoming available for mesoscale processes. In particular, the convective cell(s) of the polar North Atlantic determine the bottom water mass that from its northern source spreads through the abyssal layers of the global ocean.

All these sub-scale mixing processes, with the possible exception of mesoscale eddies, are extremely difficult to measure in the field and, furthermore, are not resolved by the ocean general circulation models currently used for climate studies. Hence the necessity of stimulating research into process studies, both theoretical and observational, leading to improved or new parameterizations of ocean mixing in its different forms, and their related effects on the heat and, in general, water properties transports by the large-scale circulation at all depths.

The second most important role the oceans play in climate occurs in the regions where they are strongly coupled to the atmosphere. By and large, the ocean is driven by the atmosphere and the ocean circulation is a response to atmospheric forcing, i.e., wind stress, heat, and moisture fluxes. In the tropical/equatorial regions, however, the ocean exerts the strongest feedback on atmospheric motions thanks to the intense sea surface heat exchanges. Thus in the tropical regions the interannual to decadal modes of climate variability are coupled ocean-atmosphere modes. The most famous of all is the Pacific El Niño/Southern Oscillation (ENSO) mode that has been extensively studied since the early '80s. El Niño is the appearance in the Pacific interior of an anomalously warm tongue of water that changes the convective atmospheric cell above it. In normal conditions, the atmospheric convective loop involves upwelling of warm air over the western Pacific which moves eastward at height and downwells over the eastern Pacific.

During El Niño, due to the warm water pool in the basin interior, two convective loops are produced, with upwelling of warm air over the pool, and two branches moving at height both westward and eastward, finally downwelling over the western Pacific and Central America. El Nino is succeeded by its opposite phase, La Niña, in which the warm pool is replaced by a cold one. This coupled oscillation of the atmosphere-ocean system has an irregular periodicity of a few years and has profound consequences on the fisheries and the economy of central/southern America. A major observational effort, the Tropical Atmosphere Ocean (TAO) array, has been in place since 1994, becoming the Triton/TAO array in 2000 with Japan participating in the western part. It comprises 11 arrays of multiple instrumentation moorings regularly distributed all along the equatorial band on both sides of the equator (***www.pmel.noaa.gov/tao***). The TAO array has produced an incredibly rich time series of observations that have improved both the theoretical understanding and the modeling and prediction of ENSO.

Nothing analogous exists in the Atlantic and even less in the Indian Ocean.

In the tropical Atlantic, in the last decade, the Prediction and Research Moored Array in the Atlantic (PIRATA) has been put in place, through cooperation mostly involving France, the U.S., and Brazil. The PIRATA array, however, is much more irregular, sparse, and limited, coarsely spanning the equatorial band and not resolving well the most important mode of variability. This is the interhemispheric dipole or meridional sea surface temperature (SST) gradient mode. The SST north-south gradient in fact controls the position of the InterTropical Convergence Zone (ITCZ) where the northern and southern trade winds converge (Jochum et al., 2004). The ITCZ in its seasonal north-south migration is responsible for rainfalls or droughts over Brazil and West Africa and related epidemics of tropical diseases.

In the Indian Ocean, only in 2008 has a proposal been put forward for a multinational collaboration leading to RAMA: the Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction (McPhaden et al., 2009). In the Indian Ocean the most important coupled mode of variability is the Indian Ocean Dipole (IOD), consisting of east-west anomalies of SST and precipitation/drought. The IOD is similar to ENSO in its mechanism but is much more short lived.

The paucity of observations in the tropical Atlantic and Indian oceans have considerably retarded our understanding, modeling, and prediction of these coupled modes, which are extremely important not only because of their societal consequences but because it is through them that the ocean actually drives the atmosphere. These regions and coupled mechanisms should constitute a priority of observational and theoretical research.

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A New Method for Arms Control
Bernstein, from page 1

example of the fact that it takes a dedicated and coherent strategy to succeed. I am encouraged by the early appointment of Gary Samore to the National Security Council as "Nonproliferation Czar." Samore's work clearly includes the December expiration of the Start I Treaty, the 2010 Nuclear Non-Proliferation Treaty (NPT) review, and working with Congress to pass the Nuclear Test Ban Treaty.

Prior administrations have approached nuclear arms reductions either through negotiated treaties or by unilateral steps. While treaties often have produced valuable results, they suffer from the length of time most have required for completion. Unilateral action has the advantage of rapid implementation, but may not be reciprocated.

The new method suggested here, "challenge initiatives," is a hybrid that aims at combining the good aspects of both unilateral action and treaties, while reducing their downsides. In this method, an executive order is issued as a "challenge" to the desired partners. The challenge will be valid for a fixed period of time. This can be done quietly through diplomatic channels, or publicly, as is suitable for each specific case. Such an initiative has the virtue of clearly demonstrating a definite goal, and yet not committing the challenger to action if the other side does not reciprocate. It allows for rapid improvements on specific issues, while giving time for a reasonably long negotiation period to take its course. It also allows the other side to respond to the challenge quickly, building up good will and establishing mutual confidence, while still negotiating the specific points of a legally binding agreement.

Here are three examples of challenge initiatives that I believe would be particularly useful.

I. Signaling the Administration's intention to reduce the U.S. nuclear arsenal to below the mandated Moscow Treaty level of 1,700 – 2,200 weapons by 2012 – or the presently negotiated levels of approximately 1500 weapons – to the 1,000-weapon level, while challenging Russia to follow suit. Reaching this lower level means that we will have to start engaging the other declared nuclear powers in mutual reductions. This process, which is required in working towards a world that is free of nuclear weapons, will require active diplomacy. The best time to initiate such an action is probably after the present Start negotiations have been completed.

II. Declaring a significant reduction in the number of nuclear-armed missiles on hair trigger alert, combined with a diplomatic effort to get Russia to reciprocate. This is an important risk reduction initiative that will require time to negotiate satisfactory methods of verification. In this post-Cold War era, the most likely path to nuclear war between our two nations is an accidental launch based on faulty information. Unfortunately, this is not completely unlikely. This initiative would reduce such a possibility, while further improving bilateral relations.

III. Declaring that the U.S. would not be the first to use nuclear weapons, with diplomatic initiatives to the other nuclear weapons states (including India and Pakistan) to declare the same thing. This is linked to many other nuclear arms control issues. A non-first use pledge, along with the above-mentioned initiative to reduce the size of the U.S. nuclear weapons arsenal, would go a long way towards satisfying our obligations under Article Six of the Nuclear Non-Proliferation Treaty (NPT), which demands that all states work seriously towards the elimination of their nuclear weapons. These steps would significantly ameliorate the negative effects of the failure of the 2005 Nuclear Non-Proliferation Treaty review. That failure was partially caused by a refusal of the Bush Administration to re-confirm our commitment to Article 6 of the NPT. A successful completion of the 2010 review of the Nuclear Non-Proliferation Treaty would be most helpful in persuading Iran to alter its course, particularly if the non-aligned and mid-East states join in the diplomatic pressure on Iran. A non-first use declaration would, in addition, be valuable in helping to create an international atmosphere in which the importance of having nuclear weapons would be reduced.

Our hopes are with President Obama and the new administration to succeed in the long sought goal: the post-war dream of the original scientists (who created the atom bomb to defend us from the possibility that Hitler might succeed at the same goal) to rid the earth of these most destructive weapons. Along with many of my MIT colleagues, if I can help in any way, I will be pleased and honored to do so.

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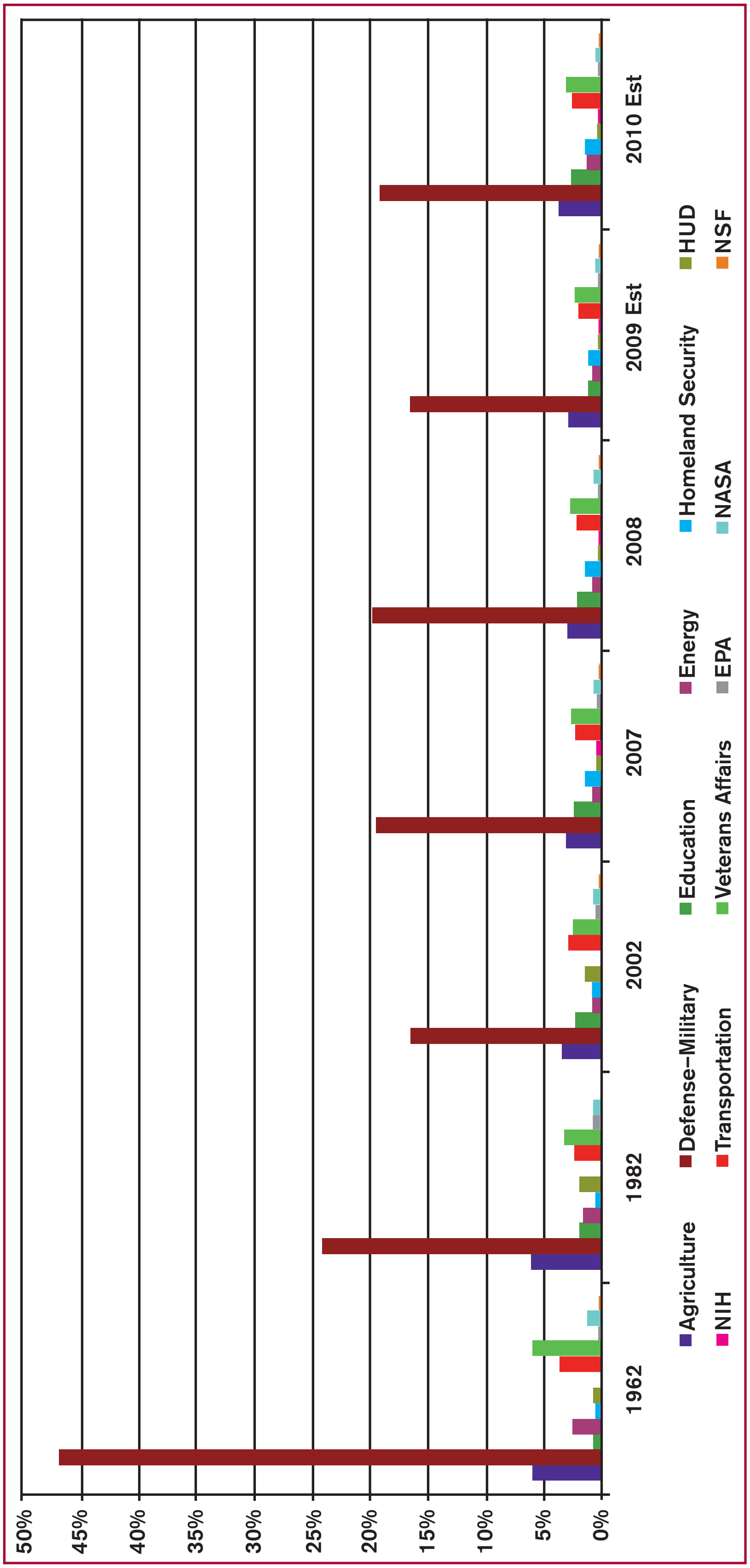
Numbers

Budget of the United States Government (1962-2010) Percentage Distribution of Outlays by Selected Agencies



Source: U.S. Government Printing Office: ***www.gpoaccess.gov/usbudget/fy10/browse.html***