ISSUES
IN SCIENCE AND TECHNOLOGY

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SPRING 2011

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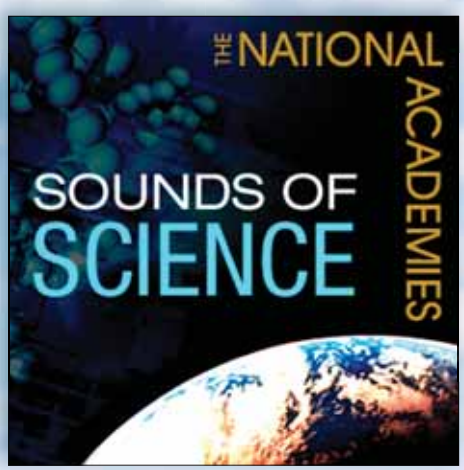

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Above: In Terms of Geography (detail), *André Skupin, 2005*
Cover: WorldProcessor: Zones of Invention—Patterns of Patents (detail), *Ingo Günther, 2006*

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FORUM

Technology innovation: setting the right policies

In "Fighting Innovation Mercantilism" (*Issues*, Winter 2011), Stephen Ezell has identified a truly vexing problem: the proclivity of important countries (notably China) to stimulate domestic innovation by using a wide variety of subsidies, such as public grants, preferential government procurement, a sharply undervalued currency, and other techniques. Elements of "innovation mercantilism" are not particularly novel, but the current scale of these practices poses a distinct threat to U.S. leadership on the innovation frontier.

To be sure, from the early days of the Republic, the U.S. government has deployed an array of public policies to promote innovation; not only patents and copyrights, but bounties and land grants to promote canals and railroads, easements to build out electricity, telegraph and telephone networks, military outlays to lay the foundations for nuclear power, civilian aircraft, the Internet, and much more.

Using Ezell's terminology, it's overly simplistic to say that U.S. innovation supports have historically been "good"—benefitting both the United States and the world—while Chinese supports are "ugly"—benefitting China at the expense of other nations. However, two features distinguish contemporary Chinese policies.

First, Chinese subsidies are combined with less-than-energetic enforcement of intellectual property rights (IPRs) owned by foreign companies. In fact, China often requires foreign companies to form joint ventures with Chinese firms, and in other ways part with their technology jewels, as the price of admission to the Chinese market. Second, during the past five years, China's sharply undervalued renminbi has enabled the nation to run huge trade surpluses, averaging more than $200 billion annually, and build a hoard of foreign exchange reserves approaching $3 trillion. A decade ago, the trade surpluses corresponded to exports of toys and textiles; increasingly, Chinese trade surpluses are now in areas such as sophisticated manufactures, electronics, and "green" machines (like wind turbines).

The burst of Chinese innovation mercantilism coincides, unhappily, with languishing U.S. support. Federal R&D outlays have declined from 1.3% of U.S. gross domestic product (GDP) in 2000 to 0.9% in 2007. Equally important, adverse features of the U.S. corporate tax system not only prompt U.S.-based multinationals to locate production abroad but also to consider outsourcing R&D centers.

What should be done? I agree with many of the specifics in Ezell's policy recommendations, but let me highlight three broad themes:

- Instead of carping at U.S.-based multinationals over taxes and outsourcing, President Obama and Congress should listen to what business leaders prescribe for keeping innovation humming in the United States.
- Any U.S. company that assembles the specifics on unfair subsidy or IPR practices by a foreign government should be warmly assisted by the U.S. Trade Representative in bringing an appropriate case, especially when high-tech products are at stake.
- The United States should no longer tolerate trade deficits that exceed 2% of GDP year after year. Balanced trade, on a multilateral basis, should become a serious policy goal.

Gary Clyde Hufbauer
Reginald Jones Senior Fellow
Peterson Institute for International Economics
Washington, DC
ghufbauer@piie.com

Protection is not the long-term route to growth and competitiveness, as Stephen Ezell argues. Although trade protection has helped to incubate local steel industries, for instance, most protected or publicly owned steel industries have lagged behind global best practices and often led to high local steel prices. In the automotive industry, India combined trade barriers to protect its infant automotive sector with a ban on FDI to create local industries but could not close the cost and performance gap with global companies. India's decision to remove both trade and investment barriers meant that productivity more than tripled in the 1990s, and some local players emerged as innovative global competitors. Protecting local producers usually comes at a cost to consumers. The high prices and limited growth of the Indian and Brazilian consumer electronics sectors can be attributed largely to the unintended consequences of policies such as Brazil's information act that protected the nascent local computer industry, and India's high, yet poorly enforced, national and state-level tariffs.

Ezell rightly argues, too, that overemphasizing exports is mistaken. Providing incentives for local export promotion can be very expensive. For instance, Brazilian state governments competing to host new automotive plants offered subsidies of more than $100,000 for each assembly job created, leading to overcapacity and very precarious financial conditions for Brazilian local governments. And in any case, manufacturing is not the sole answer to the global challenge of job creation.

Research by the McKinsey Global Institute (MGI, McKinsey & Company's business and economics research arm) finds that promoting the competitiveness and growth of service sectors is likely to be much more effective for creating jobs. Productivity improvements are a key factor in all sectors, but most job growth has come from services. In high-income economies, service sectors accounted for all net job growth between 1995 and 2005. Even in middle-income countries, where industry contributes almost half of overall GDP growth, 85% of net new jobs came from service sectors.

Another message that emerges from MGI's research is that, as your article suggests, an emphasis on local production in innovative sectors is not nearly as important as the impact of innovation on the productivity in the broader economy. Innovative emerging sectors are too small to make a difference to economy-wide growth. In the case of semiconductors, the sector employs 0.5% or less of the total workforce even among mature developed economies and has a limited direct contribution to GDP. But the sector's innovation has contributed hugely to the information technology adoption that has improved business processes and boosted productivity in many other sectors—and in that way has made a difference for economy-wide growth. These benefits often don't require local suppliers. In fact, policy efforts to protect local-sector growth can halt that growth if they increase costs and reduce the adoption and use of new technologies. For instance, low-tech green jobs in local services, such as improving building insulation and replacing obsolete heating and cooling equipment, have greater potential to generate jobs than does the development of renewable technology solutions.

Lenny Mendonca
Director
McKinsey & Company
San Francisco, California

Stephen Ezell's article captures an unhappy reality of our present world economy: that some governments are pursuing technology innovation policies that are deliberately designed to favor their domestic firms. Ezell highlights China as the contemporary archetype of purveyors of what he calls "ugly" technology innovation mercantilism—"ugly" in that the behavior hurts competing U.S. and international firms and workers. He rightly calls for U.S. government economic diplomats and trade negotiators to take aggressive multilateral, regional, and bilateral actions.

I argue that although Ezell is right to label these technology innovation mercantilist policies ugly, they pointedly fit his "bad" and even "self-destructive" categories, too, because they contradict our and their long-term inter-

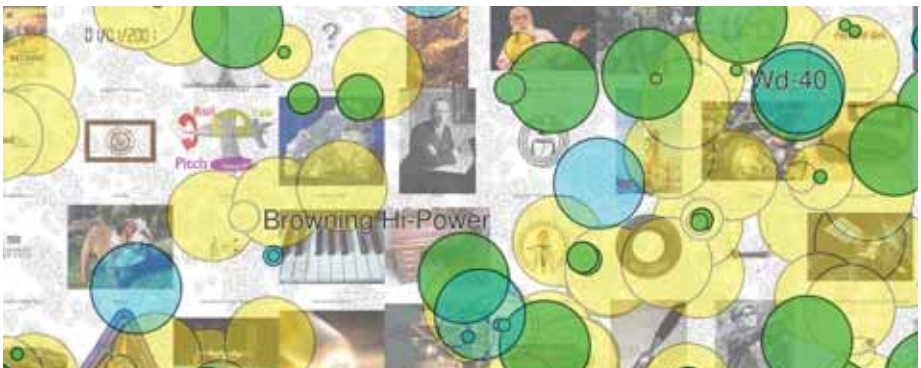
Atlas of Science

All of the images in this issue come from the book *Atlas of Science: Visualizing What We Know* (MIT Press, 2010), which was conceived and assembled under the leadership of Katy Börner, the Victor H. Yngve Professor of Information Science and director of the Cyberinfrastructure for Network Science Center at Indiana University's School of Library and Information Science in Bloomington, Indiana.

Börner's text for the jacket of the book captures the spirit that informs the book: "Cartographic maps have guided our explorations for centuries, allowing us to navigate the world. Science maps have the potential to guide our search for knowledge in the same way, allowing us to visualize scientific results. Science maps help us navigate, understand, and communicate the dynamic and changing structure of science and technology—help us make sense of the avalanche of data generated by scientific research today. . . . Not even the most brilliant minds can keep up with today's deluge of scientific results. Science maps show us the landscape of what we know."

Börner spent her sabbatical and another three years on writing the book and assembling the maps. In collaboration with research programmers and designers at Cyberinfrastructure for Network Science Center (http://cns.iu.edu) she designed many of the charts and maps and the complete layout of the book. Part four of the book covers the first three out of ten iterations of the international *Places & Spaces: Mapping Science* exhibit (http://scimaps.org). Subsequent iterations of the exhibit are devoted to science maps for different users: Economic Decision Makers (2008), Science Policy Makers (2009), Scholars (2010), Visual Interfaces to Digital Libraries (2011), Kids (2012), and Daily Science Forecasts (2013).

The exhibit is currently on display at the University of Michigan in Ann Arbor from March 7 to May 24, 2011 (http://scimaps.org/flat/exhibitions/umich/). The seventh iteration of the exhibit entitled "Science Maps as Visual Interfaces to Digital Libraries" will debut at the University of North Texas in Denton from September 28, 2011 to January 28, 2012. More information on the atlas, all citation references, and about 500 high resolution images can be found at http://scimaps.org/atlas.



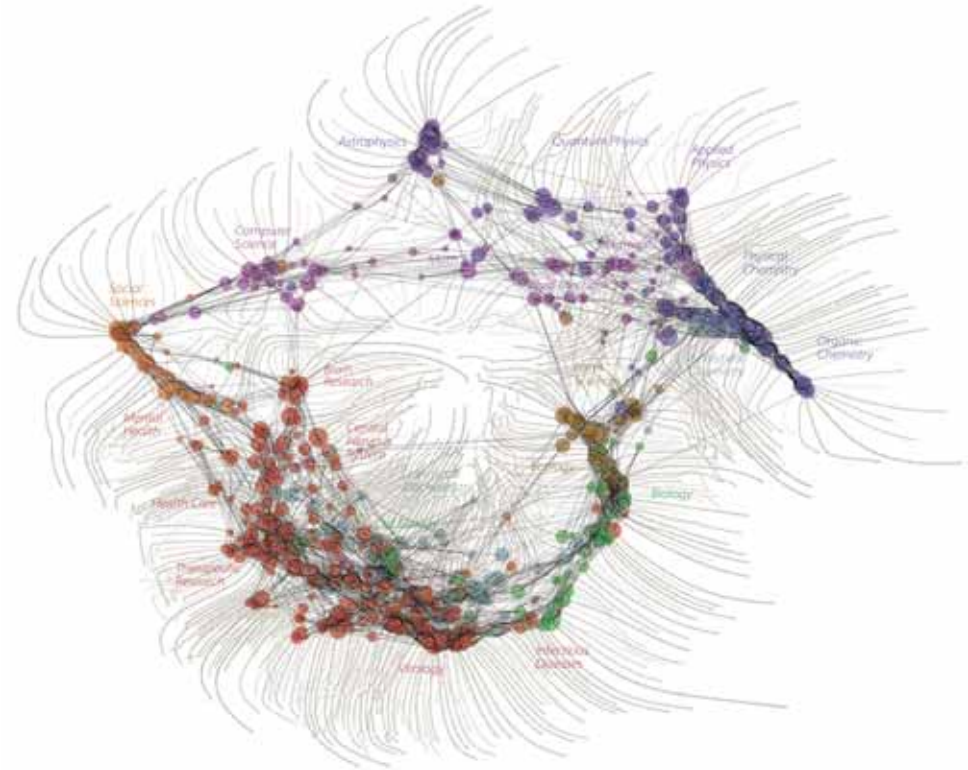
ests. The United States has built the world's best technology innovation system by investing in public-good basic research in our national laboratories and universities. But the strength of U.S. technology innovation is not money alone. European scholars, searching for explanations for why the United States has emerged as the technology innovation center of the world, say that Americans integrate public research institution science with private enterprise technology market developers better than they do in Europe and everywhere else. U.S. contributions of new medicines, medical devices, clean energy, and information technologies are due to technology laws that encourage public research laboratories and universities to license patented technologies to private enterprises, whether an established large business or a small entrepreneurial venture, whether American or foreign. Many big European, Japanese, and Korean firms conduct their most innovative work at their U.S. R&D centers. Fuelled by risk-tolerant capital markets, U.S. and international firms operating in the United States share patented technologies and collaborative know-how to get new products into the marketplace, first in the United States and then in other markets.

Nobody else has such an effective technology innovation system. Americans should not be shy about recommending our technology innovation system as a model for other countries. Studies consistently find that the most innovative companies keep their best technologies out of China and everywhere else where their intellectual property is not respected. Technology competitors and consumers suffer when the locally available technology is second-rate. Brazil's Embraer became the world's dominant midsized aircraft maker after their government opened the borders to international information technologies. Brazilian intellectual property and technology law reforms and public science and technology (S&T) investments are resulting in technology innovation unprecedented in Brazil. India's people will get access to the newest innovative medicines when Indian policymakers and judges implement policies that encourage global innovators to sell their patented medicines in the country and that make their local biomedical S&T community another hub of global innovation. The vast Indian generic marketplace will not be diminished; rather, Indian generic makers will benefit from the global know-how entering their country. We should all participate, not just our trade negotiators, in dialogues with the S&T leaders in countries around the world, especially in developing countries, where policy choices are being made about S&T institution/market relationships that will encourage new dynamism to everybody's benefit.

Michael P. Ryan
Director
Creative and Innovative Economy Center
George Washington University Law School
Washington, DC
mryan@law.gwu.edu

Climate Plan B

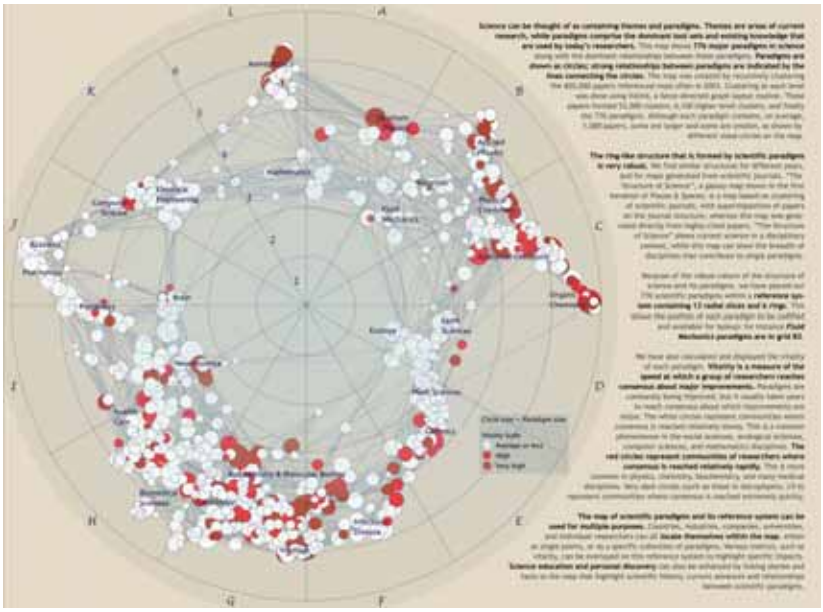
If one set out to assemble some of the worst possible policy responses to the threat of climate change, and implement them with maximum opacity to



Illuminated diagram

W. Bradford Paley, Kevin W. Boyack, Richard Klavans, John Burgoon, and Peter Kennard, 2006. *Copyright 2006 W. Bradford Paley.*

This map of scientific paradigms can be used in a "You Are Here" perspective to find your place in science: you query for your own papers in a data-driven bottom-up fashion, then follow linkages to citing papers or examine a global view of relevant works, then drill down to explore. The map can help answer salient questions: Where are my competitors or potential alliance partners? Where is the fastest moving science? Where are the patents? Where is the current public funding? Which areas are growing rapidly?



Map of Scientific Paradigms

Kevin W. Boyack and Richard Klavans, 2006

AIM

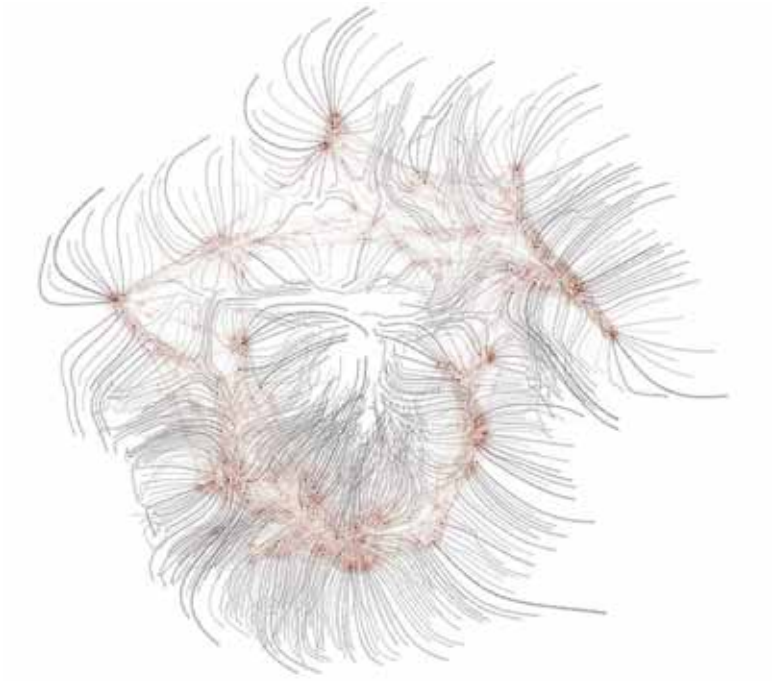
Science can be thought of as containing themes and paradigms; themes are current areas of research, while paradigms comprise the dominant tool sets and existing knowledge that are used by current researchers. What would a paradigm map of science look like? How many paradigms are currently active? How large and how vital are they?

INTERPRETATION

This map was generated by recursively clustering the 820,000 most important papers referenced in 2003 using the processing pipeline described on page 12, Toward a Reference System for Science. The result is a map of 776 paradigms, which are shown as circles on the map. Although each paradigm contains an average of 1,000 papers, they range in sizes, as shown by the variously sized circles on the map. The most dominant relationships between paradigms were also calculated and are shown as lines between paradigms. A reference system was added for means of navigation and communication.

Color-coding indicates the vitality of a research topic—the darker the red, the younger the average reference age and the more vital and faster moving the topic. The white circles represent paradigms where consensus is reached relatively slowly. This is a common phenomenon in the social sciences, ecological sciences, computer sciences, and mathematics disciplines. The red circles represent communities of researchers where consensus is reached relatively rapidly. This is more common in physics, chemistry, biochemistry, and many medical disciplines. Very dark circles (such as those in quantum physics) represent communities where consensus is reached most quickly.

Countries, industries, companies, and individual researchers can all locate themselves within the map, either as single points or as a specific collection of paradigms. Science education and discovery can also be enhanced by linking to the map stories and facts that highlight content and relationships between scientific paradigms. *Courtesy of Kevin W. Boyack and Richard Klavans, SciTech Strategies, Inc.*



How Scientific Paradigms Relate

W. Bradford Paley, Kevin W. Boyack, Richard Klavans, John Burgoon, and Peter Kennard, 2006. *Copyright 2006 W. Bradford Paley.*

The map represents more than 1.5 million scientific papers (760,000 papers published in 2004 and their 820,000 highly cited reference papers) as white dots. Each scientific paradigm (represented by a red circle) contains papers that were often cited together. Some paradigms have few papers, others many, as denoted by circle sizes. The word filaments—or flowing labels—are made up of common words unique to each paradigm, thus revealing the actual language used by the scientists who work in that area. Curved lines show paradigms are related—the stronger the relationship between paradigms, the thicker and darker those lines.

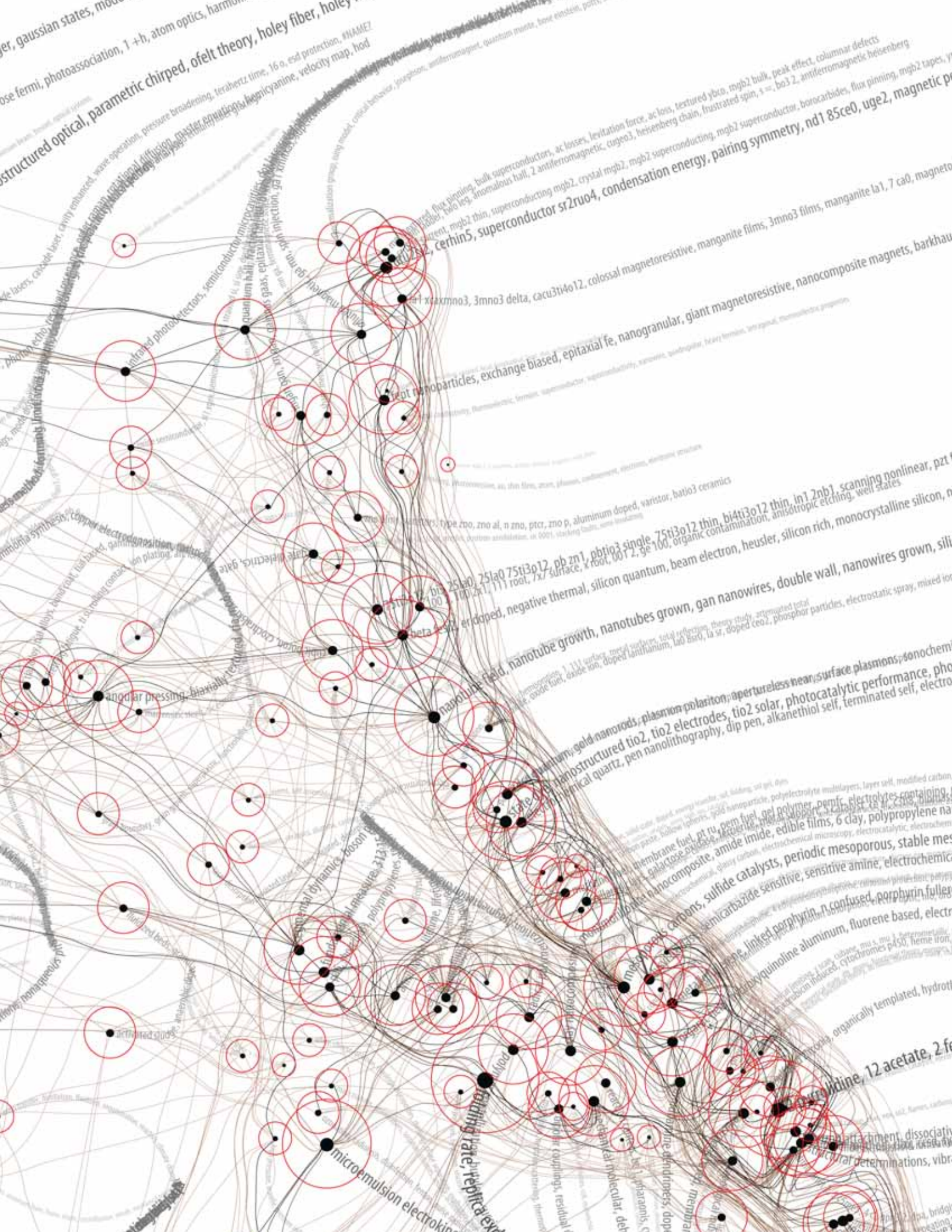
the general public, one could not do much better than William B. Bonvillian's "Plan B," as elucidated in your Winter 2011 *Issues* ("Time for Climate Plan B").

Bonvillian's plan is fundamentally undemocratic: The public, through its elected representatives, has repeatedly rejected greenhouse gas (GHG) emission controls, and polls show that the public is unwilling to pay for GHG reductions. Bonvillian's plan is also fundamentally dishonest, hiding a GHG reduction agenda behind an energy policy façade. Americans want energy policy that offers affordable and abundant energy; Bonvillian's plan would use government muscle to force consumers to buy more expensive energy, appliances, automobiles, and more.

Aside from lacking in democracy, Bonvillian's plan is a dog's breakfast of failed economic thinking. His call for increased R&D spending flies in the face of what is well known to scholars: Government-funded R&D only displaces private R&D spending. As Terence Kealey puts it in *The Economic Laws of Scientific Research*, ". . . civil R&D is not only not additive, and not only displacive, it is actually disproportionately displacive of private funding of civil R&D." It's also unnecessary: Contra to Bonvillian, there's plenty of private R&D going on. According to the Energy Information Administration, the top 27 energy companies had revenues of $1.8 trillion in 2008. At Bonvillian's estimate of energy sector R&D spending of 1% per annum, that's $18 billion. Thus, Bonvillian's support for President Obama's desired $15 billion in annual government R&D spending would simply displace what's already being spent.

The rest of Bonvillian's plan rests on the "fatal conceit" that government planners can centrally plan energy markets. Thus, he wants more government subsidies and loan guarantees to pick winning and losing technologies. He wants more regulations that burden the private sector and retard economic growth. He wants more appliance standards that reduce consumer choice and increase the cost of appliances and automobiles. He wants more government mission creep, focusing the Department of Defense on energy conservation rather than actually defending the country. These are old, economically illogical, historically failed public policy approaches. This is not so much a Plan B, but a rerun of the big-government nonsense of the pre-Clinton era.

Rather than pouring market-distorting subsidies, tax credits, regulations, "performance standards," and other such economically nonsensical things into an already bad economy with tragically high levels of unemployment, what we need to do is to take the "resilience option." We should address threats of climate variability—manmade or natural—by increasing the resilience of our society, while revving up our economy through the use of free markets. We can do this best by eliminating subsidies to climatic risk-taking, streamlining environmental regulations, removing subsidies to all forms of energy, removing housing and zoning restrictions that make relocation harder, and making maximum use of free markets to deliver goods and services that are fully priced, in-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corporating the price of climatic risk. That is a true Plan B.

Kenneth P. Green
Resident Scholar
American Enterprise Institute
Washington, DC

Reducing access barriers

In "Reducing Barriers to Online Access for People with Disabilities" (*Issues*, Winter 2011), Jonathan Lazar and Paul Jaeger do an excellent job of raising a warning and calling for action. If anything they understate the case, and the implications of their arguments should extend beyond regulation and procurement to research, standards, and policies shaping America's digital future.

Lazar and Jaeger note that roughly 20% of the U.S. population has at least one disability. By age 45, most people face changes in their vision, hearing, or dexterity that affect their use of technology. Everyone will experience disability in their lifetime. There is an even larger proportion of the population that at any given time has a limitation that is not typically tracked as a disability but is nevertheless affecting their ability to leverage technology to achieve their full potential and live rich lives (for example, illness, injury, poverty, or mild impairment). We are seeing a growing population of cognitive disorders that also can affect and be affected by the use of technology. Further, everyone at some point experiences contextual disability (such as noisy environments, cognitive load from distractions, and glare from bright sunlight). A 2003 Forrester Research study suggests that 60% of adult computer users could benefit from accessibility features. Although the focus of Lazar and Jaeger is appropriately on those formally identified as having disabilities, the goal should be a world in which everyone is achieving their potential irrespective of individual differences.

Lazar and Jaeger note that although the Internet has clearly opened opportunities for people with disabilities, many Web sites are inherently problematic, depending on a given person's set of disabilities and goals. This is an issue today, but it will become more of an issue tomorrow. It is clear that the digital future that is emerging will require even greater dependence on technology in order to fully engage with the world. This future can be the fulfillment of a dream, or it can be a nightmare.

To increase access to the wealth of information, communications, and services that are emerging, Lazar and Jaeger call for a more aggressive stance within federal and state governments. We can aim higher. We have the ability to create a digital world that adapts to each individual's personal characteristics. Cloud computing, the processing power and intelligence that are evolving behind it, and the increasing ubiquity of wireless networks mean that most individuals will rarely if ever need to be isolated. The variety of devices available to the individual is increasing, more and more information about the world and how we can interact with it is available, and the palette of technologies that extend the range of natural user interactions and experiences is increasing ever more rapidly. Everyone should be able to appropriate the set of technologies that makes sense to accomplish their goals and extend their potential.

Government, academia, and industry should be working together, not just reactively to ensure that the digital world is accessible but collaborating to create the infrastructure for a fully accessible digital future and to drive the innovation that embracing full diversity can unleash.

Arnold M. Lund
Director, User Experience
Microsoft Corporation
Redmond, Washington
alund@acm.org

Jonathan Lazar and Paul Jaeger effectively articulate the importance of accessible technology. I'd like to emphasize that the field of accessible technology is broad-reaching and a rich source of innovation.

The market for accessible technology extends far beyond people with severe disabilities. Naturally, there is a wide variety in the level of people's abilities. One person may experience a persistent disability, such as permanent vision loss. Another person may experience vision strain at the end of a long working day. The value of making technology accessible is that it can be used by a broad set of people, in a way that meets their unique requirements. And that technology can adapt as the person's abilities change, which can result from changing health, aging, or merely being in an environment or situation that reduces vision, hearing, mobility, or speech or increases cognitive load. Therefore, the market for accessible technology expands to people with mild impairments, occasional difficulties, the aging population, and the mainstream population in various situations.

The technology industry should realize that a powerful outcome of making technology accessible is that it drives innovation in the computing field as a whole. The resulting innovations are core building blocks for new, exciting computing experiences. Take, for example, screen-reading software, which reads aloud information on the screen with a computer-generated voice. A person who is blind relies on the screen reader to interact with their computer, listen to documents, and

There is no free lunch or free green energy. It's time for our political leaders to tell us honestly that it's going to cost us a lot to preserve the future for our grandchildren.

browse the Web. Other groups of people also benefit from screen readers, such as people learning another language and people with dyslexia. Listening to information read aloud helps with language acquisition and comprehension. Yet another application of screen-reading technology is the growing trend of eyes-free computing. An emerging application of eyes-free computing is driving a car while listening to driving directions or email or interacting with entertainment devices.

This dynamic ecosystem of services and devices needs to be engineered so all the pieces work together. Our engineering approach at Microsoft is one of inclusive innovation. The principle behind inclusive innovation is that the entire ecosystem of products and technologies needs to be designed from the ground up to be usable for everyone. This will result in robust solutions that will benefit a broad population. To build accessible technology from the ground up requires dedication across the entire software development cycle. From product planners to the engineers, the teams need to incorporate accessibility into their fundamental approach and mindsets. At Microsoft, our accessibility initiatives include outreach, education, and research with public and private organizations. These collaborations are key to delivering accessible technology and reaching our goal of educating others who are creating technology solutions.

Annuska Perkins
Senior Program Manager, Accessibility Business Unit
Microsoft Corporation
Redmond, Washington
Annuska.perkins@microsoft.com
http://www.microsoft.com/enable

No free energy

"Accelerating the Pace of Energy Change" (*Issues*, Winter 2011) by Steven E. Koonin and Avi M. Gopstein is a refreshingly frank look at the challenge we face to protect our climate's and nation's futures. We in the United States are likely to assume that as a nation we can accomplish anything if we have the will to do so. After all, we designed the nuclear bomb in less than 5 years and accomplished the goal of the Apollo program in less than 10. But these projects constructed a few items, albeit very complex ones, from scratch. As the article points out, the existing energy system is huge, even by U.S. government standards. It consists of an enormous capital investment in hardware, matched by a business strategy that generates a modest but reliable return on investment.

It's tempting to hope that one or more technical innovations will be discovered to solve the problem, such as cheaper solar cells, economical means to convert grass into ethanol, inexpensive CO2 sequestration, etc. As an applied scientist, I enthusiastically endorse R&D to improve all potential contributors to our future energy supply and energy conservation. But if we follow the authors' reasoning, technical innovations can contribute only a small part of the solution. Even after the benefits of an innovation are obvious, there will be a long delay before the capital structure catches up with it; that is, waiting for existing equipment, which has already been paid for, to approach the end of its useful life and require replacement.

The alternative, investing in new equipment and infrastructure before the normal replacement cycle, is expensive, as is forcing the use of less economical alternative energy supplies. The money will not come from existing utility company profits, nor from current government revenues. It must be provided by citizens, either through increased taxes or increased energy costs. There is no free lunch or free green energy. It is time for our political leaders to tell us honestly that it's going to cost us a lot to preserve the future for our grandchildren. It is also time to stop spending precious resources on illusions of green energy, like corn ethanol.

As the authors point out, essential ingredients for inducing energy companies to make changes are stability and predictability. Unfortunately, the U.S. Congress rarely commits itself even one year ahead. That matches poorly with energy investments whose useful life may be 50 years. The only alternative I can imagine is to formulate a long-term plan that receives suf-

From a macro perspective we need young workers to move from depressed areas to booming areas. The mobility bank would help to finance the short-term costs of making such a move.

ficient public endorsement that future legislators are hesitant to abandon it. There are precedents; each is called a "third rail of American politics." One requirement of such a plan is absolute honesty: If we agree to pay the cost of such a plan, we don't want to be surprised later, except by savings we didn't expect. Please don't tell us about savings that may never appear and don't assume that the economy will always remain at peak levels.

Victor Van Lint
1032 Skylark Drive
La Jolla, California
vicvanlint@sbcglobal.net

Telling science stories

I see considerable irony in the fact that Meera Lee Sethi and Adam Briggle ("Making Stories Visible: The Task for Bioethics Commissions," *Issues*, Winter 2011) begin their analysis of the role of narrative in explaining science with a story of their own: a story about David Rejeski's childhood fascination with Captain Marvel, ham radio, and rockets. To do so mythologizes their human subject (Rejeski) just as surely as Craig Venter's analogies serve, in the view of these authors, to tell us a fairy story about synthetic biology. We are invited here to see Venter as an evil genius bent on misleading the public by oversimplifying synthetic biology and downplaying its risks, while Rejeski comes across as the authentic superhero who can bring him to task for this transgression.

A scientific journal article is, in its own way, a narrative story, with a tendency to mythologize its subject: the experiment or study that it reports. Everyone working in science knows that research does not proceed as neatly, cleanly, or predictably as the tersely worded research publications that survive peer review tend to suggest. So it is not just "the public" (whoever they are) that needs stories to explain the complex nature of scientific truth. Scientists tell stories to one another all the time. The problem for the rest of us often amounts to deciding which stories we should believe. On this point I agree with Sethi and Briggle.

I also agree that there is money in synthetic biology, and that Venter and others can certainly smell it. What I am less certain of is whether Rejeski's use of scary images from science fiction helps his credibility as a spokesperson for "the public." He may hope that such images can scare regulators into fearing a panicked populace, thus pushing for more aggressive regulation, but this is a rhetoric that may be self-defeating to the extent that it suggests public fears are simply silly.

As someone who taught media studies for 20 years, I know how easy it is to mistake popular-culture images for what various publics are actually thinking. Worth noting in this context: Research by Michael Cobb and Jane Macoubrie at North Carolina State has suggested that Americans who have read *Prey* might be less fearful of nanotechnology than those who have not, a phenomenon probably attributable to the fact that science fiction fans tend to like science.

Indeed, Americans in general tend to like science, and I know of no hard evidence that they fear synthetic biology. They certainly do not fear nanotechnology, which in some ways, as Rejeski's shop has helped publicize, perhaps they should. Science fiction is one of the few truly popular forums in which our hopes and our fears about new technology can be explored, but its significance should not be overstated. As someone who would like to see a stronger voice for various publics in making science policy, I believe we should think more carefully about how public opinion is actually formed, as well as how it is best consulted. Media content is not "what people think."

Susanna Hornig Priest
School of Environmental and Public Affairs
Editor, *Science Communication*
University of Nevada, Las Vegas
Las Vegas, Nevada
susanna.priest@unlv.edu

Reversing urban blight

Michael Greenstone and Adam Looney present an excellent overview of how economists think about the household-level consequences of local job destruc-

tion ("Renewing Economically Distressed American Communities," *Issues*, Winter 2011). During a deep recession, job destruction increases and job creation slows. Those who own homes in cities that specialize in declining industries will suffer from the double whammy of increased unemployment risk and declining home prices. Poverty rises in such depressed cities. In such a setting featuring bleak job prospects for young people, urban crime, unwed pregnancy rates, and school dropout rates will rise, and a culture of poverty is likely to emerge.

Empirical economists continue to try to identify effective public policies for reversing such blight. The broad set of policies can be divided into those aimed at helping the depressed place and those aimed at improving the quality of life of the people who live in the place. Greenstone and Looney sketch out three innovative proposals. The first is place-based, whereas the second and third are person-based.

I am least optimistic about the beneficial effects for depressed communities from introducing empowerment zones. Rents will already be quite low in these depressed areas. I am skeptical about whether a tax cut and grants would lure new economic activity to the area. It is more likely that the new tax haven would attract firms who would have located within the city's boundaries anyway but now choose the specific community to take advantage of this tax break. The intellectual justification for luring firms does exist in the case of firms that offer sharp agglomeration benefits. In his own research, Greenstone (along with Moretti and Hornbeck) has identified cases of significant beneficial spillovers to other local industries from luring specific plants (http://emlab.berkeley.edu/~moretti/mdp2.pdf).

I have mixed feelings about the proposal to retrain displaced workers. James Heckman's evaluation of the Job Training Partnership Act of the 1990s convinced me that the returns from such programs for adult workers are low (http://ideas.repec.org/p/nbr/nberwo/6105.html). I wish this was not the case.

I am most optimistic about the potential benefits from the mobility bank. The United States consists of hundreds of local labor markets. From a macro perspective, we need young workers to move from depressed areas to booming areas. The mobility bank would help to finance the short-run costs of making such a move.

Although such a mobility bank helps the people, how can we help the depressed cities? Depressed cities feature low rents. New immigrants often seek out such communities. Utica, New York, has experienced an infusion of immigrants from Colombia and Somalia. The United States has a long history of immigrant success stories, and increased immigration might be one strategy for revitalizing these cities.

Housing demolition in blighted neighborhoods is a second strategy for reducing local poverty. Housing is highly durable. When Detroit was booming in the 1960s, it made sense to build houses there, but now Detroit has too many houses relative to local labor demand. Cheap housing can act as a poverty magnet. The mayor of Detroit recognizes this point and has instituted a policy for knocking down low-quality homes and building up new green space (http://www.nytimes.com/2010/06/21/us/21detroit.html).

Matthew E. Kahn
Professor of Economics
University of California at Los Angeles
Los Angeles, California
mkahn@ioe.ucla.edu

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FROM THE HILL

Obama proposes essentially flat 2012 R&D budget

On February 14, the Obama administration proposed a fiscal year (FY) 2012 R&D budget of $147.9 billion, a $772 million or 0.5% increase from FY 2010. Although the overall budget is essentially flat, the president carves out increases for his priorities in areas such as clean energy R&D, education, infrastructure, and innovation.

The White House released its budget request the same week as the new Republican majority in the House approved a bill to provide funding for the remainder of the 2011 fiscal year that includes significant cuts in R&D spending.

In releasing the federal R&D budget request, John Holdren, director of the White House Office of Science and Technology Policy, said that "This is a budget that our nation can be proud of. It provides solid research and development investments to achieve game-changing advances in areas of crucial importance to 's future."

Overall, basic and applied research and nondefense research fare very well in the president's budget request. Basic research would grow almost 12% to $32.9 billion. Applied research would increase 11.4% to $33.2 billion. Total nondefense research would increase 6.5% to $66.8 billion.

The president's budget keeps the National Science Foundation (NSF), the Department of Energy's (DOE's) Office of Science, and the National Institute of Standards and Technology (NIST) on a multiyear path to doubling their budgets. The NSF R&D budget would increase 16.1% to $6.3 billion. The DOE Office of Science budget would increase 9.1% to $4.9 billion. The NIST budget would increase dramatically by $284 million to $872 million, mostly because of a ramping up in investments in cyberinfrastructure research and advanced manufacturing technologies. Because funding for part of FY 2011 still has not been approved, all figures for FY 2012 use a FY 2010 baseline for comparison.

Climate change is also a priority in the administration's budget. Funding for the U.S. Climate Change Research Program, an interagency initiative, would increase more than 20% to $2.6 billion.

Several key agencies would see modest increases in their budgets, including the National Institutes of Health, which would receive a $1 billion or 3.4% increase to $31.2 billion. The National Aeronautics and Space Administration R&D budget would rise by $559 million or 6% to $9.8 billion. The National Oceanic and Atmospheric Administration (NOAA) budget would increase by $36 million or 5.2% to $728 million.

Other agencies did not fare so well. The U.S. Department of Agriculture (USDA) budget would decline by 17.7% to $2.15 billion, mostly because of reductions in building and facilities, congressionally designated projects, and extramural research. The Department of Interior R&D budget would drop by $49 million to $727 million. The U.S. Geological Survey budget would decrease by 8.2% to $607 million. The Environmental Protection Agency (EPA) budget would decline by more than 12% to $579 million. The Department of Defense R&D budget would decline by 4.9% to $76.6 billion, although most of the decrease is because of cuts in development. Basic research would increase by 14.5% to $2.1 billion.

The president's FY 2012 budget request stands in stark contrast to the bill passed by the House on February 19 that would cut FY 2011 discretionary funding by $61 billion below FY 2010 enacted levels. Under the bill, which was rejected by the Senate, R&D as a whole would be cut by $6.41 billion, 4.4% less than FY 2010. Overall, the president's budget request totals $7.4 billion or 12.5% more in nondefense R&D investment than the House bill. Some of the

"From the Hill" is prepared by the Center for Science, Technology, and Congress at the American Association for the Advancement of Science (www.aaas.org/spp) in Washington, D.C., and is based on articles from the center's bulletin Science & Technology in Congress.

R&D in the FY 2011 and FY 2012 Budgets by Agency
(budget authority in millions of dollars)

	FY 2011 Current CR	**FY 2011 House**	Change from FY 2010 Percent	**FY2011 Senate**	Change from FY 2010 Percent	**FY 2012 Budget**	Change from FY 2010 Percent
TOTAL R&D (Conduct of R&D and R&D Facilities)							
Defense (military)	81,442	**77,189**	-4.2%	**76,739**	-4.8%	**76,633**	-4.9%
S&T (6.1-6.3 + medical)	*13,307*	***13,308***	*0.0%*	***13,309***	*0.0%*	***13,311***	*0.0%*
All Other DOD R&D	*68,135*	***63,881***	*-5.1%*	***63,430***	*-5.7%*	***63,322***	*-5.9%*
Health and Human Services	31,948	**30,345**	-3.4%	**31,943**	1.7%	**32,343**	2.9%
National Institutes of Health[1]	*30,157*	***28,583***	*-5.2%*	***30,159***	*0.0%*	***31,174***	*3.4%*
All Other HHS R&D	*1,791*	***1,762***	*38.8%*	***1,784***	*40.5%*	***1,169***	*-7.9%*
Energy	10,783	**9,328**	-13.9%	**10,133**	-6.5%	**12,989**	19.9%
Atomic Energy Defense	*4,074*	***4,074***	*5.7%*	***3,851***	*-0.1%*	***4,522***	*17.3%*
Office of Science	*4,481*	***3,515***	*-22.4%*	***4,141***	*-8.5%*	***4,940***	*9.1%*
Energy Programs	*2,228*	***1,739***	*-29.1%*	***2,141***	*-12.8%*	***3,527***	*43.7%*
NASA	9,911	**9,820**	6.0%	**9,979**	7.7%	**9,821**	6.0%
National Science Foundation	5,374	**5,223**	-4.1%	**5,355**	-1.7%	**6,320**	16.1%
Agriculture	2,619	**2,239**	-14.2%	**2,548**	-2.4%	**2,150**	-17.7%
Commerce	1,331	**1,199**	-10.8%	**1,298**	-3.4%	**1,720**	28.0%
NOAA	*684*	***593***	*-14.3%*	***660***	*-4.6%*	***728***	*5.2%*
NIST	*589*	***542***	*-7.8%*	***573***	*-2.5%*	***872***	*48.3%*
Transportation	1,054	**970**	-9.3%	**1,049**	-1.9%	**1,215**	13.7%
Homeland Security	887	**803**	-9.4%	**727**	-18.0%	**1,054**	18.8%
Veterans Affairs	1,162	**1,162**	0.0%	**1,162**	0.0%	**1,018**	-12.4%
Interior	776	**750**	-3.4%	**770**	-0.8%	**727**	-6.3%
US Geological Survey	*661*	***646***	*-2.2%*	***657***	*-0.6%*	***607***	*-8.2%*
Environ. Protection Agency	590	**552**	-6.4%	**576**	-2.3%	**579**	-1.9%
Education	356	**350**	-0.9%	**356**	1.0%	**480**	36.0%
Smithsonian	226	**224**	5.1%	**226**	6.1%	**212**	-0.5%
All Other	575	**575**	1.8%	**575**	1.8%	**650**	15.0%
Total R&D	149,034	**140,730**	-4.4%	**143,435**	-2.5%	**147,911**	0.5%
Defense R&D	85,516	**81,263**	-3.8%	**80,590**	-4.6%	**81,155**	-3.9%
Nondefense R&D	63,518	**59,467**	-5.1%	**62,845**	0.3%	**66,756**	6.5%

Source: OMB R&D data, H.R.1 as passed by the House, Senate bill as posted on appropriations website, agency budget justifications, and agency budget documents.
Note: The projected GDP inflation rate between FY 2010 and FY 2012 is 2.7 percent.
All figures are rounded to the nearest million. Changes calculated from unrounded figures.
1/ H.R.1: Sec.1812 sets the average total cost of all Competing RPGs awarded during FY 2011 at a maximum of $400,000.
Sec.1850 directs NIH to award at least 9,000 new competing research grants in FY 2011.

biggest differences are in funding for energy R&D, the NIH, and the NSF.

Major R&D cuts in the House bill, compared to FY 2010, include: the USDA, $415 million; NIST, $160 million; NOAA's Operations, Research, and Facilities budget, $454 million; NSF, $360 million; fossil energy R&D, $131 million; the Department of Education's Mathematics and Science Partnership Program, $180 million; and NIH, $1.63 million. Additionally, the House bill would prohibit the use of federal funds for NOAA's Climate Service, the Intergovernmental Panel on Climate Change, and EPA programs involving greenhouse gas registry, greenhouse gas regulation, offshore drilling, mountaintop mining, mercury emissions from cement plants, and Chesapeake Bay cleanup.

Because Congress could not agree to a bill funding the government for the full fiscal year, it approved a temporary bill that extended funding through March 4 but which also cut spending by $4 billion below enacted FY 2010 levels. The cuts included $41 million in the Department of Homeland Security's Science and Technology Program and $77 million and $292 million, respectively, in DOE's Office of Science and Energy Efficiency and Renewable Energy program.

In a March 3 letter sent to Senate Majority Leader Harry Reid (D-NV) and Minority Leader Mitch McConnell (R-KY), the Task Force on American Innovation, which is made up of about 170 scientific and other organizations, said the cuts in the House bill would have a "devastating impact" on the NSF, DOE's Office of Science, NIST's core research programs, and science, technology, engineering, and math (STEM) education programs contained in the America Competes law, a major priority of the research community.

In a flurry of activity in the lame-duck session in December 2010, Congress unexpectedly approved reauthorization of the America Competes Act. The primary goal of the Act is to authorize increased funding over three years, from FY 2011 to FY 2013, for the NSF, NIST, and the DOE's Office of Science. NSF would receive $7.4 billion, $7.8 billion, and $8.3 billion; NIST would receive $919 million, $971 million, and $1.04 billion; and the Office of Science would receive $5.3 billion, $5.6 billion, and $6 billion. In addition, the legislation provides modest increases for DOE's Advanced Research Projects Agency-Energy to $300 million, $306 million, and $312 million, respectively. Given the new political landscape in, these increases are now in question.

Scientific integrity guidelines released

More than 21 months after President Obama requested them, the White House Office of Science and Technology Policy (OSTP) on December 10, 2010, released government-wide guidelines on scientific integrity. The document elaborates on the principles laid out by the president on March 9, 2009, and provides guidance to executive departments and agencies on how to develop policies on issues involving scientific integrity.

The guidelines are in response to controversies that occurred during the George W. Bush administration. A number of scientists, scientific organizations, and congressional leaders accused Bush officials of taking steps that politicized science.

The memorandum states that science should be free from "inappropriate political influence." To strengthen government research, the memo states that job candidates should be hired "primarily" on their merits, that data and research used to support policy decisions should undergo peer review when possible, and that clear conflict-of-interest standards and appropriate whistleblower protections should be promulgated. Additionally, when appropriate, agencies should make scientific and technological information readily available, communicate scientific findings to the public in a clear and accurate manner, and detail assumptions, uncertainties, probabilities of outcomes, and best- and worse-case scenarios of scientific findings.

The memorandum states that for media interview requests, agencies should make available an "articulate and knowledgeable spokesperson" who can portray a research finding in a nonpartisan and understandable manner. Also, after appropriate coordination with their immediate supervisor and the public affairs office, federal scientists may speak to the media and the public about their findings, and the public affairs office cannot ask or direct scientists to change their findings.

The guidelines call on agencies to establish policies that promote professional development of government scientists and engineers and encourage research publication and the presentation of research at professional meetings. Also, the guidelines say that government scientists and engineers should be allowed to be editors and editorial board members of scholarly and professional journals, serve as officers and board members of professional societies, and receive honors and awards.

Reaction to the guidelines was mixed, with some observers saying they left too much discretion to individual agencies.

Climate negotiations inch forward in Cancun

Expectations for the 2010 international climate negotiations in Cancun were far more modest than 2009's Copenhagen conference, which allowed many to declare the December 2010 meeting of the 190 nations that are party to the United Nations Framework Convention on Climate Change a success. But key decisions on how to move forward on a global system to reduce greenhouse gas (GHG) emissions after the Kyoto Protocol ends in 2012 were left until the next meeting in , to be held from November 28 to December 9, 2011. Delegates did, however, agree that cuts will be needed by both developed and developing countries, and they made progress on other significant issues.

The Cancun agreements established a Green Climate Fund to help developing countries mitigate and adapt to climate change. Developed and developing countries will share control of the fund, with the World Bank initially serving as trustee. Much of the funding for the fund's adaptation efforts will come from a "fast track finance" fund with an initial commitment of $30 billion and a goal of increasing the amount to $100 billion by 2020, although how the funds will be raised has yet to be resolved. In addition, a new framework and committee was established to promote action on adaptation.

Several agreements were advanced to help reduce GHG emissions through the use of technology and incentives for reducing deforestation. Governments agreed to boost technological and financial support for curbing emissions from deforestation and forest degradation in developing countries. Technology transfer mechanisms were established.

Progress was made in developing standards for the monitoring, reporting, and verification of emissions reductions, for both developed and developing countries, which has been a sticking point between China and the United States.

Patent reform moves ahead

On March 8 the Senate passed the America Invents Act by a vote of 95-5. Meanwhile, Rep. Lamar Smith (R-TX), chairman of the House Judiciary Committee, said that he plans to introduce similar legislation in the House. Both Congress and the Obama administration see reform of the patent system as a means of jumpstarting the U.S. economy and increasing innovation.

The bill would convert the U.S. patent system to a first-to-file regime, the method used in most countries, from the first-to-invent system currently used. It would allow the U.S. Patent and Trademark Office to set its own fees, thus raising the funds needed to hire more patent examiners and decrease the patent backlog, now estimated at more than 700,000 applications.

Furthermore, the bill creates three satellite patent offices, allows certain technology to receive priority for approval, and requires courts to transfer a patent infringement case to a venue that is more convenient than the one at which action is pending. The bill also gives third parties the opportunity to petition the validity of a patent once it is awarded.

Food safety reform bill finally passes

After months of congressional debate and delay, President Obama on January 4, 2011, signed major food safety legislation that will greatly expand the authority of the Food and Drug Administration (FDA) to regulate food production.

The FDA Food Safety Modernization Act will, for the first time, allow the FDA to issue a mandatory recall of food deemed tainted or unsafe. In the past, the agency has relied on voluntary recalls. The bill also gives the FDA the authority to detain food and suspend a facility's operations should either be found to pose a health risk.

The new law calls on the FDA to create a system to facilitate the tracing of any product back to its origin. Should any shipment of produce, for example, be found tainted with a harmful bacteria, the tracing system would make it simple to track down the farm from which it originated. The law also calls on the Secretary of Health and Human Services to conduct a comprehensive evaluation of common food contaminants and create a nationwide educational program on food safety.

Although the legislation enjoyed widespread support, some critics pointed out that it failed to resolve key jurisdictional issues. Notably, although the FDA generally oversees most food products, the Department of Agriculture (USDA) handles meat, poultry, and eggs. With many food products being processed and packaged in locations handling food under both FDA and USDA jurisdictions, overlap between the two entities becomes understandable, as do gaps in oversight.

EDITOR'S JOURNAL

KEVIN FINNERAN

Washington's Media Maze

Policy analysis should not be merely an academic exercise. The goal is to inform and influence public policy, and therefore it has to reach the movers and shakers and the decisionmakers. That means it has to arrive at the right time via the right medium. But how does one do that in a world of network and cable TV, traditional and satellite radio, print newspapers and magazines, the online sites of the traditional media outlets and the proliferating Internet-only sources of information, email news services and listserves, laptops and tablets, Blackberries and iPhones and Androids, tweets and social networks, uTube and Tivo?

Well, one does it in many different ways because the target audience absorbs information via numerous routes. Fortunately, a remarkably helpful guide to the media maze has recently become available online thanks to the generosity of the *National Journal*. After years of proprietary surveys of how Washington insiders acquire their information, *National Journal* has decided to make the results available for free online at www.nationaljournal.com/wia. The Washington in the Information Age is a fascinating treasure trove of data about how Capitol Hill staff, federal officials, and the Beltway cognoscenti use a wide variety of information sources. And the data is all presented in an addictive interactive format that is easy to use and difficult to surf away from.

The online site enables one to look at responses to dozens of questions and to break out the results by the sector where the respondent works, by political party, and by age. Some results are predictable: Republicans read George Will and Democrats read Paul Krugman. Others are not: In many respects the 20-somethings are not that different from the 50-somethings in how they seek information. I'm not going to try to pinpoint all these distinctions. In what follows, all the percentages reflect the answers of the total pool of respondents. Although interesting, the differences among subgroups do not alter the overall picture.

As one would expect, when asked what is the source of information about breaking news events, the overwhelming favorites are email alert, news website, and television, with TV being particularly important for Capitol Hill staff who are rarely out of sight of a news channel. Twitter and RSS feeds rank almost as low as print magazines.

But when the question is how to acquire analysis and opinion about a national news story, print newspapers rival news websites for the lead, with more than 60% of respondents listing them among their top four sources. Only 20% list blogs among their top four, trailing behind radio. Blogs are making more inroads on Capitol Hill, where 35% of staff list them among their top four.

When asked how they read their daily news, the respondents vastly prefer screens to paper. About 40% rely on digital sources primarily or completely, and an additional one-third use print and digital equally. Fewer than 3% use print exclusively. This is not encouraging news for a magazine such as *Issues*, which is primarily a print medium. But *Issues* is not delivering daily news, and this audience has a very different approach to less time-sensitive information.

When they were asked how they read monthly maga-

zines, the response was dramatically different. Three out of four respondents read them solely or mostly in print. Only 6% read them only in digital form. This probably reflects the length of the articles and the fact that they are reading them at home or on airplanes. It is reassuring to know that the magazine is not yet ready for the trash bin of history.

As significant as the medium in which information is consumed is the timeframe in which it is wanted. *National Journal* has been conducting this survey for many years, but in the past only small pieces of information were shared with outsiders. One critical insight that did emerge was the overwhelming importance of timeliness to Capitol Hill staff operating under the enormous pressure of the legislative agenda. Most staff focus on specific areas of policy and have little time to stay broadly informed. Even within their areas, they typically can concentrate only on the specific questions being actively debated in Congress. If the topic of your report or article is not on the agenda when it is published, do not expect Hill staff to read it right away. But when a topic is on the agenda, Hill staff often find it hard to acquire as much information as they want. For those who produce information and analysis, the key is to feed that information to the staff when they need it. It might be stale to you, but it could be a revelation to congressional staff.

The current survey provides more fine detail on the importance of timeliness. When asked where they would look for information they needed in the next two hours, and that's not an unusual situation, the respondents overwhelmingly favored the major news sites and an Internet search. Only about 10% mentioned an academic expert. But if they had a couple of days to obtain the information, the leading sources would be the think tanks and academic experts, with about 65% of respondents naming them. Only about a quarter of the respondents listed blogs.

This should be very reassuring to those whose stock in trade is intellectual rigor. Although we hear plenty of moaning about the shallowness of policy debates and the dominance of bumper-sticker analysis, this survey indicates that the people who make and directly influence national policy value expertise and thorough analysis. For those of us who provide it, the key is to make certain that our contributions reach the target audience when they are wanted. *Issues* maintains a free searchable online archive of published articles and also assembles collections of articles on major topics such as energy, competitiveness, public health, and national security.

Washington is a noisy place, and the clamor for attention seems to create a cacophony of faceless voices of which only the loudest and crudest can be heard. When asked what word best describes their response to the proliferation of media content, the most common response was "overwhelmed." But it appears that the voices of the better informed, the more thoughtful, and the more responsible are the ones that are being listened to.

When asked which sources of information they trust, 90% of respondents named the mainstream media such as the *New York Times*, CNN, and National Public Radio. Only 20% cited online-only sources such as the Huffington Post and Drudge Report, and 10% named blogs. The results were consistent when they were asked which columnists, bloggers, or opinion makers they follow regularly online. The favorites come from the print world: Krugman, Will, Thomas Friedman, and David Brooks. The online commentators such as Matt Drudge and Josh Marshall appear much further down the list.

The upshot of the survey is that although the paths by which news and analysis reaches the political elite is changing because of new technology, the sources of authoritative opinion are weathering the storm. Whether read online or in print, the *New York Times*, the *Washington Post*, and the *Wall Street Journal* are still recognized as having the editorial judgment and journalistic standards that instill confidence. Uninformed opinion and simplistic analysis may seem to dominate debate in the crisis of the day, but when time allows—and eventually there is time—Washington turns to the intellectuals in think tanks and universities because they understand the value of deep knowledge and careful reasoning.

OK, this isn't true of everyone in Washington, and perhaps it's true only on the best days of those who participated in the survey. But it's still a reminder to those capable of providing informed expert opinion that this is a valued commodity in Washington. We shouldn't be tempted by the siren call of instant headlines, catchy one-liners, and volume-driven debates. That is not what will drive policy in the long run, and besides, we pointy heads aren't very good at it.

Clearly written, evidence-based, made-available-when-needed policy analysis and prescriptions, even when produced on paper, does have power in Washington, and this survey shows that the users are asking for it.

PAUL CITRON

Medical Devices: Lost in Regulation

The implanted medical device industry was founded in the United States and has been a major economic success and the source of numerous life-saving and life-improving technologies. In the 1950s and 1960s, technological innovations such as the cardiac pacemaker and prosthetic heart valve meant that thousands of suffering Americans had access to treatment options where none had existed before. And because so many breakthrough devices were developed in the United States, the nation's citizens usually had timely access to the latest technological advances. In addition, U.S. physicians were at the forefront of new and improved treatments because they were working alongside industry in the highly dynamic innovation process. In fact, they rose to worldwide preeminence because of their pioneering work on a progression of breakthrough medical therapies.

But that was then. Although the United States is still home to numerous medical device companies, these companies no longer bring cutting-edge innovations to U.S. patients first. And U.S. clinical researchers now often find themselves merely validating the pioneering work that is increasingly being done in Europe and elsewhere in the world. Worse still, seriously ill patients in the United States are now among the last in the world to receive medical innovations that have secured regulatory approval and clinical acceptance elsewhere in the developed world.

What's behind this erosion of leadership and late access to innovations? Simply stated, an overreaching, overly burdensome, and sometimes irrelevant Food and Drug Administration (FDA) regulatory process for the most sophisticated new medical devices. To be fair, occasional device recalls have caused great political pressure to be placed on the FDA for somehow "allowing" defective products to harm patients. The agency's response to political pressure has been to add additional requirements and to ratchet up its tough-cop posture in order to assuage concerns that it is not fulfilling its responsibility to the public. It is presumed, incorrectly, that a lax approval process is responsible. In most instances, however, the actual cause of a recall is outside the scope of the approval process. The most frequent causes of recalls are isolated lot-related subcomponent failure; manufacturing issues such as operator error, processing error, or in-process contamination; latent hardware or software issues; and packaging or labeling issues. In addition, company communications that describe incorrect and potentially dangerous procedures used by some medical personnel are also considered a recall, even though the device is not faulty. Face-saving implementation of new and more burdensome clinical trial requirements, often called added rigor by the FDA, is an ineffective and wrong answer to such problems.

Excessive approval burdens have caused a once-vibrant medical innovation engine to become sluggish. Using the FDA's statistics, we learn that applications for breakthrough approvals are near an all-time low. It is not that companies have run out of good ideas, but the regulatory risks have made it impractical to invest in the truly big ideas. A slow but inexorable process of added regulatory requirements superimposed on existing requirements has driven up complex-

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Infectious Diseases

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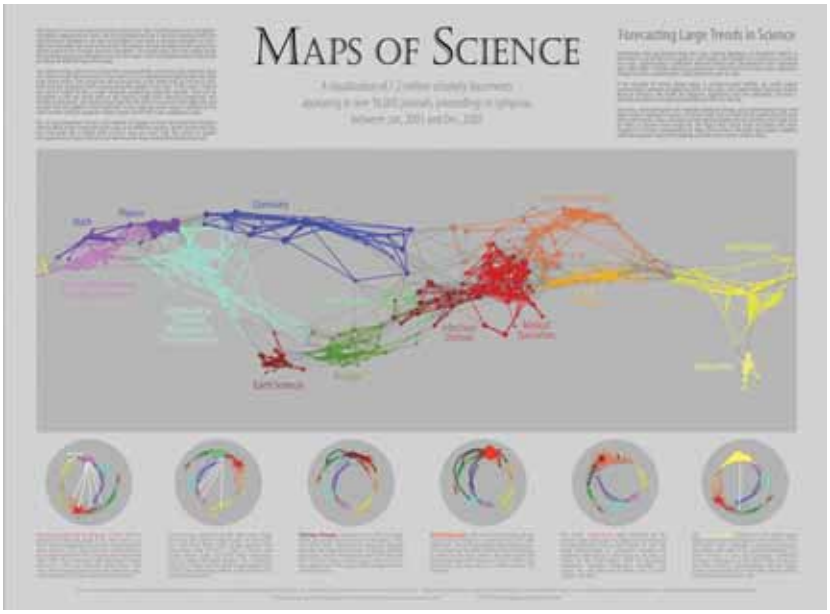
Infectious Diseases, indicated by the dark red shape above, has an overall decrease in connectedness (2%)

Medical Specialties, indicated by the red shape above, has an overall decrease in connectedness (2%) with



Maps of Science: Forecasting Large Trends in Science

Kevin W. Boyack and Richard Klavans, 2007

AIM

All previous large-scale maps of science were generated using data from the Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). How would the map of science change if data from the Arts and Humanities Citation Index (AHCI) were added? Would that create a second continent, or would arts and humanities constitute a peninsula? Which discipline is bridging the gap between the sciences, arts, and humanities? What might happen if Scopus data were folded in as well? Scopus covers only the last 10 years but has twice as many titles as SCI and SSCI combined. Will the global structure of science change with the addition of all this new data? Do we now have enough data to predict future changes in the structure of science based on year-to-year changes in a five-year time window?

INTERPRETATION

This most recent map of science, also called the UCSD Map of Science, is based on the largest set of scientific literature yet mapped—about 7.2 million papers published in more than 16,000 separate journals, proceedings, and series over a fiveyear period (2001–2005) retrieved from WoS and Scopus databases. A three-dimensional layout places disciplines—groups of journals—on a sphere. This overcomes problems with previous maps of science that had imposed borders and avoids potential boundary effects. Using this spherical projection to understand scientific disciplines as topography upon a globe, viewers can now explore science in all directions without "falling off the map." Using a Mercator projection, the spherical layout was flattened onto a two-dimensional map to ease navigation and exploration.

A forecast of how the structure of science may evolve in the near future was generated by evaluating the changes in the connectedness of various regions of the map between 2001 and 2005. In that time frame, the rate of change has been stable, and it will likely continue to be in the near future. This map and variations on it are used daily by their makers for planning, evaluation, and education at national, corporate, and personal levels. These maps serve as tools to determine which areas of science are most closely connected, which are most or least intellectually vital, and which produce the most patents. *Courtesy of Richard Klavans, SciTech Strategies, Inc.*

THE RESEARCH COMMUNITY SHOULD TAKE THE INITIATIVE TO ENSURE THAT ALL DOCTORAL AND POSTDOCTORAL TRAINEES RECEIVE INSTRUCTION IN THE ETHICAL STANDARDS GOVERNING RESEARCH.

ity and cost and has extended the time required to obtain device approval to levels that often make such investments unattractive. It must be noted that the market for many medical devices is relatively small. If the cost in time and resources of navigating the regulatory process is high relative to the anticipated economic return, the project is likely to be shelved. The result is that companies will instead shift resources toward making improvements in existing products, which can receive relatively rapid supplemental approval and start generating revenue much sooner. Some patients will benefit from these updated devices, but the benefits are likely to be much less impressive than those that would result from a major innovation.

Perhaps the best measure of the FDA's stultifying effect on medical device innovation is the delay, often of several years, between device approval in Europe (designated by the granting of the CE mark) and approval in the United States. The Europeans require that so-called Class III medical devices (products such as implanted defibrillators, heart valves, and brain stimulators) must undergo clinical trials to prove safety and functionality as well as compliance with other directives that relate to product safety, design, and manufacturing standards. In addition, the European approach relies on decentralized "notified bodies," which are independent commercial organizations vetted by the member states of the European Union for their competence to assess and control medical device conformance to approval requirements. The primary difference in the U.S. system is a requirement for more and larger clinical trials, which can be extremely time-consuming and difficult to assemble. Ultimately, the European approach places more responsibility on physicians and their clinical judgment rather than on government officials who may have little appreciation of or experience with the exigencies of the clinical circumstance.

These Class III devices are complex and can pose a risk of significant harm to patients if they are unsafe or ineffective. It is for this reason that the FDA's pre-market approval (PMA) pathway for these products is arduous and rigorous. It should be. Rigor, however, must be tempered with expert judgment that compares the demonstrable benefits with the possible risks to patients. And in setting requirements for evidence, regulators must distinguish between data that are essential for determining device safety and effectiveness and data that are nice to have.

Not to be lost in the FDA's quest to avoid possible patient harm, however, is the reality that PMA devices offer the greatest potential for patient benefit. Delays in the approval of effective devices do result in harm to patients who need them. If we examine the date of approval for the identical device in Europe and the United States, we see that most devices are approved much later in the United States. Three examples illustrate this point. Deep brain stimulation for ineffectively managed symptoms of tremors and Parkinson's disease was approved for use in the United States 44 months after European approval. A novel left ventricular assist device that permitted patients with severe heart failure to receive critical circulatory support outside the hospital was approved 29 months later. A pacemaker-like device that resynchronized the contraction sequence of heart muscle for patients suffering from moderate to severe heart failure was approved 30 months after it became available for patients in Europe.

These examples are drawn from experiences over the past 20 years. Each has matured into a treatment of choice. Table 1, which is based on data from the first 10 months of 2010, shows that delays continue to be long. Of the 11 new devices approved in this reporting period, 9 received the CE mark between 29 and 137 months earlier. It is not known whether the sponsor of the other two devices applied for a CE mark. In the case of an intraocular lens listed in the table, the FDA noted that more than 100,000 patients had already received the implant overseas. This level of utilization is significant by medical device standards and suggests strongly that its attributes have made it part of routine clinical practice. Yet U.S. patients had to wait more than five years for it to be available.

A legitimate question is whether the hastier approval of Class III devices in Europe harms overseas patients. A study

conducted by Ralph Jugo and published in the *Journal of Medical Device Regulation* in November 2008 examined 42 PMA applications that underwent review between late 2002 and 2007. Of the 42, 7 resulted in FDA disapproval, of which 5 had received prior CE mark approval. Reasons for disapproval were attributed to study design, failure to precisely meet primary study endpoints, and the quality of the collected data in the FDA's opinion. In other words, the problem was that these devices failed to satisfy some part of the FDA protocol, not that the FDA found evidence that they were not safe. The majority (34 of 42) of applications garnered both European approval and a subsequent, but considerably later, PMA approval.

Examples of Class III devices that received the CE mark and were subsequently pulled from the market are few. In recent testimony before the health subcommittee of the Energy and Commerce Committee, the director of the FDA's device branch cited two examples. One involved certain breast implants. The other was a surgical sealant. These events indicate that the European approval process is imperfect, but hardly one that has subjected its citizens to a large number of unsafe devices. It is simply unrealistic to expect an event-free performance history, given the complexities and dynamic nature of the device/patient interface and the incomplete knowledge that is available.

But what about the harm caused by delaying approval? Delay may not be of much consequence if the device in question serves a cosmetic purpose or if there are suitable treatment alternatives. Delay is of major significance if the device treats an otherwise progressive, debilitating, or life-threatening disease for which medical alternatives don't exist or have only limited effects. Such afflicted patients can't wait for what has become an inefficient process to run its course. The paradox is that the FDA's current regulatory approach may be causing unnecessary patient suffering and death by virtue of the regulatory delay imposed by its requirements.

It is particularly frustrating that devices invented and developed domestically are unavailable here for significant periods of time whereas patients elsewhere receive tangible benefit. It is not unusual for second and third generations of some products to be available internationally before the now outdated device finally secures U.S. approval.

The example of a minimally invasive transcatheter heart valve for the treatment of inoperable aortic stenosis illustrates the implications of excessive delay on the well-being of ill patients. Patients suffering from severe aortic stenosis have an estimated 50% mortality within 2 years after symptom onset if they do not undergo open-heart surgery for valve repair or replacement. Quality of life is adversely affected because of shortness of breath, limited exercise capacity, chest pain, and fainting episodes. A definable subset of affected patients includes those who are too frail to undergo the rigors of open-heart corrective valve surgery. The transcatheter approach, whereby a new replacement valve is inserted via the vasculature, much the way in which coronary balloon angioplasty is done, offers a much less invasive and less traumatic therapeutic option for the frail patient. Even though the technology and procedure are still evolving, clinical results have been impressive, and thousands of patients have received it. In a recently published clinical study, one-year mortality has been reduced by 20 percentage points when compared to the mortality of patients in the standard medical care group. Quality-of-life measures also improved substantially. The transcatheter heart valve was approved in Europe in late 2007; it is still awaiting FDA approval. A transcatheter valve of different design was approved in Europe in March 2007 and has produced impressive results in high-risk patients. Over 12,000 patients in Europe and 40 other countries where approval has been granted have received this valve. It too is still not approved in the United States. In the case of a disease with a poor prognosis, years of delay do not serve the best interests of affected U.S. patients, especially if there is credible clinical evidence that a new intervention performs well.

A more subtle effect of over-regulation is the loss of a leadership position by U.S. physicians and clinical researchers. Whereas pioneering clinical trials used to be the province of U.S. physicians at major academic medical cen-

ters, today non-U.S. physicians and medical centers are conducting a substantial and growing number of safety and effectiveness trials. As a result, overall clinical expertise and identification of ways to further improve a new technology have shifted overseas. International physicians increasingly supplant U.S. clinical researchers as medical pioneers. The United States can no longer be assured that its physicians are the preeminent experts at the cutting edge or that U.S. patients are receiving world-class treatments.

The peer-reviewed medical literature serves as a good indicator of where innovation in clinical practice and technology is taking place. The role of journals is to publish findings that are new, true, and important. Reported findings inform the future course of medical practice. A review of the current medical literature concerning transcatheter heart valves, as an example, shows that non-U.S. investigators and centers dominate the field. Published reports not only document the initial clinical experience but also identify advances in technique, refine indications for use, and propose next-generational improvements. High-caliber clinical studies are, without question, being performed in the United States as part of the data package for the FDA, and they are producing valuable information. The point is that although they are adding layers of relevant confirmatory data, they are not driving the cutting edge of medical practice.

A rigorous approval process for medical devices is absolutely necessary. However, the process must be relevant for the safety and effectiveness questions that pertain to the product under review. The process must be efficient, streamlined, administratively consistent, predictable, and conducted with a sense of urgency. It must limit its scope of requirements to those data that are central to demonstrating safety and effectiveness. There are always more questions that could be asked of a new product. A patient-centered regulatory process prioritizes and limits questions to those that are essential to the demonstration of safety and effectiveness in the context of the disease. The FDA has a very legitimate role to play in ensuring that new technologies are sufficiently safe and effective for patient use. This is a relative, not absolute, standard. Benefits must be balanced against risk. As practiced today, the regulatory process is unbalanced at the expense of innovations that could help patients.

Current FDA processes for the approval of medical device innovations need to be reengineered to balance the quest for avoidance of possible harms with the potential for helping today's seriously ill patients. The agency must also limit the scope of studies to address necessary questions rather than to aspire to scientific elegance and excessive statistical certainty. As Voltaire said, "The perfect is the enemy of the good." The European experience demonstrates that it is possible to make safe and effective new medical devices available to patients much more quickly. Actual clinical experience demonstrates that an excessively cautious and slow regulatory process conflicts with the interests of patients suffering from serious and progressive diseases. They simply don't have the luxury of time.

Paul Citron (paulcitron@msn.com), a founding member of the American Institute for Medical and Biological Engineering, retired from Medtronic, Inc., in 2003 after a 32-year career.

JOHN M. LOGSDON

John F. Kennedy's Space Legacy and Its Lessons for Today

Fifty years ago, on May 25, 1961, President John F. Kennedy, only four months in office, proposed before a joint session of Congress that "this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to Earth." Kennedy was blunt; he said that agreeing to his proposal would involve a burden that "will last for many years and carry very heavy costs," and that "it would better not to go at all" if the United States was not "prepared to do the work and bear the burdens to make it successful."

In the 30 months remaining in his tragically shortened presidency, Kennedy proved willing to follow through on his proposal, approving an immediate 89% increase in the National Aeronautics and Space Administration (NASA) budget and then, in the next year, another 101%. These increases started the lunar landing program, Project Apollo, on its way to becoming the most expensive peacetime mobilization of U.S. financial and human resources ever undertaken in pursuit of a specific goal. In 2010 dollars, Apollo cost $151 billion; by comparison, the Manhattan Project cost $28 billion and the Panama Canal, $8.1 billion.

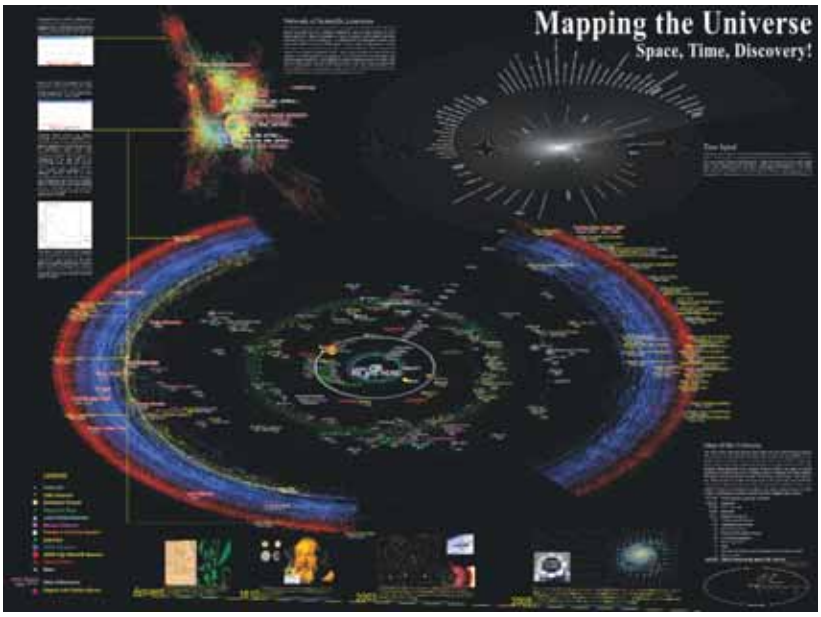
In my new book *John F. Kennedy and the Race to the Moon*, I trace the factors that convinced Kennedy that the United States had to undertake what he termed a "great new American enterprise" and the steps he took to turn his decision to go to the Moon into the effort that led to Neil Armstrong's first step onto the lunar surface in July 1969. I also reflect on what lessons the Apollo experience may have for today's situation, in space and elsewhere.

Before Kennedy decided that the United States should send people to the Moon, the U.S. reaction to a series of Soviet Union space successes, beginning with the launch of Sputnik 1 in October 1957, had been relatively muted. President Dwight Eisenhower did not believe it wise to try to compete with the Soviets in space achievements undertaken primarily for prestige purposes and thus was unwilling to approve a fast-paced U.S. effort in response to Soviet successes. In reality, there was in 1957 no "Sputnik moment" that led to accelerated government support of innovative space technology. That acceleration came only after Kennedy, seeing the global and domestic reaction to the first orbital flight of Soviet cosmonaut Yuri Gagarin on April 12, 1961, decided that the United States by default could not cede control over outer space to the Soviets and thus must enter a space race with the intent of winning it. It was a "Gagarin moment" rather than a "Sputnik moment" that precipitated massive government support for the technological innovations needed for success in space.

In retrospect, the impression is that Apollo moved forward without political problems; this is not correct. In 1961 and 1962, there was widespread political and public support for Kennedy's lunar initiative, in part propelled by the enthusiasm of the initial flights of Project Mercury, including Alan Shepard's suborbital mission on May 5, 1961, and John Glenn's three-orbit flight on February 20, 1962. But by 1963, there was rising criticism of Apollo from several fronts. Eisenhower called the race to the Moon "nuts." Many Republicans suggested that Kennedy should be spending more money on military space efforts nearer the Earth rather than on a lunar adventure. Leading scientists and liberals joined forces to suggest that Project Apollo was a distortion of national priorities and that there were many more worthy uses for the funds being spent on going to the Moon. Congress cut the NASA budget by 10% in 1963, slowing down its exponential increase.

Kennedy was quite sensitive to these criticisms, and in April, August, and October 1963 mandated major reviews of the Apollo commitment. The last of these reviews examined the options of slowing down Apollo, giving up on the Moon goal but continuing to develop the heavy-lift Saturn V Moon rocket, or canceling Apollo altogether. It concluded that none of these options were preferable to staying the course.

This review was not completed until November 29, 1963; by then, Kennedy had been dead a week. It is probable that Kennedy would have agreed with its conclusion; he was speaking of the space program in very positive terms in the



Mapping the Universe: Space, Time, and Discovery!

Chaomei Chen, Jian Zhang, Lisa Kershner, Michael S. Vogeley, J. Richard Gott III, and Mario Juric, 2007

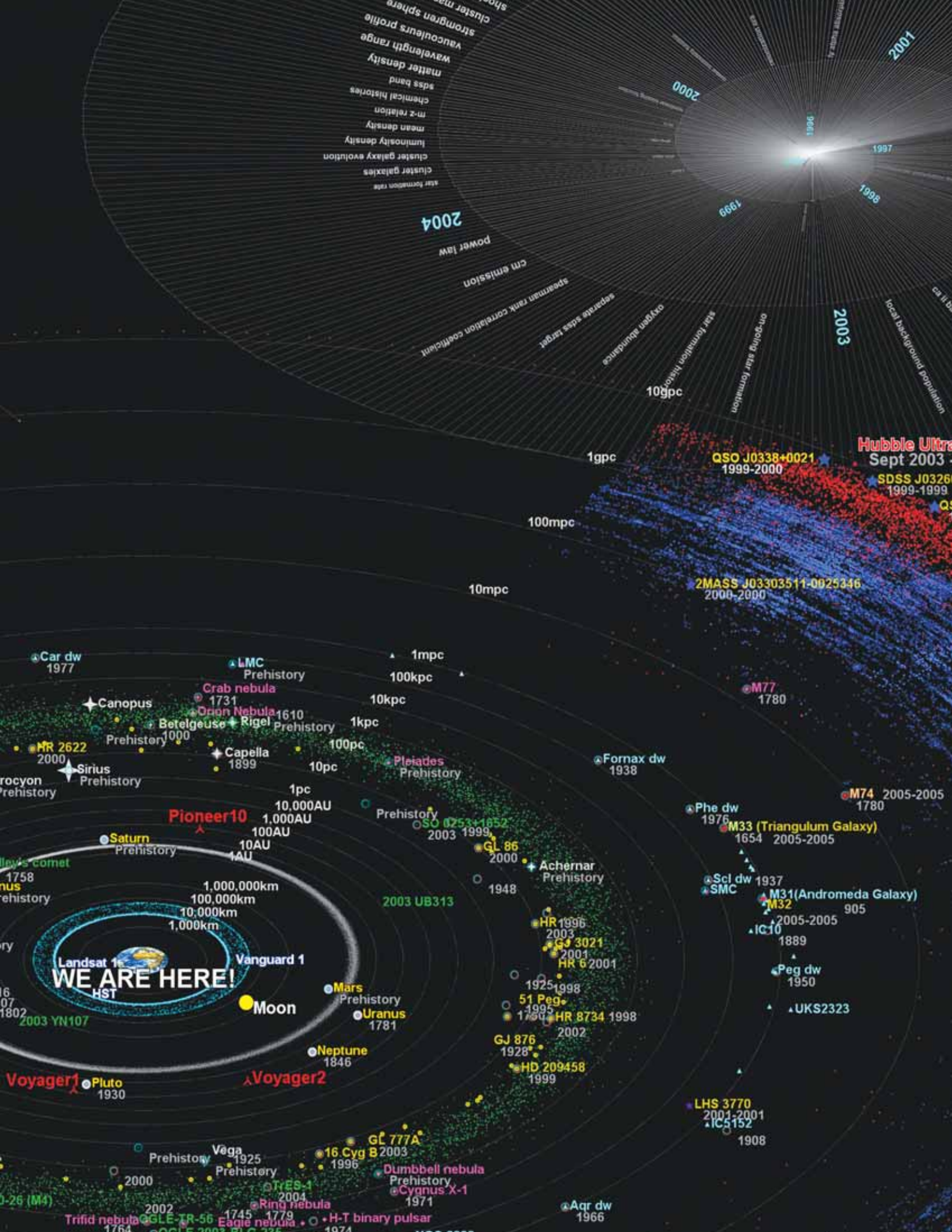
AIM

People have always been fascinated by the stars and their relationship to cradle Earth. Astronomy was one of the first sciences practiced. Many children were inspired to choose scientific careers by the first man in space, the first man on the moon, or the Mars Exploration Rover Mission. But how can we best communicate the immense size and complexity of the physical data, scholarly activities, and resulting scientific theories?

This map aims to communicate the structure of the universe and discoveries made by the Sloan Digital Sky Survey (SDSS). Relevant scientific literature, SDSS data, and imagery are used to show how theory and tool developments have influenced progress in astronomy.

INTERPRETATION

This map represents space, time, and our discoveries of phenomena in both. Space is shown as a large circular Map of the Universe. Planet Earth—the starting point of mankind's discoveries—occupies the center. More than 600,000 astronomical objects, including some of the most distant quasars discovered by the SDSS, were positioned according to their correct ascension and the natural logarithm of their distance from Earth. The map also shows major discovery dates and the durations of accelerated citation growth (continuous bursts of citations). Time is captured as a Time Spiral at the top right, which plots the sequence of newly emergent themes over time. Themes were extracted from astronomical literature relevant to SDSS's work. Discoveries and their many interlinkages are shown as an evolving Network of Scientific Literature. Yellow lines cross-reference concepts, citation hubs, and the paths leading to discoveries; they also highlight past and current hot spots. Short-term predictions of research trends can be made by linear extrapolation of the current average citation acceleration rate in the SDSS literature of 3.17 years with a standard deviation of 1.8 years. Candidates for points of growth in the near future are suggested in the network and in the time spiral. *Courtesy of Drexel University and Princeton University.*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days before his assassination. But Kennedy was also in the fall of 1963 pursuing another option: turning Apollo into a cooperative project with the Soviet Union. This is another aspect of the lunar landing program that has disappeared from memory.

Indeed, the 1961 decision to race the Soviet Union to the Moon was a reversal of Kennedy's preference as he entered the White House. In his inaugural address he suggested "let us explore the stars together," and in the first months of the Kennedy administration a White House task force worked on identifying areas of U.S.-Soviet space cooperation. Gagarin's flight demonstrated to Kennedy that the United States had to focus on developing its own leading space capabilities, but the hope for cooperation never completely vanished from Kennedy's thinking. As he met Nikita Khrushchev face to face in Vienna on June 3–4, 1961, Kennedy suggested that the United States and the Soviet Union join forces in sending people to the Moon. Khrushchev in 1961 was not open to such a prospect.

By 1963, the context for U.S.-Soviet space competition had changed. The United States had demonstrated to the world its technological and military power; the Soviet Union in 1961 backed off from a confrontation over access to Berlin and then in October 1962 yielded to U.S. pressure to remove its missiles from Cuba. Sobered by how close the two superpowers had come to nuclear war, Kennedy in 1963 proposed a new "strategy of peace" to reduce U.S.-Soviet tensions; an early success of this strategy was the signing of the Limited Test Ban Treaty in August 1963.

Kennedy, returning to his original point of view, thought that space cooperation might be a good next step in his strategy. He also was bothered by the increasing costs of Apollo and the chorus of criticisms of the lunar landing program. In a September 20, 1963, address to the General Assembly of the United Nations (UN), he made an unexpected, bold proposal. "Why," he asked, "should man's first flight to the Moon be a matter of national competition?" and suggested that the United States and the Soviet Union explore the possibility of "a joint expedition to the Moon." Kennedy was quite serious in this proposal. When NASA seemed to be dragging its feet in coming up with approaches to U.S.-Soviet cooperation, Kennedy on November 12, 1963, directed NASA Administrator James Webb to take charge of government-wide planning for "cooperation in lunar landing programs." With Kennedy's death 10 days later, Apollo became a memorial to the fallen young president, and any possibility of changing it into a cooperative U.S.-Soviet effort disappeared. The country remained committed to the goal set for it by Kennedy.

Post-Apollo decline

One conclusion of *John F. Kennedy and the Race to the Moon* is that the impact of Apollo on the evolution of the U.S. space program has on balance been negative. Apollo turned out to be a dead-end undertaking in terms of human travel beyond the immediate vicinity of this planet; no human has left Earth orbit since the last Apollo mission in December 1972. Most of the Apollo hardware and associated capabilities, particularly the magnificent but very expensive Saturn V launcher, quickly became museum exhibits to remind us, soon after the fact, of what once had been done.

By being first to the Moon, the United States met the deadline that had provided the momentum that powered Apollo; after Apollo 11, that momentum rapidly dissipated, and there was no other compelling rationale to continue voyages of human exploration. In 1969 and 1970, even as the initial lunar landing missions were taking place, the White House canceled the final three planned trips to the Moon. President Richard Nixon had no stomach for what NASA proposed: a major post-Apollo program aimed at building a large space station in preparation for eventual (in the 1980s!) human missions to Mars. Instead, Nixon decreed, "we must think of them [space activities] as part of a continuing process . . . and not as a series of separate leaps, each requiring a massive concentration of energy. Space expenditures must take their proper place within a rigorous system of national priorities . . . What we do in space from here on in must become a normal and regular part of our na-

In a September 20, 1963, address to the General Assembly of the United Nations, Kennedy made an unexpected, bold proposal. "Why," he asked, "should man's first flight to the Moon be a matter of national competition?" and suggested that the United States and the Soviet Union explore the possibility of "a joint expedition to the Moon."

tional life and must therefore be planned in conjunction with all of the other undertakings which are important to us." Nixon's policy view quickly reduced the post-Apollo space budget to less than $3.5 billion per year, a federal budget share one-quarter of what it had been at the peak of Apollo. With the 1972 decision to begin the shuttle program, followed in 1984 with the related decision to develop a space station, the United States basically started over in human spaceflight, limiting itself to orbital activities in the near vicinity of Earth.

The policy and technical decisions not to build on the hardware developed for Apollo for follow-on space activities were inextricably linked to the character of Kennedy's deadline for getting to the Moon "before this decade is out." By setting a firm deadline, Kennedy put NASA in the position of finding a technical approach to Apollo that gave the best chance of meeting that deadline. This in turn led to the development of the Saturn V launcher, the choice of the lunar orbit rendezvous approach for getting to the Moon, and the design of the lunar module spacecraft optimized for landing on the Moon. None of these capabilities were relevant to any politically feasible post-Apollo space effort.

The Apollo program also created in NASA an organization oriented in the public and political eye toward human spaceflight and toward developing large-scale systems to achieving challenging goals. It created from Texas to Florida the large institutional and facility base for such undertakings. Reflecting that base, which remains in place today, is a coalition of NASA and contractor employees, local and regional politicians, and aerospace industry interests that has provided the political support that has sustained the space program in the absence of a Kennedy-like presidential commitment to space achievement. With the Nixon White House rejection of ambitious post-Apollo space goals, NASA entered a four-decade identity crisis from which it has yet to emerge. Repetitive operation of the space shuttle and the extended process of developing an Earth-orbiting space station have not been satisfying substitutes for another Apollo-like undertaking. NASA has never totally adjusted to a lower priority in the overall scheme of national affairs; rather, as the Columbia Accident Investigation Board observed in its 2003 report, NASA became "an organization straining to do too much with too little." All of this is an unfortunate heritage of Kennedy's race to the Moon.

Lessons from Apollo?

Project Apollo also became the 20th-century archetype of a successful, large-scale, government-led program. The success of Apollo has led to the cliché "if we can put a man on the Moon, why can't we . . .?" This is not a useful question. What was unique about going to the Moon is that it required no major technological innovations and no changes in human behavior, just very expensive mastery over nature using the scientific and technological knowledge available in 1961. There are very few, if any, other potential objectives for government action that have these characteristics.

The reality is that attempts to implement other large-scale nondefense programs during the past 40 years have never been successful, in the space sector or in the broader national arena. Both President George H. W. Bush in 1989 and President George W. Bush in 2004 set out ambitious visions for the future of space exploration, but neither of those visions became reality; the political and budgetary commitments needed for success were notably missing. In 2010, President Obama proposed a dramatic move away from the Apollo approach to space exploration, stressing the development of new enabling technologies and widespread international collaboration. He also declared that the Moon would not be the first destination as humans traveled beyond Earth orbit. This proposal has been met with skepticism and substantial political controversy. Even in its modified form as reflected in the 2010 NASA Authorization Act, its future is at best uncertain. The strength of the political coalition created by Apollo is very resistant to change.

In the nonspace sector, there have been few opportunities for large-scale government programs that do not require for their success a combination of technological innovation and significant changes in human behavior. The attempts to de-

clare a "War on Cancer," for example, required not only research breakthroughs but also changing the smoking habits of millions of Americans. Attempts to move toward U.S. "energy independence" run afoul of limited R&D spending and the complex ties between non-U.S. energy suppliers and the U.S. financial and government sectors. Providing adequate health care for all Americans turns out to be primarily a political, not merely a technical, challenge. Managing global environmental change has high technical uncertainties and challenging social inertia to overcome. And so on.

This record of nonachievement suggests that the lunar landing decision and the efforts that turned it in into reality were unique occurrences, a once-in-a-generation or much longer phenomenon in which a heterogeneous mixture of factors almost coincidentally converged to create a national commitment and enough momentum to support that commitment through to its fulfillment. If this is indeed the case, then there is little to learn from the effort to go to the Moon that is relevant to 21st-century choices. This would make the lament "if we can put a man on the Moon, why can't we . . .?" almost devoid of useful meaning except to suggest the possibility that governments can succeed in major undertakings, given the right set of circumstances. Other approaches to carrying out large-scale government programs will have to be developed; the Apollo experience has little to teach us beyond its status as a lasting symbol of a great American achievement.

What future for space?

No one aware of today's government deficits and the overall economic situation can suggest that the United States in 2011 commit the type of financial support to future space efforts that Kennedy made available to carry out Apollo. Kennedy made and sustained his commitment to developing the capabilities needed to reach the Moon before the Soviet Union because doing so was clearly linked to enhancing U.S. global power and national pride in the Cold War setting of the 1960s. Today, there most certainly is no pressing national security question, the answer to which for which the answer is "go to an asteroid," or indeed anywhere else beyond Earth orbit. Space exploration is now a discretionary activity, not a national imperative. This country's leaders need to decide, under very difficult circumstances, whether their image of the U.S. future includes continued leadership in space exploration, and then make the even harder choice to provide on a continuing basis resources adequate to achieving that leading position.

What faces the country today with respect to the future in space is in many ways a more challenging decision than that which faced Kennedy a half-century ago. In his final months in the White House, Kennedy was prescient enough to discern one path toward a sustainable space future: making space exploration a cooperative global undertaking. In the September 1963 UN speech, Kennedy observed that "Surely we should explore whether the scientists and astronauts . . . of all the world cannot work together in the conquest of space, sending some day . . . to the Moon not representatives of a single nation, but representatives of all our countries." That admonition remains relevant today.

John M. Logsdon (logsdon@gwu.edu) is Professor Emeritus of Political Science and International Affairs at the Space Policy Institute, Elliott School of International Affairs, George Washington University, Washington, DC.

SENATOR JEFF BINGAMAN

An Energy Agenda for the New Congress

In spite of bipartisan support, numerous critical energy initiatives languished in the previous congressional session. The need to take action is even more pressing for the current Congress.

At the beginning of this new Congress, it is already becoming clear that energy policy will have a major place on the agenda. Part of that is because the president made clear in his State of the Union Speech that he will give energy a major priority in his administration. In part, it is because our energy security is dependent on overseas supplies and global stability. The events that we have seen unfold in North Africa and the Middle East are stark reminders that the world is an unpredictable place. Whenever geopolitical events potentially affect our access to affordable energy supplies, it is a spur to consider energy policies that might reduce those geopolitical risks.

But perhaps more important than any of those reasons is the competitive pressure the United States is experiencing from other major world economic powers as they take a very leading role in clean energy markets. According to *Bloomberg New Energy Finance*, new investment in clean energy globally reached nearly a quarter of a trillion dollars in 2010. That was a 30% jump from where it was in 2009, and a 100% increase from the level in 2006.

China alone invested $51.1 billion in clean energy in 2010, making it the world's largest investor in this sector. China now manufactures over half of the photovoltaic modules used globally. In 2010, China installed about 17 gigawatts of new wind capacity, roughly half of the total capacity installed globally, with virtually all the equipment being supplied by its domestic manufacturers.

But the concern about the competition for clean energy jobs is not just about China. Europe also made major strides last year toward competing in these markets. Countries such as Germany, the Czech Republic, Italy, and the United Kingdom, have emphasized small-scale distributed electricity-generation projects. In Germany, 8.5 gigawatts of new photovoltaic capacity were added in 2010. The United States must be aware of these initiatives as it considers its course of action.

It is also significant that other countries consume energy more efficiently than does the United States. According to the International Energy Agency, Japan, the United Kingdom, and Canada are all ahead of the United States in implementing policies to make sure they get the most out of every BTU that they consume. Japan, for example, has its Top Runner program, which encourages competition among appliance and equipment manufacturers to continuously improve the efficiency of those appliances and that equipment.

So the question is: How does the United States respond to this competition for clean energy jobs? I believe that to


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WorldProcessor: Zones of Invention—Patterns of Patents

Ingo Günther, 2006

AIM

Globes are used to chart continents, seas, and countries—as well as political borders that separate them. They can also be used to depict socioeconomic data and the social, cultural, and political conflicts arising from them. WorldProcessor globes (http://www.worldprocessor.com) depict a broad spectrum of global data sets of political conflicts; socioeconomic studies; environmental data; technological developments; and the spread of people, knowledge, and disease. Over the last 20 years, Gunther has mapped data on globes as navigational guides in a globalized world. WorldProcessor is one of the first projects that introduced the notion of information mapping to the art world.

INTERPRETATION

The WorldProcessor globe of *Patterns of Patents & Zones of Invention* (WorldProcessor #286) plots the total number of patents granted worldwide, beginning with nearly 50,000 in 1883, reaching 650,000 in 1993 (near the North Pole), and rapidly approaching 1 million in 2002 (in the southern hemisphere). Geographic regions where countries offer environments conducive to fostering innovation are represented by topology. Additionally, nations and countries that have an average of 500 or more U.S. patents per year granted to their residents or companies are called out in red by their respective averages in the years after 2000. Gunther sculpted a three-dimensional distortion of the physical globe in such a way that would recover the original shape of the data graph (see also page 192, WorldProcessor Globes). *Courtesy of Ingo Günther.*

Since its launch in 1988, the WorldProcessor project has mapped 350 topics on more than 1,000 plastic globes. Data sets for the globes at right come from publicly available sources, such as institutions, governments, fact books, newspapers, and magazines. Because conditions change over time, they often produce an updated series of globes. For example, [155-10] Company vs. Country, which reveals that some company's yearly gross income is larger the entire gross national product of a given country, is the 10th update and revision of this globe.

remain at or near the forefront of this strongly developing market, the United States needs to do at least four things:

- First, it needs to ensure that it remains at the forefront of energy R&D, because innovation is the source of its greatest competitive strength. The president made that point in his State of the Union Speech and in other forums as well.
- Second, it must ensure that it has a strong domestic market for clean energy technologies. Without clean energy market pull in the United States, there will not be the incentive to manufacture and deploy these technologies here.
- Third, it has to ensure that it has the necessary financial infrastructure and the incentives to provide the capital needed to build advanced energy technology projects.
- Finally, it needs to have explicit policies to promote the development of U.S. manufacturing capabilities for these clean energy technologies.

I think these four items or elements should be at the heart of whatever comprehensive energy legislation we undertake in this Congress. Let me say a few more words about each of them.

R&D

The first item to consider is support for advanced energy technology R&D. The United States has traditionally led the world in many of the characteristics that are essential to having an innovation economy. It has the predominant share of the world's best research universities. It is the world's largest source of financial capital. It has a disproportionate share of the world's leading innovators in high technology. But these advantages are shrinking rapidly. In 2007, U.S. energy research expenditures were at about 0.3% of gross domestic product (GDP). Japan was at about 0.8% of GDP, and even China was at about 0.4%. Since then, overseas competitors have significantly increased their research investments in energy, while U.S. investments in this area have grown only modestly. It is clear that if Congress is to put together any kind of bill that deserves to be labeled as comprehensive energy legislation, we need to address the huge gap between where the nation's investment in energy technology research is and where in fact it ought to be.

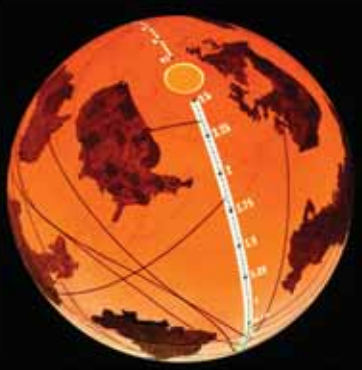
In his State of the Union address, President Obama correctly identified this as a major priority for the appropriations process this year. He followed up on that speech by submitting a budget proposal for the Department of Energy (DOE) in February that increased the department's budget by nearly 12%, with strong funding increases proposed for basic energy sciences, the Advanced Research Projects Agency–Energy, and expanded technology programs for solar, wind, geothermal, and biomass energy. And he did all this at a time when he was proposing government-wide budget cuts to deal with the deficit. His willingness to make thoughtful and forward-leaning investments in energy R&D demonstrates the priority he has given to this area.

The second item is ensuring robust domestic demand for clean energy technologies. It is not enough just to support the research. Getting clean technologies developed, manufactured, and deployed in the United States will require a robust and certain demand for clean energy in the marketplace. This reality was underscored to me during a trip recently to Silicon Valley. I spoke to various people there involved in financing and developing clean energy projects. The message I heard consistently was that uncertain U.S. demand for clean energy is preventing many promising clean technologies from being developed in this country. Companies will not establish a manufacturing base where they do not see a strong market. Private capital sources are, in fact, exerting intense pressure on U.S. clean energy innovators to establish their manufacturing base overseas, where government policies are creating this strong clean energy demand.

We have to take seriously the marketplace reality that the high-wage clean-energy manufacturing of the future will be located both close to demand and in countries with the most favorable clean energy policies. My desire is to see the United States lead the world in renewable energy manufacturing, so that all of the solar panels and wind turbines that are installed around the country are not stamped "Made in China" or "Made in Germany." This is the key reason

in 80 Languages

[162] Nuclear Energy Dependency



[193-3] Fuel Consumers

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[221-4] Internet Users 2009

[333] G8 vs. G20

[319] Submarine Fiberoptic Network

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[233] Rainfall

[331] Energy Consumption vs.GDP

[156] Global Trade Currents

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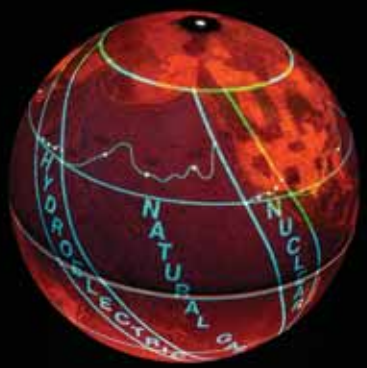
[250-2] Freedom of the Press



[177-2] Fuel Consumption and Prices

[8-4] Life Expectancy 2002

[312] Time Zon

why I have long supported a Renewable Electricity Standard. The country needs to have long-term market predictability for renewable electricity. On-again, off-again production tax credits are no match for the comprehensive approaches being put in place by other countries.

The third item is support for deployment. Although end-use demand is certainly one of the first things an entrepreneur or potential investor looks at when deciding where to locate operations, the analysis does not end there. There is an equally important question: Is there a path to full commercialization of this technology? How can one build the first-of-a-kind project (or the first-few-of-a-kind projects) using a new clean energy technology to demonstrate its actual cost and performance? This is what the private sector wants to see before it will invest in a technology.

This is a particular problem for clean energy technology, because the capital costs in this area are higher than those of previous U.S. high-tech success stories such as information technology or biotechnology. No investor in today's marketplace can match these capital requirements alone. Asian and European countries have set up institutions to address the problem. They have already successfully lured companies to commercialize and manufacture their U.S.-developed clean energy technologies in those markets. The United States needs to set up similar institutions if it hopes to support clean energy jobs at home.

The fourth element is support for manufacturing. If the nation wants clean energy jobs, it needs to have policies to encourage domestic manufacturing. In addition to providing a predictable market for clean energy and a robust financing capability for first-of-a-kind projects, domestic companies need to have incentives for manufacturing the critical components for clean energy technologies. Other countries, most notably China, have complemented their clean energy market standards with robust tax incentives and other fiscal subsidies specifically targeted at manufacturing clean energy components. And as a result, the United States has gone from being a world leader in producing clean energy technologies and enjoying a green trade surplus of more than $14 billion in 1997, to a green trade deficit of nearly $9 billion in 2008. The country cannot afford to sit idly by as its economic competitors move clean energy manufacturing steadily overseas, and deprive Americans of solid job opportunities.

So these are four key strategic elements that need to be included in any energy legislation in this Congress, if an energy bill is to help us compete in global energy markets in the future. None of these individual ideas are new, but their interconnection is now more apparent. A few years ago, it seemed possible that the country could do just one or a few of these things and be successful. It is now clear that action is required on all four of them and on a level that is competitive with what other countries are doing.

Policy prescriptions

Let me now describe some of the specific policy initiatives that I think will be very timely to pursue in the Senate this year. Most of these initiatives will be items I hope to champion in the Committee on Energy and Natural Resources. This is not intended to be an all-inclusive list. The committee has 22 members, many of whom have just been appointed. I anticipate numerous meetings and extensive bipartisan dialogue over the next few weeks as we work out our legislative roadmap for this Congress. But the following topics are issues that I think are particularly crucial for us to address. They are also issues where we did have strong bipartisan consensus in the 111th Congress. This gives us a good place to start our deliberations this year.

The cheapest energy is the energy we do not have to use by operating more efficiently. So, clearly where I'd start with is energy efficiency. In the last Congress, we had a very productive dialogue in the Energy Committee and among businesses, manufacturers, and efficiency advocates interested in appliance and equipment energy efficiency. The result was a package of legislative provisions that codified consensus agreements to update certain existing appliance standards, to adopt new appliance standards, and to improve the overall functioning of DOE's efficiency standards program. Many of these efficiency provisions were part of the comprehensive energy bill we reported out of committee in 2009. Others were subsequently approved by the committee or incorporated into bipartisan bills.

These sorts of standards are essential if U.S. appliance manufacturers are to remain competitive in world markets, which will increasingly demand highly efficient appliances and equipment. By ensuring a strong domestic market for energy-efficient products, we keep innovation and jobs here in the United States, while realizing significant energy and water savings and major cost savings to the consumer.

Obviously we had great difficulty in getting any sort of legislation though in the lame duck session of the last Congress; we were not able to enact these consensus provisions. We had overwhelming broad bipartisan support, but not unanimous support, in the Senate. This is an important piece of our early agenda in this Congress, and I have introduced a follow-on bill along with Senator Murkowski and other colleagues. At a recent hearing before the Energy Committee, the bill was broadly endorsed by industry, con-

By ensuring a strong domestic market for energy-efficient products, we keep innovation and jobs here in the United States, while realizing significant energy and water savings and major cost-savings to the consumer.

sumer, and environmental groups. I look forward to advancing it to consideration by the full Senate.

There is also much that can and should be done to promote efficient use of energy in other parts of the economy. In residential and commercial buildings, a broad coalition supported Home Star, a program for residential building efficiency. Similar interest was apparent with commercial buildings in a program called Building Star. I plan to continue to advance the goals of these proposals in this Congress, although the form in which we provide funding to promote these goals may need to change. In transportation, two proposals from the previous Congress deserve a closer look. First, we should provide a greater point-of-sale incentive to vehicle purchasers, with dealership rebates that would be larger for the more fuel-efficient cars. Senators Lugar, Snowe, and others cosponsored this legislation with me in the previous Congress. A second set of proposals dealt with diversifying the sources of energy that we use in transportation. This bill, which was proposed by Senators Dorgan and Alexander, passed out of the Energy Committee on a 19-4 vote.

Energy efficiency in manufacturing and industrial operations is also important. The legislation reported by the committee last year contained a comprehensive program on manufacturing energy efficiency that had good bipartisan support. Again, I hope we can move forward with this legislation.

Another priority is the one highlighted by the president in his State of the Union speech: moving to a cleaner energy mix in the way we generate electricity. For a number of years, I have advanced a proposal for a Renewable Electricity Standard to ensure long-term and predictable demand for renewable clean energy resources. The president proposed to expand on that concept by including a broader suite of technologies such as nuclear energy, coal with carbon capture and storage, and natural gas generation. The president's stated goal, as he described it, is to obtain 80% of the nation's electricity from such clean energy sources by 2035. The White House has asked us to work with them to see how the provisions for this Clean Energy Standard would be developed. Obviously, there are a lot details to work out. I am pleased that the administration has reached out to the committee to consult on this subject.

Perhaps no topic garnered more scrutiny during the previous Congress's markup that the Renewable Electricity Standard. I plan to work with colleagues on both sides of the aisle in the committee to determine how we can craft a workable legislative proposal to achieve what the president has set out as his goal. As we do so, a number of key design questions will need to be answered: What counts as a clean energy technology? How does the proposal account for existing clean energy sources? Does the credit trading system that we have developed for renewables in our proposal for renewable resources fit with these other resources?

With respect to financing assistance for energy projects, I think there are at least three top priorities for early attention in this Congress: reforming the current loan guarantee program for clean energy projects, providing financing support for advanced energy manufacturing in this country, and providing reasonable stability and predictability in the tax provisions that apply to clean energy projects and technologies.

The first of these is to replace the current loan guarantee program for clean energy technologies with a Clean Energy Deployment Administration. CEDA would be a new independent entity within DOE, with autonomy like the Federal Energy Regulatory Commission has. It would provide various types of credit to support the deployment of clean energy technologies, including loans, loan guarantees, and other credit enhancements.

This proposal received strong bipartisan support in the Energy Committee as part of the larger energy bill we reported. It also had a broad range of external support from clean energy developers, innovators, and venture capital firms. Fixing the problems of the current DOE loan guarantee program and ensuring that we have an effective financing authority for a broad range of clean energy technologies, including renewables, nuclear, energy efficiency, and carbon capture and storage, needs to be one of our highest priorities. I am committed to moving ahead with that legis-

lation in this Congress.

The second priority in the area of financing assistance relates to encouraging the domestic location of manufacturing facilities and replenishing the fund to award tax credits under section 48C. This section provides up to a 30% tax credit for the costs of creating, expanding, or reequipping facilities to manufacture clean energy technologies.

The initial funding was vastly oversubscribed; the government received $10 billion in applications for $2.3 billion in tax credits. This is a powerful demonstration of the potential for clean energy manufacturing that exists in this country. In the previous Congress, Senators Hatch, Stabenow, and Lugar joined me in filing the American Clean Technology Manufacturing Leadership Act. This bill would have added another $2.5 billion in tax credit allocation authority. President Obama has since called for an additional $5 billion. I hope we can help reintroduce bipartisan legislation to ensure this credit's continuation at the president's proposed level. Although this is a matter that will be handled in the Finance Committee, it is an important near-term bipartisan opportunity in this Congress.

The third essential element is to bring stability and predictability to this part of the tax code in order to attract private capital to clean energy projects. If you look at this part of the tax code, many of the energy-related tax incentives will expire at the end of 2011, including the section 1603 program; the credit for energy-efficient residential retrofits; the credit for construction of new energy-efficient homes; the credit for energy efficient appliances; and the incentives for alcohol fuels (mostly ethanol), biodiesel, and renewable diesel. Other energy-related tax incentives are set to expire at the end of 2012, 2013, and 2016.

One other major challenge and priority for the committee in this Congress will be to address the proper and effective regulation of energy development to order to protect the public health and safety and the environment. I have discussed this with Michael Bromwich, the director of the Bureau of Ocean Energy Management, Regulation, and Enforcement, and he is working very hard to get his arms around this critically important issue.

One of the important lessons learned from the National Commission on the Deepwater Horizon Oil Spill is that in the long run, no one—least of all the regulated industry—benefits from inadequate regulation and underfunded regulators. In the aftermath of the Deepwater Horizon disaster, the Committee on Energy and Natural Resources last June came together and unanimously voted out a bipartisan bill to address the key problems uncovered by our hearings on the disaster. Unfortunately, Congress did not enact our bipartisan bill.

At its first hearing in the current Congress, the committee heard from the co-chairmen of the President's Commission on their recommendations. I hope to introduce in the near future a bipartisan follow-on bill to last year's legislation. I hope that we can repeat our bipartisan success of the previous Congress in developing a bill that recognizes the need to develop the rich resources of the outer continental shelf but also to minimize the potential impact on the marine and coastal environment and on human health and safety.

Finally, an item that I hope the Energy Committee can address early in this Congress deals with perhaps the nation's most pressing energy security problem: the vulnerability of the electrical grid to cyber attack. A major disruption of the electric transmission grid, or the equipment it contains, as part of a cyber attack could have disastrous consequences. We need to ensure that adequate preventative measures are in place across the grid. The problem is that we don't currently have mechanisms to ensure that these needed steps are being taken. The whole grid is as vulnerable as its weakest link. In the previous Congress, the Energy Committee twice passed legislation to address this need. The House of Representatives also sent a bill to the Senate on this subject, but again, due to the inability to process legislation in any mode other than unanimous consent in the Senate, we were not able to pass the legislation into law. I hope to work with the members of the committee on both sides to deal with this issue early in this Congress.

In conclusion, this Congress has before it an aggressive agenda of issues and proposals that relate to energy in all its forms and uses. At the same time, we face a daunting partisan environment in Congress for legislation of any type, as well as the added challenge of responding to higher prices for fuels and electricity that are being occasioned both by the energy demand created by global economic recovery and by instability in North Africa and the Middle East. My plan is to work to achieve bipartisan engagement with both the returning and new members of the Senate Energy and Natural Resources Committee, so that we make visible progress on a suite of energy bills that the full Senate could consider in the first several months of this year.

Jeff Bingaman is a Democratic senator from New Mexico and chair of the Senate Energy and Natural Resources Committee.

BURTON RICHTER

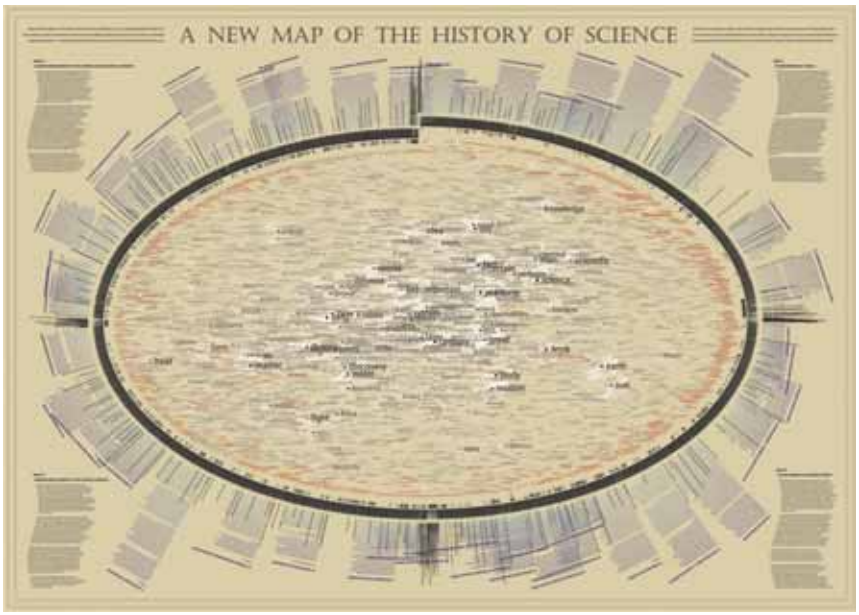
Energy in Three Dimensions

The rationale for energy policy must be about more than climate change and green energy.

The United States has been unable to develop any coherent energy program that can last past changes in the control of our federal executive or Congress. The latest failure was the Waxman-Markey cap-and-trade bill that would have driven an enormous change in the country's energy supply system in the name of controlling global warming. It barely passed the House and went nowhere in the Senate, where what had started as a nonpartisan and more moderate effort by Senators Graham, Kerry, and Lieberman died in the polarized atmosphere that developed in the campaign season leading up to the 2010 congressional elections.

I wonder if a big part of our current problem is an overemphasis on "greenness," leading to a too-narrow focus on climate change as the sole driver for action. The public debate on energy is dominated by climate change and its deniers and its exaggerators. The deniers say global warming is a fraud or that it has nothing to do with human activities so we can't do anything about it anyway. The exaggerators say that unless we move within a decade to obtain 30% of our electricity from a narrowly defined group of renewable energy sources the world will descend into chaos by the end of the century. Between these two extremes are many members of Congress who see a need for government action on energy but do not believe that the country needs to move immediately to run the country on wind generators and solar cells. This group includes many Democrats who did not support the Waxman-Markey bill in the House.

Making major changes in the country's energy systems has a major impact economically as well as technically. There are potential benefits from making changes to energy sources that go beyond the climate issue, as important as that issue is. For example, the cost of the oil we import is about equal to our balance-of-trade deficit. If all cars, SUVs, pickups, and minivans traveled 50 miles per gallon of gas, our oil imports could be cut in half, reducing our balance-of-trade deficit by about $200 billion and decreasing emissions as well. The *En-*



TextArc Visualization of "The History of Science"

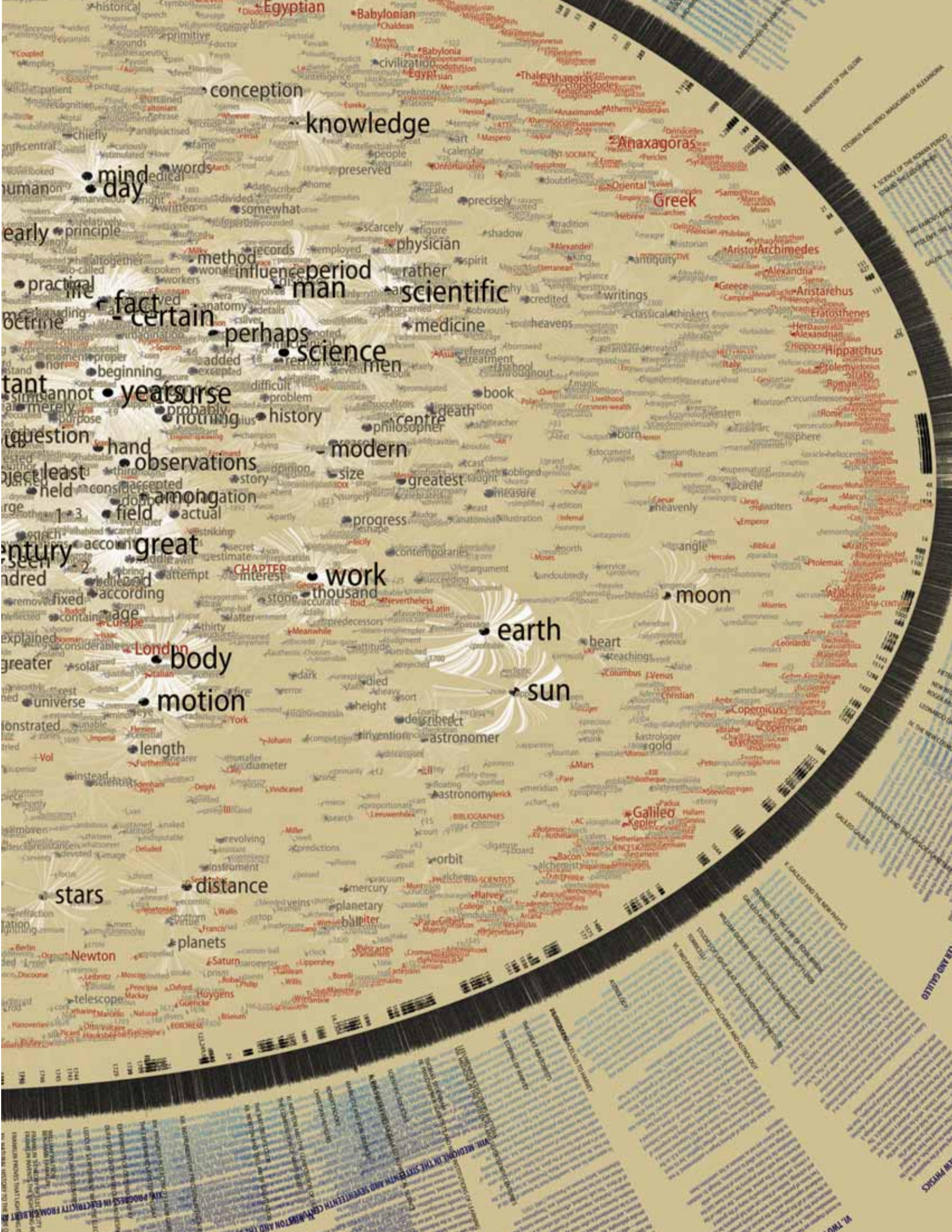
W. Bradford Paley, 2006

AIM

Imagine you are given a manuscript with thousands of lines, and you need to make sense of it in very little time. Is there any way that you could possibly understand the main characters that drive the story, their relationships and interactions, and the topics covered without having sufficient time to read the book? Is there any way to visually analyze the structure of a text and gauge the professionalism of the writer? TextArc was designed to address not only these needs, but also to map the history of science.

INTERPRETATION

This map shows a TextArc visualization of four volumes of a book by Henry Smith Williams, *A History of Science*. The intelligent organization of the books and the culturally recognized way of organizing science quickly become apparent. The history's first two volumes are organized in a strictly chronological fashion, so as the book wraps from 12:00 to 6:00 around the right side of the ellipse, it is organized as a timeline. The next two volumes distinguish two major domains—making two timelines—of more recent scientific exploration: the physical sciences from 6:00 to 9:00 and the life sciences from 9:00 back to 12:00. Since the scattered words are pulled toward the places where they are used in the text (see the map itself for a better description of the layout), a particular kind of structure emerges: names of individuals that are mentioned but once or twice appear along the outer boundaries, while frequently cited concepts that are common to science of all eras—for example, system, theory, and experiment—are drawn to the center. Even more interesting is that the main subjects of focus for certain areas are neither near the specific edges nor the general center, but in a local, topical band between the two: mind, knowledge, and conception during the philosophic beginnings of science; moon, earth, sun, and stars at a later time; electricity, light, and natural forces in the recent physical sciences; and animals, disease, development, and brain in the recent life sciences, for example. *Courtesy of W. Bradford Paley.*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CHAPTER
BIBLIOGRAPHIES

ergy Future: Think Efficiency study that I led for the American Physical Society concluded that 50–mile-per-gallon single-fuel vehicles can easily be produced in the 2020s.

National security must also be an essential consideration in energy policy. Delivering a single gallon of fuel to the front in Afghanistan requires a supply chain that consumes hundreds of gallons of fuel. Improvements in the efficiency of military vehicles would result in enormous savings in addition to reducing the exposure to danger of military personnel throughout the supply chain. Small solar or wind systems to provide power to forward bases would be treasured. Reducing U.S. dependence on oil would also make an important difference in foreign policy, making it possible to be more assertive in relations with oil-supplying nations in the Middle East and perhaps even with President Chavez of Venezuela.

Too much of the energy debate in recent years has suffered from a one-dimensional focus on climate change. But the systems that need to be changed to do something about global warming affect all dimensions of society: the economy, national security, and a variety of environmental concerns. Energy policy is too important to be entirely subsumed under a debate about climate science. Federal action on energy will occur only after we confront a number of realities that are creating unnecessary barriers to progress:

- The exclusive focus on climate change as a justification for action on energy has excluded potential allies.
- The emphasis on ultra-green technologies that are not yet ready for the big time has let the desire for the perfect drive out the available good.
- Pushing policies that are as narrowly targeted as renewable portfolio standards has prevented many larger and less costly emissions reductions to be made in the nearer term than have been made with the renewables.

The one-dimensional focus of the energy debate on climate change has led to stalemate, and the way to break out of it is to broaden the base of support by working in all three dimensions where we may find allies ready for action, though their reasons may be different from those driven by concern about climate change. This need not be difficult. In fact, across the country there are signs that some federal agencies, state governments, and private companies are already putting this strategy into practice. Motivated by a variety of concerns, they are taking actions that are moving the nation's energy system in the right direction:

- The Excelon Corporation plans to spend $5 billion in the next six years on efficiency and on increasing the output of its nuclear power plants.
- No new coal plants have been started this year because natural gas prices are so low.
- NASA has let two contracts (Lockheed-Martin and Northrop-Grumman) for airplane concepts that might cut fuel consumption in half.
- California soundly defeated the ballot proposition that would have suspended its greenhouse gas reduction program. Most of the counties that voted Republican in the California senatorial campaign voted against the proposition.

The states are coming together to do regionally what Washington is unwilling to do nationally. There are now three regional compacts on reducing greenhouse gas emissions:

- The Regional Greenhouse Gas Initiative includes 10 Northeastern and mid-Atlantic states and has a cap-and-trade system.
- The Midwest Greenhouse Gas Reduction Accord includes six states and one Canadian province.
- The Western Climate Initiative includes seven states and four Canadian provinces.

Economic realities and enlightened self-interest can spur private companies to make the investments that will benefit the nation as well as their stockholders. There are many in government who may not accept a global warming argument, but who can be persuaded by an economic or security argument. Voters in the states are providing evidence that there is broad support for sensible action on energy. National policymakers need to hear the message that there is not just one rationale for setting policies that will transform the nation's energy system. Although the reasons for action may differ, there is agreement on the general direction of the change that is needed.

If the goal is to do everything possible to reduce greenhouse gas emissions, is there any sound reason not to provide incentives for energy efficiency, natural gas, and nuclear power, all of which are relatively inexpensive, effective, and scalable now?

Immature technology

It is easy to forget how long it takes a new energy technology to mature and become cost-effective at scale and how much longer it takes to make a major penetration into the national infrastructure. A November 2010 report from the President's Council of Advisors on Science and Technology (PCAST) concluded that we have to plan for a 50-year period to transform the nation's energy infrastructure.

A shortcoming of much of the proposed legislation in Washington and the states is that we are pushing too hard on what is not ready and not hard enough on what is ready. For example, the National Renewable Energy Laboratory's *Western Wind and Solar Integration Study* on integrating 35% of electricity delivery by wind and solar over the entire Great Plains and the West concluded that it could be done, but the system could not be made stable without having available backup for 100% of wind and solar capacity. Why? Because sometimes there are periods of days when the wind does not blow or the Sun does not shine, and we cannot afford blackouts of long duration.

When advocates of renewable power calculate the cost of wind and solar systems, they rarely mention the very high cost of building, maintaining, and operating a large backup system. Likewise, they are likely to ignore the cost of building long-range high-power transmission lines to deliver power from the remote locations where renewable systems are often built to the urban and suburban areas where the electricity is needed, nor do they factor in the very long and difficult regulatory path that must be followed before the lines can be built. It can take longer to win approval for a transmission line than for a nuclear power plant.

When large-scale energy storage systems become available, and when part of the environmental movement stops suing to block the transmission lines that other parts of the environmental movement want to build to distribute renewable electricity, perhaps wind and solar can reach the scale being promoted. Meanwhile, up to 10 or 15% of demand is all that can be reasonably expected from renewable sources.

We cannot seem to stop doing things that make no sense at all. Hydrogen for transportation is an example. The program should be abandoned or sent back to the laboratory for the development of better catalysts and more efficient end-to-end systems that can make it deployable and affordable at scale. It makes no sense to use energy to produce hydrogen, distribute the hydrogen by an entirely new system, and put it into cars to be used by a fuel cell to produce electricity, when we can much more efficiently distribute the electricity and put it into batteries.

Mature technology

Many of the renewable energy systems being promoted may eventually reach full scale, but they are not ready for that now. On the other hand, natural gas has become cheap with the new ability to exploit shale gas. A modern gas plant emits one-third of the greenhouse gases of an average coal plant. Changing all the coal-fired power plants in the country to modern natural gas plants would eliminate 1.4 billion tons of carbon dioxide emission annually, a quarter of total emissions.

California's Million Solar Roofs project is to install 2 to 3 gigawatts of photovoltaic (PV) capacity at a cost of $10 billion to $20 billion. For 15% of the cost, one could eliminate twice as much greenhouse gas by converting the Four Corners 2-gigawatt coal-fired power plant to natural gas. Even if PV were down to $1 per watt from today's typical $4 to $5 per watt, the coal-to-gas conversion would still eliminate more greenhouse gases for the same cost. Alternatively, one could build two nuclear power plants for today's PV cost and eliminate five times the emissions.

If the goal is to do everything possible to reduce greenhouse gas emissions, is there any sound reason not to provide incentives for energy efficiency, natural gas, and nuclear power, all of which are relatively inexpensive, effective, and scalable now? What is the rationale for emphasizing renewable portfolio standards that target only solar, wind, geothermal, and small hydroelectric technologies? Is the goal to promote the Chinese PV and wind-turbine industries, or is to reduce emissions?

Policy

In looking for ways to free energy policy from its narrow focus and to end the political stalemate, we can find some helpful, and not so helpful, suggestions in four recent reports:

- The National Academy of Sciences has issued a sequel to its *Rising Above the Gathering Storm* report first issued in 2005. It emphasizes education and innovation and recommends spending more money on energy research. But it said this before. It did not happen then and is unlikely to happen now.
- The PCAST report cited earlier says spend more money and base what you spend on a quadrennial energy review like the Department of Defense's (DOD's) quadrennial defense review. If you are thrilled at the weapons and policies coming from the DOD reviews, you might like this.

The next two are more interesting.

- The American Energy Innovation Council, whose board includes well-known current CEOs and retired CEOs such as Jeff Immelt of General Electric, Bill Gates of Microsoft, and Norm Augustine of Lockheed-Martin, among others, may have more impact. Its report *A Business Plan for America's Energy Future* discusses the multidimensional energy challenge we face and recommends a new national strategy board made up of nongovernmental people, a $16 billion–per–year innovation fund, and a better-defined role for the federal government. It won't happen soon because of the money, but the CEOs of the Innovation Council should be influential, and it has some interesting ideas.
- The most unusual is the tripartite report *Post-Partisan Power*, from the American Enterprise Institute, Brookings Institution, and a new West Coast player, the Breakthrough Institute. It says invest in education, overhaul the energy innovation system, reform subsidies, and add a few small fees so that it can be done without adding to the deficit. Any time the names of Brookings and the American Enterprise Institute are on the cover of one report, it should earn attention.

Those who are waiting for a national cap-and-trade bill or a carbon tax will have to wait at least until we see the results of the 2012 election, and maybe longer. But significant progress is possible without these measures. The heavy lifting will have to be done by industry, and the key to industry success is to establish policies that specify what the nation wants to achieve, not how industry should do it.

Politically, it will be essential to support all proposals in as many dimensions as are appropriate. A further increase in the automobile mileage standard can be justified on economic and national security grounds as well as on environmental ones. The technology already exists with hybrids, diesels, and direct-injection gasoline engines.

Reject renewable portfolio standards, and opt instead for emission reduction standards. Because natural gas is cheaper and better than coal today, it should be encouraged. Government, and forgive me for saying so, environmentalists, are better off focusing on the goals, and not on how to reach them.

Tell the electric power industry to reduce emissions by some percentage by some date and then get out of the way. Competitive companies will determine what mix of efficiency management, natural gas, renewable sources, and other measures is quickest and cheapest. We will need solar and wind eventually, so they need some support, but not at the expense of limiting cost-effective action today.

Don't be too clever by half, as the Brits say. One too-clever regulation is California's low carbon fuel standard. It requires that one count all the carbon in a megajoule of each fuel, including the energy and emissions that go with making the fuel, and then reduce that amount by 10% by 2020. There are smart people who love this. It was adopted by California in April 2009, and more states are considering following California's lead. The theory is that it forces emissions included in fuel production to be counted, so, for example, if one uses more oil from Canadian tar sands to make gasoline, the carbon score goes up. But emissions depend on both fuel and efficiency. Larger and less costly reductions in emissions can be made by focusing on the efficiency side: A diesel will reduce emissions by about 20% as compared to a gasoline engine; a hybrid will reduce it by 50%. So why waste effort and money on the fuel side? Once again, set the goals and get out of the way.

The fundamental question is, can environmental, scientific, business, and policy organizations put together a coherent message that brings in as many allies as possible, starts large-scale action with things that are scalable and affordable today, and encourages the innovation we will need for tomorrow?

It will not be easy, but it is the only way we will turn things around.

Burton Richter (brichter@slac.stanford.edu) is director emeritus of the Stanford Linear Accelerator Center and the winner of the 1976 Nobel Prize in physics.

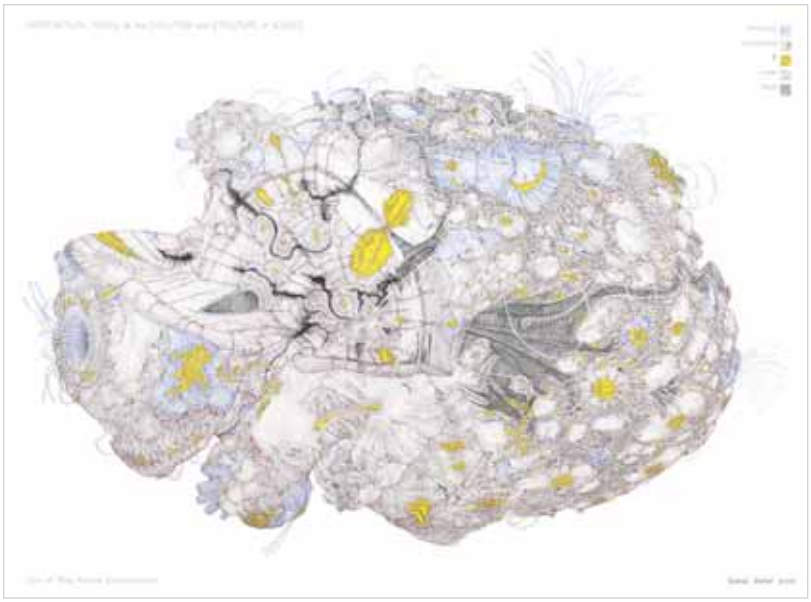
RICHARD A. MATTHEW

Is Climate Change a National Security Issue?

The case for linking climate change and national security is robust but imperfect, and today there is a serious debate about whether it makes sense.

Around the planet there is growing momentum to define climate change as a security issue and hence as an agenda-topping problem that deserves significant attention and resources. In December 2010, for example, while poised to start a two-year term on the United Nations Security Council, Germany announced its intention to push to have climate change considered as a security issue in the broadest sense of the term. Germany's objective captures a sentiment that has been expressed in many venues, including several recent high-level U.S. national security documents. The May 2010 version of the National Security Strategy repeatedly groups together violent extremism, nuclear weapons, climate change, pandemic disease, and economic instability as security threats that require strength at home and international cooperation to address adequately. The February 2010 Quadrennial Defense Review links climate change to future conflict and identifies it as one of four issues in which reform is "imperative" to ensure national security. This sentiment has met resistance, however, and today there is a serious debate about whether linking climate change to security, and especially to national security, makes sense.

The case in support of this linkage integrates three strands of argument. The first builds on efforts to expand a very narrow definition of the term "national security" that was dominant during the 20th century. The narrow meaning was shaped by a specific set of events. After World Wars I and II, a third major war involving nuclear weapons was widely regarded as the single greatest threat to the survival of the United States and indeed to much of the world. In response to this perception, the National Security Act of 1947 sought "to provide for the establishment of integrated policies and procedures for the departments, agencies, and functions of the Government relating to the national security." Its focus was on strengthening the country's military and intelligence capabilities, and the government was supported in this effort



Hypothetical Model of the Evolution and Structure of Science

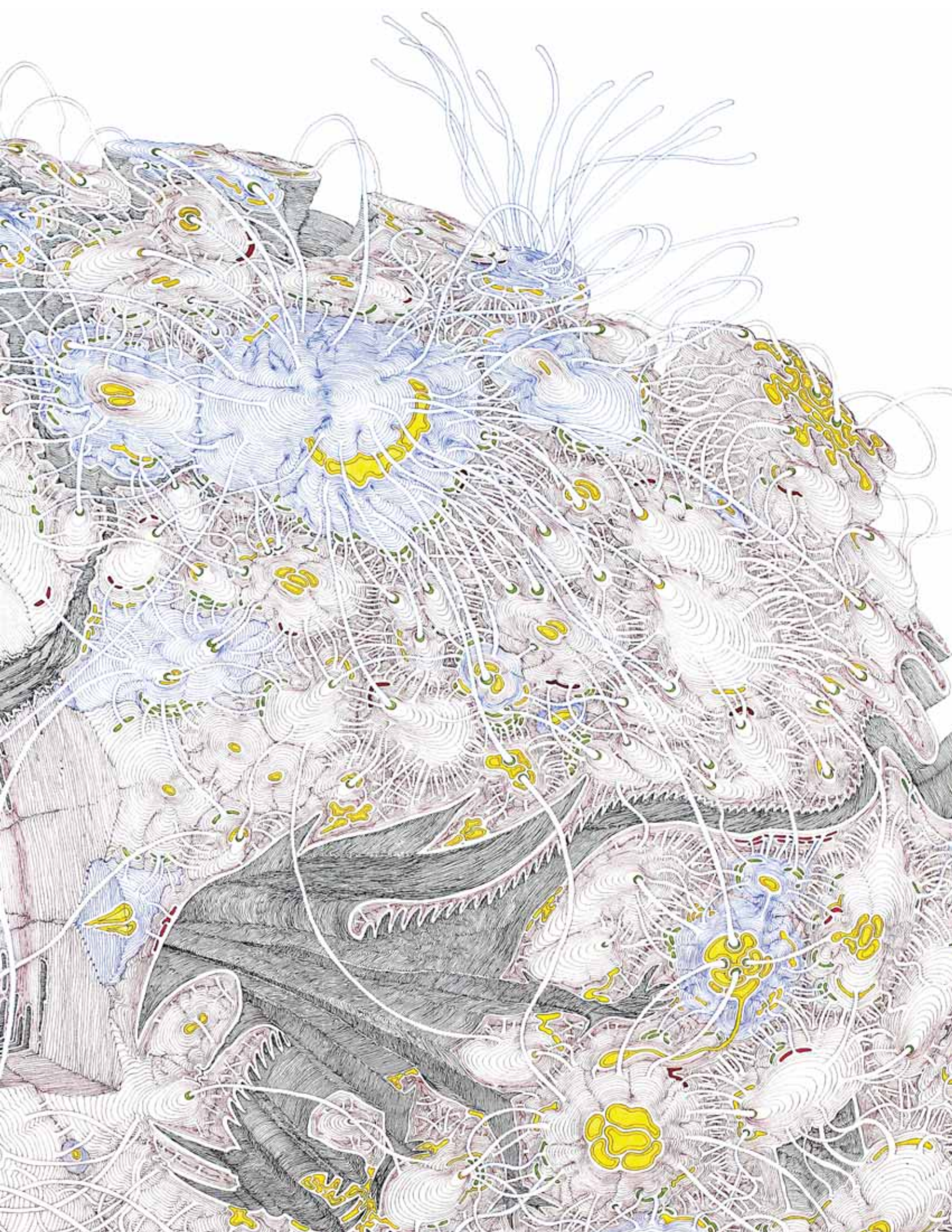
Daniel Zeller, 2007

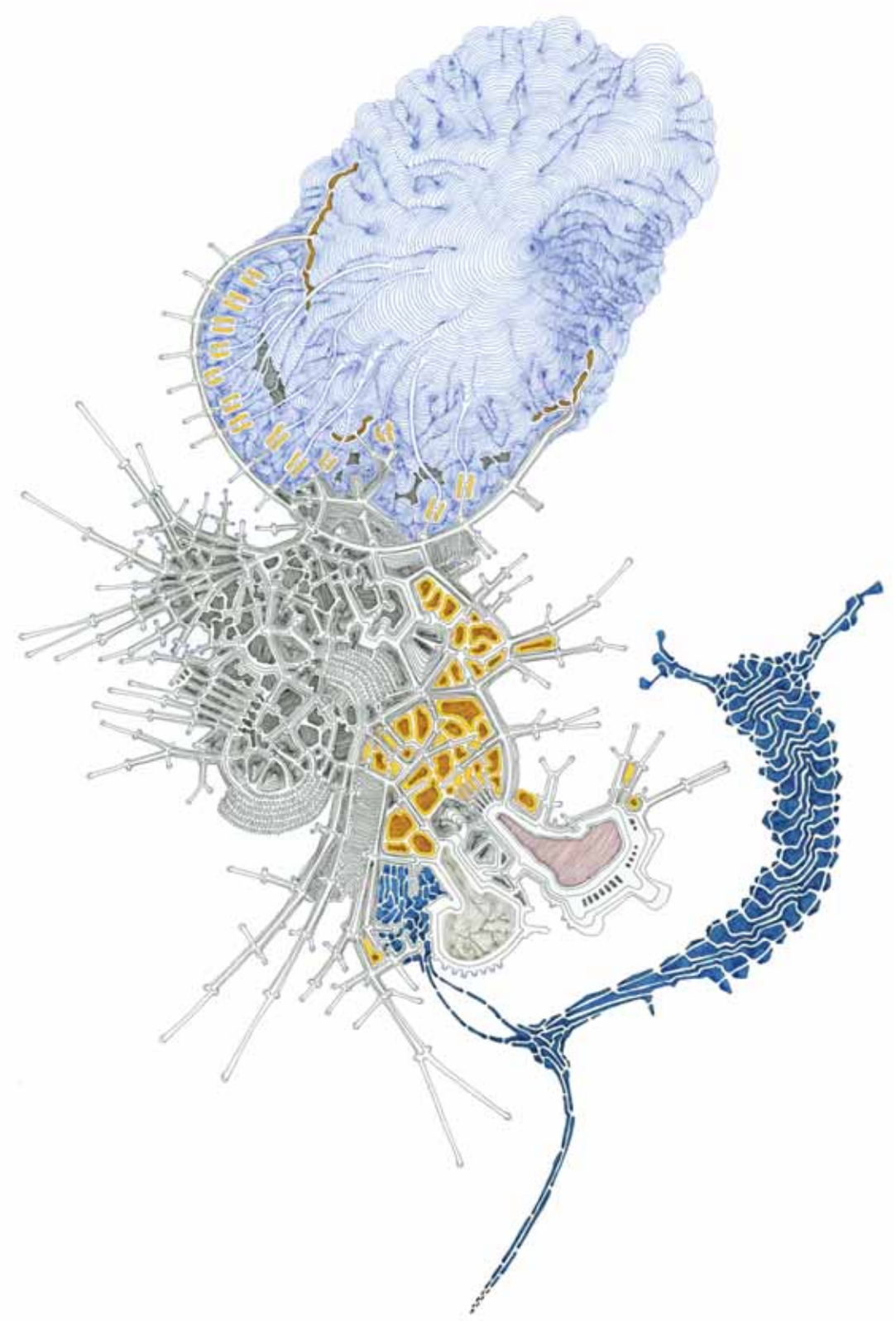
AIM

How can the structure and evolution of science be conceptually represented and visually mapped? What metaphors might work best to depict established and emerging fields, the impact of funding, the continuous and often desperate search for novelty and reputation? Will there be monsters that guard undiscovered lands of knowledge?

INTERPRETATION

This drawing conceptualizes science as layers of interconnected scientific fields. Starting with the original scientific thought, science grows outward in all directions. Each year, another layer is added to the meteor-shaped manifestation of knowledge. New fields (blue) emerge and established fields (brown) merge, split, or die. The cutout reveals a layering of fat years that produce many new papers and slim years when few papers are added. Each research field corresponds to a tube-shaped object. Some have rapid growth patterns, due to electronic papers that are interlinked within days. Other fields communicate knowledge via books—in which case, years may pass before the first citation bridge is established. Blue tentacles could symbolize the search for opportunities and resources or activity bursts due to hype and trends. The injection of money (yellow) has a major impact on how science grows. There are voids in our knowledge that may take the shape of monsters. The trajectories of scientists who consume money, write papers, interlink papers via citation bridges, and fight battles on the front lines of research could be overlaid. Yet, scientists are mortal. All they leave behind are the knowledge structures on which future generations can build. *Courtesy of Daniel Zeller.*





DANIEL ZELLER, *Superficial Inquiry*, *2005*.

Tentacles represent explorations of new opportunities, moving away from established fields (brown) and sometimes establishing new fields (blue).

Because some resources are becoming increasingly scarce and others increasingly valuable, the prospects for environmental factors gaining weight in the security arena appear robust.

through the rapid buildup of independent think tanks and security studies programs at colleges and universities throughout the country. National security was seen by most experts as a condition that depended on many factors, and hence the broadest goals of the national security community were to build and maintain good allies, a strong economy, social cohesion and trust in government, democratic processes, civil preparedness, a skilled diplomatic corps, and powerful, forward-looking military and intelligence agencies. For more than four decades after World War II, however, efforts to improve national security were assessed against estimates of the threats of nuclear war and communist expansion, and invariably emphasized the paramount importance of military and intelligence assets. National security was largely about the military and intelligence capabilities necessary for preventing or winning a major war.

In the 1990s, this powerful architecture was challenged in several ways. First, with the rapid and largely unexpected collapse of the Soviet Union came the question: Since there were no other countries likely to launch a full-scale nuclear attack against us, could we now reduce our large military and intelligence expenditures and invest in other areas? Second, as the 20th century drew to a close, it became evident that the nature of violent conflict had changed from short, brutal, and decisive interstate wars to long, somewhat less brutal, and frequently inconclusive civil wars. Under the quagmire conditions of this new generation of warfare, superior military capability did not translate inexorably into victory.

Finally, having spent so much time focused on the particular threat of military-to-military conflict, analysts asked if we should now be looking at threats more broadly and even considering alternative ways of thinking about security. By middecade, human security and some variant of global security had gained support as alternative or complementary ways of thinking about security. Further, in the United States and abroad, conceptions of security threats expanded to include issues such as terrorism, disease, and global economic crisis.

As the era of great wars receded, some observers concluded that violence was now mainly structural, a fact hidden or ignored during the Cold War, when the threat of large-scale violence was linked to an ideologically based power struggle. From the structuralist perspective, victory and defeat were unproductive ways of thinking about security. Instead, improvements in security depended on extensive reform of the global economy, the international system of states, the divide between nature and civilization, and entrenched patterns of gender and ethnic inequality. Many others agreed that our new era of security underscored the limits of military force, which had been the centerpiece of much 20th-century security policy. Hence, at the very least, we needed to carefully rethink security and reconsider what was needed to provide it, a reflection that would certainly lead to important, if not necessarily structural, change.

One of the issues invigorating all of these challenges to Cold War security thinking (challenges that, incidentally, were not entirely new and had been voiced at various times throughout the 20th century) was a growing concern about environmental degradation and stress. Indeed, just as the Cold War ended, the Rio Summit on Environment and Development catalyzed global attention around climate change, biodiversity loss, and deforestation; underscored the need for national, regional, and global conservation strategies; and introduced a transformative vision that involved shifting the entire planet onto the path of sustainable development. In this context, a handful of observers argued that, in light of the trends observed by scientists from multiple disciplines, the Cold War peace dividend should be redirected toward environmental rescue, and that failing to do this could push the world toward higher and higher levels of insecurity.

The second strand woven into the case for integration picks up on this latter intuition. A central question of this strand of analysis is: What could happen if we fail to act to promote sustainable development and allow alarming environmental trends to continue more or less unchecked? Building on arguments that extend at least as far back as 18th-century demographer Thomas Malthus, who worried that population growth would outstrip increases in food produc-

TABLE 1

Climate change and national security

National security concerns / Climate change impacts	Weakening of elements of national power	State failure	Disruption and violent conflict
Changes in water distribution	Job loss in rural areas	Reduce agricultural outputs, basic needs unmet	Increased competition for water
Severe weather events	Undermine economic strength	Funds diverted to disaster relief, away from infrastructure, etc.	Displace people into areas where they are not welcome
Heat waves	Pandemics	Greater demands to meet basic needs	Riots in urban areas
Drought	Undermine economic development	Deepen social inequality as some groups control food and water	Displace people into areas where they are not welcome
Sea-level rise	Destroy coastal military bases	Increase inequality and promote extremism as some people lose land	Put the survival of states such as the Maldives and Bangladesh at risk
Flooding	Reduce military effectiveness in the field	Destroy critical infrastructure	Increase urban strife

The examples in Table 1 are not meant to be definitive but rather to indicate how climate effects could affect national security. Clearly many of these examples could be reiterated in many boxes.

tion, leading to a period of intense famine, war, and disease, a contemporary generation of scholars used case studies and other methodologies to explore linkages between environmental stress and two national security challenges: violent conflict and state failure. Although simple, causal relationships have proved elusive—a generic problem in the study of war and peace—patterns have been identified that many have found compelling. To simplify what is becoming a rich field of inquiry, certain natural resources, especially when they suddenly become scarce (water or arable land) or acquire high value (diamonds or timber) can become a significant factor affecting government behavior, development prospects, population flows, and forms of competition. Under certain conditions, such challenges trigger innovation and adaptation, but under other conditions they contribute to violent conflict and other types of insecurity. Because some resources are becoming increasingly scarce and others increasingly valuable, the prospects for environmental factors gaining weight in the security arena appear robust.

Scholars such as Thomas Homer-Dixon, for example, focus on the adverse social effects of scarcity of water, cropland, and pasture. Scarcity, he argues, results from a decrease in the supply of a resource, an increase in the demand for a resource, or a socially engineered change in access to a resource. Under conditions of resource scarcity, Homer-Dixon contends that developing countries may experience resource capture (one group seizes control of the resource) or ecological marginalization (people are forced to move into resource-poor lands), either of which may contribute to violent conflict. Continuing this trajectory of thought, Colin Kahl argues that resource scarcity may generate state failure (a collapse of functional capacity and social cohesion) or state exploitation (in which a collapsing state acts to preserve itself by giving greater access to natural resources to groups it believes can prop it up). Although some researchers are not persuaded by arguments linking environmental stress to state failure and violent conflict, many others regard them as compelling, and many policymakers and practitioners

have absorbed these arguments into their world views.

The third strand of analysis involved in integrating climate change and national security builds on the environment and security literature by focusing on the real and potential societal effects of climate change. Climate change scientists are observing changes in the distribution of water, increases in the intensity of severe weather events, longer heat waves, longer droughts, and sea-level rise and flooding. Some worry that continued global warming will move the planet across critical thresholds, causing "black swan" events such as massive gas releases, rapid glaciation, or microbial explosions. There are several ways in which such changes could generate threats to national security.

Summarizing the discussion above, challenges to national security can be organized into three groupings: anything that weakens the elements of national power; contributes to state failure; or leads to, supports, or amplifies the causes of violent conflict. Climate change has the potential to have a negative impact in each of these domains (see Table 1).

National power. National power depends on many variables, including environmental factors such as geography and resource endowment, military capacity, intelligence capacity, and a range of social factors, including population size and cohesiveness, regime type, and the size and performance of the national economy. Climate change has the potential to affect all of these elements of national power. For example, militaries may be less effective at projecting and exercising power if they have to operate in flooded terrain or during a heat wave. Warming that affects land cover could reduce a country's renewable resource base. Intelligence is difficult to gather and analyze in a domain marked by uncertainty about social effects.

Perhaps the area of greatest concern, however, is that climate change might undermine economic development, especially in poor and fragile states. The economist Paul Collier has argued that the bottom billion people on the planet currently live in states that are failing to develop or are falling apart. He contends that these states are often enmeshed in interactive conditions and processes that inhibit development: chronic violent conflict, valuable natural resources such as oil or diamonds that groups vie to control, unstable neighboring countries creating chronic transboundary stress, and government corruption and inefficiency. An increase in costly and hard-to-manage events such as floods, droughts, heat waves, fires, pandemics, and crop failures would probably be an enormous additional burden on these countries, introducing a daunting new layer of development challenges and hence weakening a central element of national power.

State failure. The authors of the 2009 report of the International Federation of the Red Cross and Red Crescent Societies wrote that, "The threat of disaster resulting from climate change is twofold. First, individual extreme events will devastate vulnerable communities in their path. If population growth is factored in, many more people may be at significant risk. Together, these events add up to potentially the most significant threat to human progress that the world has seen. Second, climate change will compound the already complex problems of poor countries, and could contribute to a downward development spiral for millions of people, even greater than has already been experienced." The 2010 report notes that the cost of climate-related disasters tripled from 2009 to 2010 to nearly $110 billion. Disasters are costly, and the costs appear to be mounting dramatically. From the perspective of state failure, disasters are deeply alarming because they shift scarce funds away from critical activities such as building infrastructure, investing in skills development, and implementing employment and poverty-reduction programs, and into emergency relief. Such a shift can have a direct and very negative impact on a government's functional capacity.

The same argument can be advanced for the diffuse longer-term effects of climate change that might affect food security, public health, urban development, rural livelihoods, and so on. Under conditions of either abrupt or incremental change, people may be displaced into marginal lands or unwelcoming communities, enticed by extremist ideology, compelled to resort to crime in order to survive, or take up arms, all of which risk overtaxing the government, deepen-

ing social divisions, and breeding distrust and anger in the civilian population.

The gravest climate change threat, however, is that states will fail because they can no longer function as their territories disappear under rising seas, an imminent threat to the Maldives and some 40 other island states. Glacial-outburst floods might cause similar devastation in countries such as Nepal, and a change in the ocean conveyer that warms the northeast Atlantic Ocean could cause countries such as the United Kingdom to disappear under several feet of ice within a few years. These starkly existential threats have become the single most important national security issue for many vulnerable countries. Last year, the president of the Maldives held a cabinet meeting underwater to bring attention to this type of threat.

Violent conflict. Building on the insights of Homer-Dixon, Kahl, and many others, it is reasonable to suggest that climate-induced resource scarcities could become key drivers of violent conflict in the not too distant future. On this front, another area of particular concern has to do with so-called climate refugees. In 2006, Sir Nicholas Stern predicted that 200 million people could be permanently displaced by mid-century because of rising sea levels, massive flooding, and long, devastating droughts. Large flows of poor people from rural to urban environments and across ethnic, economic, and political boundaries would cause epic humanitarian crises and be extremely difficult to manage. One can easily imagine such stress becoming implicated in violent conflict and other forms of social disruption.

Stern's prediction is of the back-of-the-envelope variety and has faced criticism from researchers such as Henrik Urdal, who argues that the "potential for and challenges related to migration spurred by climate change should be acknowledged, but not overemphasized. Some forms of environmental change associated with climate change like extreme weather and flooding may cause substantial and acute, but mostly temporal, displacement of people. However, the most dramatic form of change expected to affect human settlements, sea-level rise, is likely to happen gradually, as are processes of soil and freshwater degradation." The bottom line, however, is that nobody knows for sure what the scale and social effects of climate-increased population flows will be.

The basic concerns suggested above are well captured in the many publications that followed the publication of the 2007 Intergovernmental Panel on Climate Change (IPCC) reports. For example, the CNA Corporation report National Security and the Threat of Climate Change concluded that "climate change acts as a threat multiplier for instability in some of the most volatile regions of the world." Further, it predicted that "projected climate change will add to tensions even in stable regions of the world." Similarly, the German Advisory Council on Global Change's report World in Transition: Climate Change as a Security Risk said that "Climate change will overstretch many societies' adaptive capacities within the coming decades." The tenor of much recent writing is that climate change will weaken states that are already fragile, and it will contribute to violent conflict, intensify population displacement, increase vulnerability to disasters, and disrupt poverty alleviation programs, especially in South Asia, the Middle East, and sub-Saharan Africa, where large numbers of people, widespread poverty, fragile governments, and agricultural economies conspire to create heightened vulnerability.

The counterargument

The case against linking climate change to national security raises concerns about each of the strands of argument outlined above and is rather intuitive. Insofar as the language of national security itself is concerned, three important criticisms have been advanced. In a series of editorials in Foreign Policy magazine, Stephen Walt contends that a careful reading of the arguments about climate change made in the CNA report and in similar documents makes it clear that this is simply not a national security issue, at least not for the United States. In the foreseeable future, climate change may cause serious problems in places such as Bangladesh that spill over into places such as India, but these problems and the responses they will trigger are better described as hu-

The tenor of much recent writing is that climate change will contribute to violent conflict, intensify population displacement, increase vulnerability to disasters, and disrupt poverty alleviation programs.

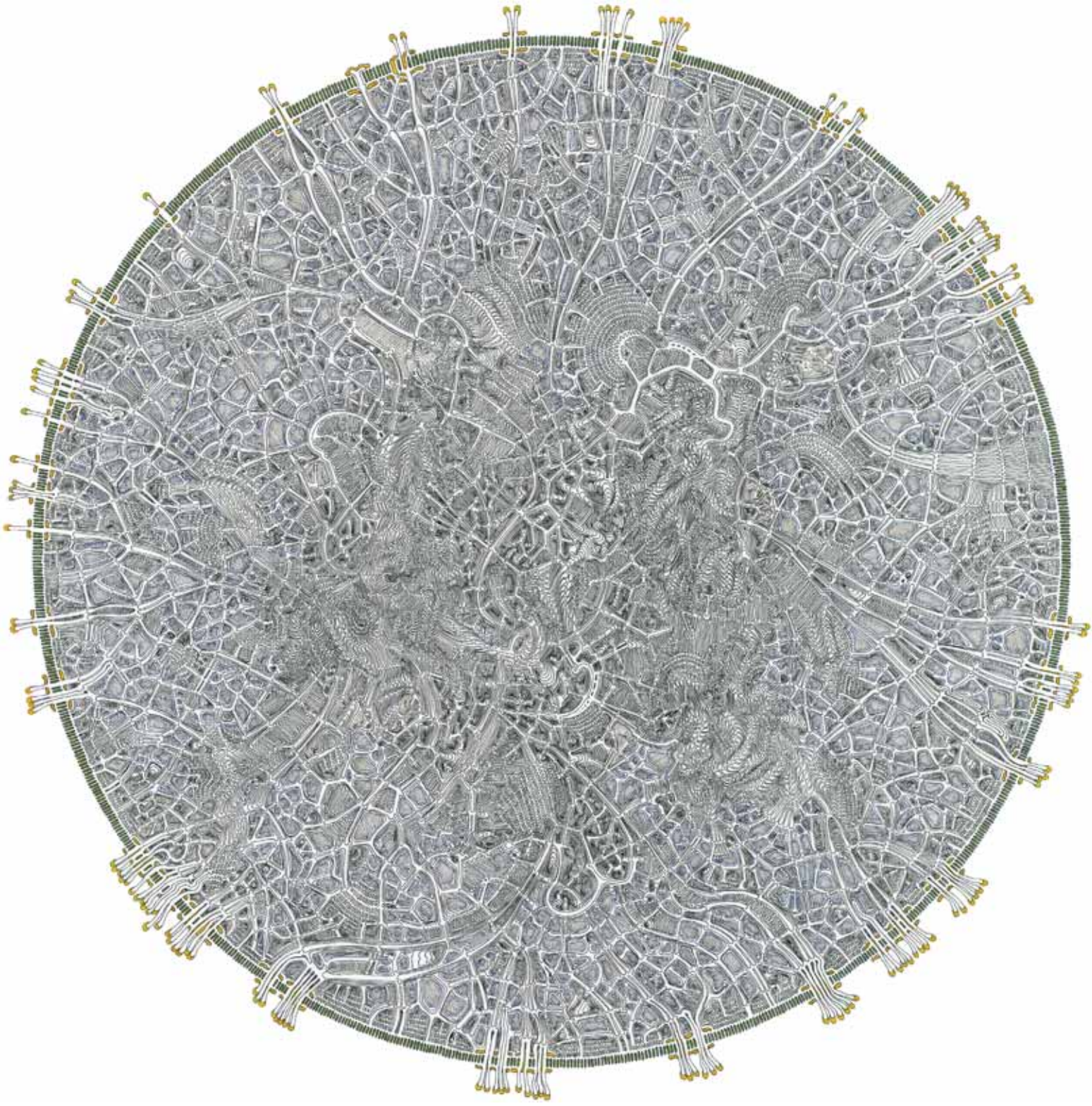
manitarian issues. For Walt and other realist thinkers, national security is about the survival of the state, and apart from black swan events we can imagine but not predict or prepare for, threats of this magnitude have been and continue to be threats of military aggression by other states. Walt asks us to consider what we gain in terms of analysis, strategy, and policy formulation by expanding the domain of national security into areas where immediate or near-term threats to the survival or even well-being of the United States are vague or unknown, even though the rhetoric used to describe them is often urgent and dramatic.

A very different concern comes from scholars such as Daniel Deudney, Barry Buzan, and Ole Waever, who worry about militarizing or securitizing climate change and the environment. Like Walt, they are not suggesting that climate change is a trivial matter; rather, they worry about whether framing it as a national security issue and thus linking it to military and intelligence tools is wise. This linkage, they suggest, might inhibit certain forms of global cooperation by drawing climate change into the zero-sum mentality of national security. It might encourage Congress to authorize significant funds, a good thing in principle, but insofar as these funds are expended through the defense community, this may prove a costly and inefficient way of promoting adaptation, mitigation, and disaster response. It might encourage the government to conclude that extraordinary measures are acceptable to fight climate change—actions that could make many scientists, development specialists, social entrepreneurs, business leaders, and environmentalists uncomfortable.

Finally, a third concern has been expressed within the United Nations (UN), largely in response to efforts by the secretary general and by countries such as Germany to frame climate change as an issue that should be considered by the UN Security Council. On the one hand, this could give the five countries of the world that are permanent members of the Security Council—China, France, Russia, the United Kingdom, and the United States—enormous leverage over this issue, and not all of the other member countries are convinced that this would lead to good, fair, and effective outcomes. On the other hand, some countries in the UN, especially the G77 countries, think that it may prove to be in their long-term interest to have climate change framed as primarily a development issue rather than as a national or even global security issue. Such a frame could serve as the basis for lucrative compensation payments, development assistance, and special funds for adaptation and mitigation. In short, then, linking climate change and national security may compromise responses to the former, muddy the rationale of the latter, reinforce global inequities, and reduce development assistance as resources are transferred to humanitarian and military activities.

The second strand of argument has to do with the relationship between environmental stress and major outcomes such as violent conflict and state failure. Critics of this literature, such as Nils Petter Gleditsch and Marc Levy, point to its methodological and analytical weaknesses. To date, studies have been inconclusive. There appears to be a correlation between certain forms of environmental change, such as sudden changes in water availability, and violent conflict or state failure, but the findings are tentative and must compete with other variables that correlate nicely with disastrous social outcomes. Case studies are often quite persuasive, but they are in some sense easier to shape and their authors may be selecting for relationships that in fact are atypical.

Insofar as the case for integrating climate change and national security draws on arguments that environmental stress contributes to violent conflict and state failure, these skeptics emphasize that this literature is young and flawed by speculation. A frequent concern is that after the initial outburst of largely theoretical claims advanced in the 1990s, there has not been much progress in weeding through these claims and bolstering and clarifying those that are most promising from the perspective of empirical data. Moreover, very little has been done to estimate the extent to which environmental stress has generated effective positive responses such as innovation, adaptation, and cooperation. If for every Haiti there are a dozen Costa Ricas, then the alarm



DANIEL ZELLER, *Permeable Unit, 2006*.

In a note to the artist, Katy Börner made the following comment about this work: "Science grows from the first nitial scientific idea outwards in the all directions, forming a meteorite-shaped object. It might look a little bit like your *Permeable Unit, 2006*. The initial scientific idea is at the center. Each year, new papers are added that are interlinked to previous papers, creating tree-ring-like layers. Tubelike elements start anywhere between the center and the outer crust (today's knowledge) of science. They represent scientific fields that grow and shrink in size over time."

bells may be ringing too loudly.

Finally, the third strand of the case for integrating climate change and national security is rooted largely in the IPCC reports, and especially AR4, released in 2007. But although increases in the amount of carbon in the atmosphere, the severity of storms, the average global temperature, and so on are well documented, the social effects of these trends are far more speculative. Will climate change really tend to intensify the (possibly weak) relationships between environmental stress and national security? Even if it does, is securitizing these relationships wise, or should they be cast more explicitly in terms of humanitarian crises, global inequities, development challenges, population displacements, and poverty alleviation?

The Danish economist Bjorn Lomberg has been vocal in this arena, arguing that the environmental/climate security community underestimates the vast stocks of human ingenuity that are available to ease adaptation. Lomberg argues further that it is not at all clear that investments in climate change response are the best investments to make in terms of the safety and welfare of the human species. Here the idea of the fungibility of different forms of capital is relevant. If over the next 50 years we can make great gains per dollar invested in technologies that can be used for multiple purposes, and much smaller gains in terms of shifting the alarming global trend in carbon emissions, is the latter really a wise course of action? A large stock of technological capital, enabled by shrewd investments today, might be far more beneficial to the current poor and to all future generations than steps that marginally reduce greenhouse gas emissions or add small amounts of forest cover, or than steps that do much more along these lines but only by radically reducing investments elsewhere.

Action or lethargy?

The case for linking climate change and national security is robust but imperfect. This is partly because there remains considerable uncertainty about how climate change will play out in different social contexts and partly because the term national security is loaded with expectations and preferences that some analysts find worrisome.

If one finds the linkage persuasive, then there is much the United States can and should be doing on this front. For the past decade, innovation and response have taken place mainly at the state and city levels. Although this activity has in many ways been remarkable, it has not been uniform across the United States, and it connects poorly into larger global initiatives. In this latter regard, the United States has been particularly lethargic, a lethargy nourished by massive but not clearly successful investments in the war on terrorism and the financial bailout.

A few more years of lethargy could be detrimental to the United States in several ways. It could strengthen China, which has an enormous amount of capital to invest and is directing some of this into alternative energy and green technology—far more than the United States is. With or without climate change, the world's need for new sources of cheap and reliable energy is growing, and China is positioning itself for an emerging market that could be huge. Delaying might force the United States to contend with a considerably more robust multilateral framework for addressing climate change, a framework that it has not helped to design or synchronize with other multilateral institutions that it does support. Delaying could impose huge long-term costs on the U.S. economy, as it finds itself compelled to deal with water shortages, dust bowls, and hurricanes in an emergency mode. Katrina disabused everyone, except perhaps politicians and other government officials, of the notion that the nation is adequately prepared for the severe events that climate science predicts. Even if the United States does not increase its own vulnerability to megadisasters, inaction may not be cheap, as the country finds itself embroiled in costly humanitarian efforts abroad. And finally, in the worst-case scenario, lethargy might enable the sort of global catastrophe that climate scientists have described as possible. It is hard to imagine what competing investments of the nation's resources would warrant ignoring this issue.

So is climate change a national security issue? Climate

change is the most protean of science-based discourses, with an admixture of confidence and uncertainty that allows it to be integrated into any political agenda—from calls for sweeping reforms of the international system to those for more research and debate. Climate change does not mobilize agreement or clarify choices so much as engender reflection on the values we hold, the levels of risk we are comfortable assuming, the strengths and weaknesses of the institutions and practices that exist to meet our personal needs and allocate our shared resources, and the sort of world we want to bequeath to our children and grandchildren.

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Richard A. Matthew (rmatthew@uci.edu) is an associate professor in the Schools of Social Ecology and Social Science at the University of California, Irvine, and founding director of the Center for Unconventional Security Affairs (www.cusa.uci.edu).

LAWRENCE J. MAKOVICH

The Smart Grid

Separating Perception from Reality

Instead of a disruptive technology poised to transform the power sector in a decade, expect a more evolutionary change toward a "smarter" grid, with more modest results.

There is a widespread expectation in the United States and around the world today that the smart grid is the next big thing, a disruptive technology poised to transform the electric power sector. The belief is that the use of smart meters and other devices and systems will allow consumers to manage their own electricity use to radically reduce energy costs. The implementation of a smart grid system will enable the widespread use of renewable energy sources, allow more-distributed electricity generation, and help reduce carbon emissions.

The reality, however, is more complex and sobering. The smart grid idea is more accurately characterized as an extension of innovations that have been ongoing for decades. Change will continue but will be incremental because the technology is still evolving and because most consumers do not want the more flexible and uncertain pricing schemes that would replace the predictable and stable pricing of today's system. Indeed, it appears that most consumers, at least in the short term, will not benefit from moving to a smart grid system. Although a smart grid would probably help slow increases in electricity bills in the long run, it will not reduce them, because too many other factors will be pushing prices and power usage up in the years ahead.

The evidence from an IHS Cambridge Energy Research Associates study, which draws on the knowledge and experience of those closest to smart grid implementation, is that the smart grid "revolution" is off to a bumpy start and that there will be many more bumps in the road ahead. That road is still worth pursuing, but we will need to develop a more realistic understanding of how the electric power system in the United States is evolving. Instead of a demand-side–driven transformation of consumer behavior and the elimination of future capacity needs, expect a supply-side, engineering-driven application of smart grid technologies to improve network operation and reliability in the short term and to slow growth in generating capacity needs in the long

run. In many respects, we already have a smart grid in the United States. In coming decades, we will be moving to a "smarter" grid. The pace will be gradual, but the eventual benefits will be real.

The smart grid narrative

In the United States and other developed countries, an appealing and optimistic vision of the future smart grid has gained credence, even though the move toward a smarter grid is likely to turn out quite differently. In the current narrative, the United States and others are currently crippled by a balkanized "dumb" grid with endemic cascading failures, a result of continued reliance on antiquated, century-old technology. The solution is the smart grid: a continental-scale network of power lines incorporating advanced meters, sensing, and communication and control technologies that are linked through universal standards and protocols. It will be coordinated with advanced two-way broadband communication technologies that feed data into complex optimization software systems, allowing control technologies to deliver a more secure, self-healing, higher-quality, and lower-cost power network.

Smart grid deployment, the story continues, will dramatically reshape power use. The smart grid will present consumers with real-time power prices and displays of information regarding power use by specific end uses. These price signals and information streams will empower consumers to have more control over their power consumption. Consequently, the smart grid will alter consumer decisions either directly through behavioral changes or indirectly through preprogrammed smart appliances and control applications. As a result, market failures will be fixed and much of the low-hanging fruit of the efficiency gap will be harvested. These efficiency gains will provide enough savings to drive monthly power bills lower. In addition, the gains in reducing peak power demand will be more than enough to offset the baseline growth in power in the future. Consequently, the smart grid will eliminate the need to build conventional power plants in the years ahead.

The smart grid will also enable a transformation in power supply, the narrative says. Indeed, eventually the smart grid will allow renewable sources such as wind and solar to supplant traditional sources. The use of small-scale, distributed-generation resources will lead to a significant decarbonization of future power production. "Smart systems may well be mankind's best hope for dealing with pressing environmental problems, notably global warming," said the *Economist* in a November 6, 2010, special report.

The smart grid narrative also envisions a rapid increase in electric vehicles, which will generate power or act as batteries in the grid. In time, there will no longer be a need to build conventional power plants to deal with peak power periods because of the new distributed, small-scale power generation.

Finally, according to the current narrative, the pace of smart grid investment, including widespread installation of smart meters, demonstrates that smart grid technology is reliable, economical, and gaining enough momentum that the smart grid will be ubiquitous in power systems within a decade.

The above story about the smart grid has been repeated so often by industry leaders, technologists, and the media that is has taken on a life of its own. It is appealing because it reflects optimism that a disruptive technology can transform the power sector by solving problems that otherwise appear difficult and expensive to address with current technology, and that it can do so without downsides. But this vision is also too good to be true. In reality, forcing a technological transformation of the power sector through the deployment of smart grid technologies along with real-time power prices appears to be not only a formidable task but also not a very likely outcome any time soon.

Killer app?

Dynamic or real-time pricing, the ability to price electricity based on moment-to-moment changes in production costs, is expected to be the killer app of an emerging smart grid. The reality is that although some consumers can benefit from smart grid capabilities and dynamic pricing schemes, the majority cannot.

Real-time pricing is not a new idea. Economists have long considered the ability to use real-time prices that reflect the marginal cost of electricity at different times of the day as a more economically efficient way to price electricity. The Public Utility Regulatory Policy Act of 1978 encouraged utilities to use time-of-use–based rates to price electricity. Congress, in the Energy Policy Act of 2005, encouraged state regulators and utilities to shift from fixed rates to time-varied electric rates in order to increase energy efficiency and demand response.

But most consumers focus on their pocketbook rather than the theoretical basis of this supposedly more efficient pricing system. After all, the prospect of real-time pricing involves higher and more unpredictable prices; on an hour-to-hour basis, the marginal cost of electricity is hard to predict and can change by a factor of 100 during any given day. Research clearly indicates that most consumers far prefer the stable and predictable power pricing schemes they currently have.

Real-time power prices are usually higher than tradi-

Policy designed to support smart grid investments should avoid setting unrealistic expectations, especially the belief that smart grid programs will reduce power bills.

tional rates during peak periods and lower during off-peak periods. But most consumers use more electricity during peak periods than during off-peak periods. Thus, unless they can shift enough of their power use, typical consumers face a higher bill with a move to real-time pricing. Most consumers, according to research, doubt they can do this and expect that real-time pricing will increase their bills.

The residential consumers who are more supportive of dynamic pricing tend to be higher-income people with bigger homes who have more space to heat and to cool and more electric appliances. They are more likely to find an adequate payoff from investing in systems to manage this consumption across time and against dynamic prices. Pilot studies show that electric-intensive nonindustrial consumers respond favorably to enabling technologies such as programmable thermostats, price-alert mechanisms, or direct-load controls. In contrast, consumers with smaller homes and fewer electric appliances generally have less flexibility in shifting their power use. It is not surprising that consumer participation rates in dynamic pricing programs have usually been extremely low.

Participation in almost all dynamic pricing programs in the United States has been voluntary. Currently, time-of-use rates are offered by more than half of investor-owned utilities. Many of these programs have been offered for years, and in some cases decades. The average participation rate in such programs is estimated at 1%.

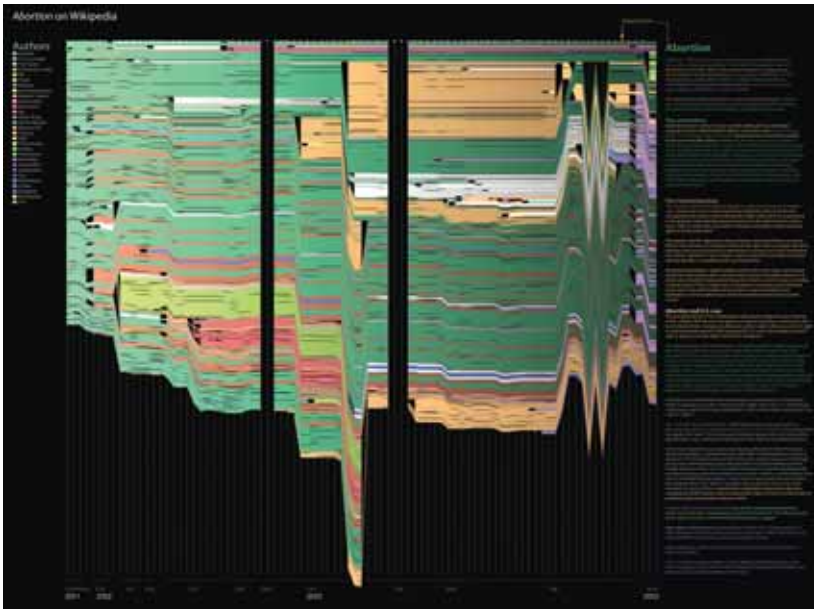
Participation in programs in Illinois is typical. Commonwealth Edison ran a residential real-time pricing pilot program from 2003 to 2006, and for the past four years has made it available to all of its residential consumers. A neighboring utility, Ameren, has a similar program. As of September 2010, Ameren Illinois and Commonwealth Edison each had about 10,000 participating customers, representing 1% and 0.3% respectively of their eligible consumers. In the eastern United States, Baltimore Gas and Electric made time-of-use rates available to residential consumers for several years, but only 6% of residential consumers opted to participate.

Arizona provides an example of how the characteristics of the customer base affect the outcomes. Consumers there tend to be more electric-intensive because of above-average cooling loads. In addition, the nature of these loads provides greater-than-average flexibility in the time pattern of electric use and thus a higher-than-average probability that shifting power use could lower a consumer power bill. The Salt River Project and Arizona Public Service (APS) have about half of their customers on a dynamic pricing scheme. APS offers four time-of-use rates to customers. A 2010 analysis of two of the rates indicated that customers saved 21% on their electricity bills as compared to being on a flat rate.

The same economic logic that helps to understand the Arizona versus Illinois results also applies to nonresidential consumers. Some industrial and commercial consumers find that power bills make up a large percentage of their operating costs. They also have the flexibility to alter their consumption pattern and can thus benefit from dynamic pricing schemes. Still, it appears that only a minority of nonresidential consumers can benefit from dynamic pricing. For example, although Georgia Power runs one of the most successful real-time pricing programs in the country, it has signed up only 20% of its largest commercial and industrial customers.

Even for large nonresidential consumers, switching to real-time pricing does not guarantee lower prices. Indeed, many face higher power bills, according to research by Severin Borenstein in a September 2005 National Bureau of Economic Research working paper. In a four-year study of 1,142 large industrial and commercial customers in Northern California, Borenstein found that holding all else constant, about 55% would see their bills rise under real-time pricing. He estimated that most customers would see their bills rise or fall by less than 10%, with more variability in their monthly payments.

A majority of power customers are not clamoring for access to dynamic pricing. So what explains the enthusiasm expressed by many who have participated in smart grid pilot projects? First and foremost is the fact that the programs have been voluntary. As a result, participants are self-selected members of a small set of the population who are in-



History Flow Visualization of the Wikipedia Entry "Abortion"

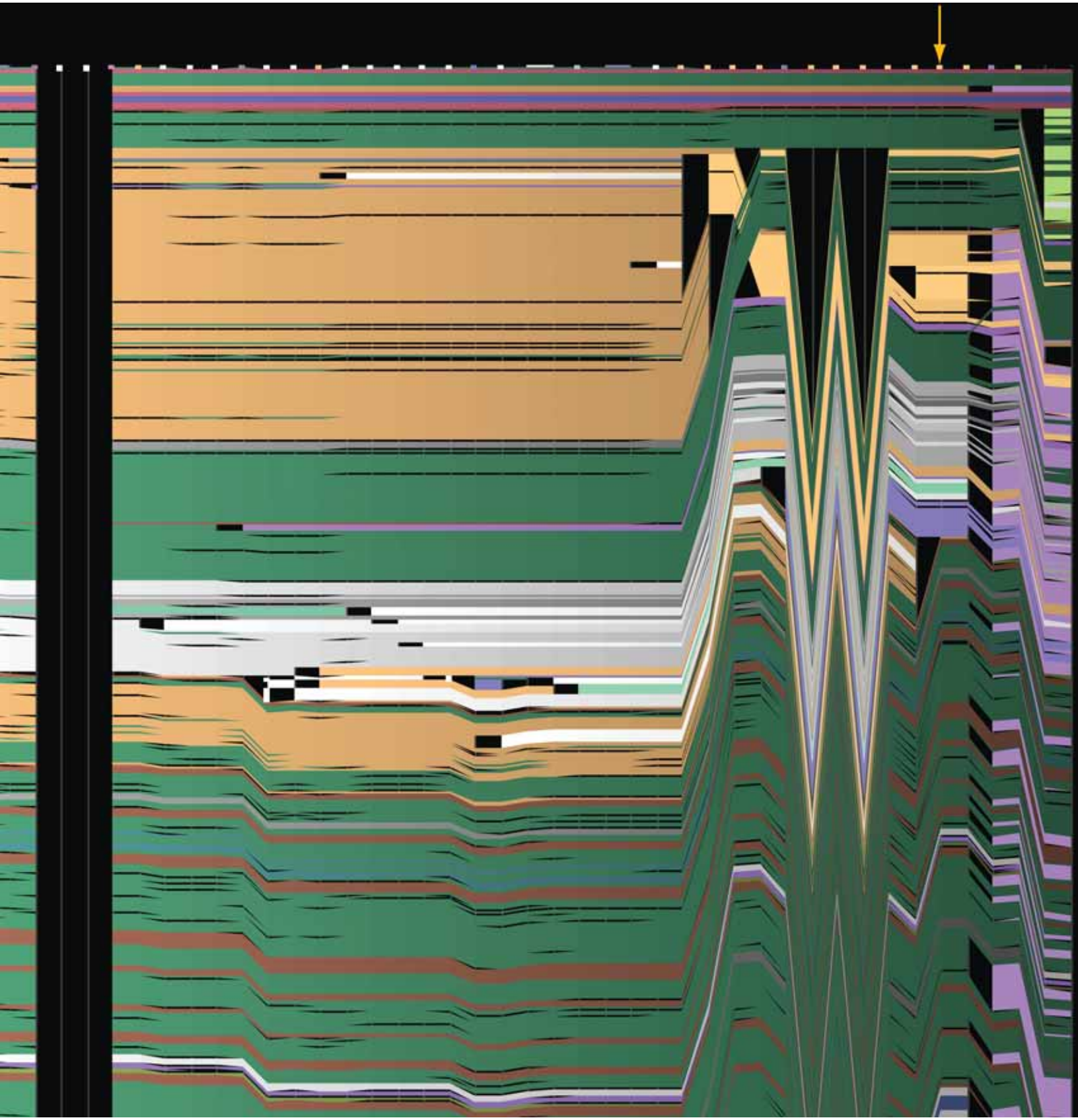
Martin Wattenberg and Fernanda B. Viégas, 2006

AIM

The History Flow visualization technique aims to chart the evolution of a document as it is edited by many people. It shows broad trends in revision histories while preserving details for closer examination. It is here applied to show the evolution of Wikipedia entries created by people all over the world. It might also be useful to study other collaborative situations, such as patterns of communication, conflict, and contributions in large-scale software development.

INTERPRETATION

This map shows the edit history of the Wikipedia entry "Abortion." The left column lists all authors who contributed to the entry with their assigned color codes. The right column shows the final version of the entry as of April 20, 2003, at 5:32 pm. The text is color-coded according to the author of the final edit. The middle column gives the History Flow visualization. Each vertical line represents a version of the entry— from December 2001 to June 2003. The total length of the line reflects the length of the entry. Line color-coding indicates which author has edited which part(s) of the text. White to gray represent the contributions of anonymous authors. Entry versions are sorted in time, from left to right. As can be seen, the page has gone through many changes over time. Note that the entry survived two complete deletions that happened in December 2002 and in February 2003. *Courtesy of Martin Wattenberg, Fernanda B. Viégas, and IBM Research.*



clined to try a new technology because they like experimenting with innovations. But self-selection bias can make pilot-project results unreliable as an indicator of how the larger population is likely to react to the new technology. It is risky to assume that if other consumers were to learn about these programs or were required to participate, they would end up loving them too. Mandatory participation could also lead to a backlash and derail any significant implementation of the technology.

Indeed, a bit of a backlash has already occurred. Many smart grid initiatives are going forward without any dynamic pricing schemes and those that do use dynamic prices employ highly muted price signals. Currently, there are no real-time pricing mandates for small customers (residential or small commercial) anywhere in the United States. This outcome of the regulatory process aligns with lessons from the past. The Maine Public Utility Commission mandated time-of-use rates for large-use residential consumers during the late 1980s, and the state of Washington mandated such rates for 300,000 residential consumers served by Puget Sound Energy in 2001. But in both cases most consumers were not able to shift enough usage to lower their electric bills, and the programs were eliminated within two years. In addition, these consumer preferences often translate into laws and regulations. California passed a law prohibiting dynamic pricing for residential customers, and New York imposed restrictions on the use of such pricing.

Many states, however, have recognized that some residential customers have the flexibility in power use to benefit from dynamic pricing and have required utilities to install a smart meter at the customer's request. As expected, only a minority of consumers have requested the meters. Also as expected, these consumers are primarily large industrial firms. However, even for larger consumers, the offerings typically involve dampened price signals that fall far short of real dynamic pricing.

In addition to lackluster consumer demand, there have also been bumps on the supply side, as utilities have struggled to install the equipment and systems needed to make the smart grid work. There have been notable examples of technology problems and cost overruns, indicating that smart grid technologies and their optimal technical configurations are not yet proven and fully commercially available.

- In Boulder, Colorado, Xcel Energy's costs to implement a smart grid program have soared from an estimated $15.2 million in 2008 to $42.1 million in February 2010.
- In Texas, Oncor Electric Delivery Company installed smart meters that later turned out not to comply with the standards set by the Public Utilities Commission of Texas. Oncor was subsequently allowed to recover $686 million from customers to install meters incorporating the new standards, as well as recover the $93 million cost of obsolete smart meters that were never installed.
- In California, the communication system included in the original smart meter deployment at Pacific Gas and Electric Company (PG&E) turned out to be incompatible with the communication and control needs of the evolving smart grid applications. PG&E was allowed to increase prices to recover almost $1 billion of associated costs. In addition, in November of 2009, PG&E was forced to temporarily stop deploying smart meters in Bakersfield, California—part of its $2.2 billion, 10-million smart meter deployment program—because of consumer complaints and lawsuits concerning perceptions of billing errors. Although these perceptions turned out to be wrong, the backlash illustrates the problem of attempting to roll out the smart grid program at the same time that power prices were increasing.
- In Maryland, the public service commission refused Pepco's request to implement one form of dynamic pricing, even on an opt-in basis, because it considered the risk too great that customers would opt into the system with the expectation of lower bills only to find that, at least initially, the new rate would result in higher bills.
- Also in Maryland, after consumer advocates challenged the cost/benefit analysis of Baltimore Gas and Electric's (BG&E's) smart grid initiative, the company's request for rate recovery of the $835 million cost of its smart grid meter deployment plan was initially denied. The state Public Service Commission (PUC) ruled against BG&E even though the company had received a $136 million grant from the U.S. Department of Energy to help fund the project. The PUC found that, "The Proposal asks BG&E's ratepayers to take significant financial and technological risks and adapt to categorical changes in rate design, all in exchange for savings that are largely indirect, highly contingent and a long way off." In rejecting the proposal, the PUC also noted that the cost estimate did not include the approximately $100 million in not-yet-depreciated value of existing meters that would be retired before the end of their useful lives.

As the above examples make clear, the direct benefits of smart grid investments have not yet proven certain or significant enough to fully offset the costs of implementation. The implication is clear: The United States is not moving to a rapid full-scale deployment of smart grid technologies and systems anytime soon. Future implementation is likely to be phased in by customer segments and be geographically uneven and far from complete in one decade.

One way to manage expectations is to stop using the term smart grid because it implies a disruptive technology investment and instead portray the evolution toward a smarter grid as just business-as-usual grid automation and modernization.

A more realistic outlook

A more realistic vision of the future begins with the recognition that the smart grid is an incremental technology trend well under way rather than a disruptive technology that will transform the power sector in the next decade. The evolution toward a smarter grid has been taking place for several decades, as the power sector has incorporated available and emerging monitoring, automation, and control and communications technologies into the grid in varying degrees. These developments have already produced tangible gains: reduced costs for metering and for service connections and disconnections, as well as improved detection and isolation of problems during power outages and faster restoration of power. These gains in security and reliability have thus far reinforced the traditional grid and large central station power system rather than created economic forces pushing toward a distributed supply structure. As a result of these changes, it is inaccurate to think of the U.S. system as having a dumb grid that technology is poised to transform into a smart grid. Instead, smart technologies are already adding another layer of visibility to the condition and operation of the grid and also adding another layer of reliability by enhancing the capabilities needed to predict potential instabilities in the system. In short, the evolution to a smarter grid is helping to maintain and improve the high levels of reliability to which consumers have become accustomed.

The evolving smart grid will allow more experiments with various dynamic pricing schemes, but they should be experiments, and they must be gradually introduced or face a possible backlash from consumers, who mostly cannot benefit from dynamic pricing and value the stable and predictable prices of the current system. As dynamic pricing schemes evolve in the years ahead, they will mostly be used by larger, electric-intensive consumers who have the capability and the money to invest in and manage the new systems.

Investment in smart grid technologies in the years ahead will depend to some degree on the political tolerance for increases in power prices, because developing a smarter grid is not likely to reduce bills, for two reasons: First, the percentage increase in prices will probably not be offset by a larger reduction in electricity use enabled by the smart grid. Second, smart grid implementation is occurring during a period of rising real power prices. Even if smart grid savings could offset costs, there are other factors that are continuing to push prices up. As a result, the case for smart grid investments will involve a different expectation: that although power prices are increasing, prices are going to be lower than they otherwise would have been but for the smart grid investments. This is a harder argument to demonstrate and thus a weaker driver for smart grid investment than the straightforward guarantee of a lower power bill.

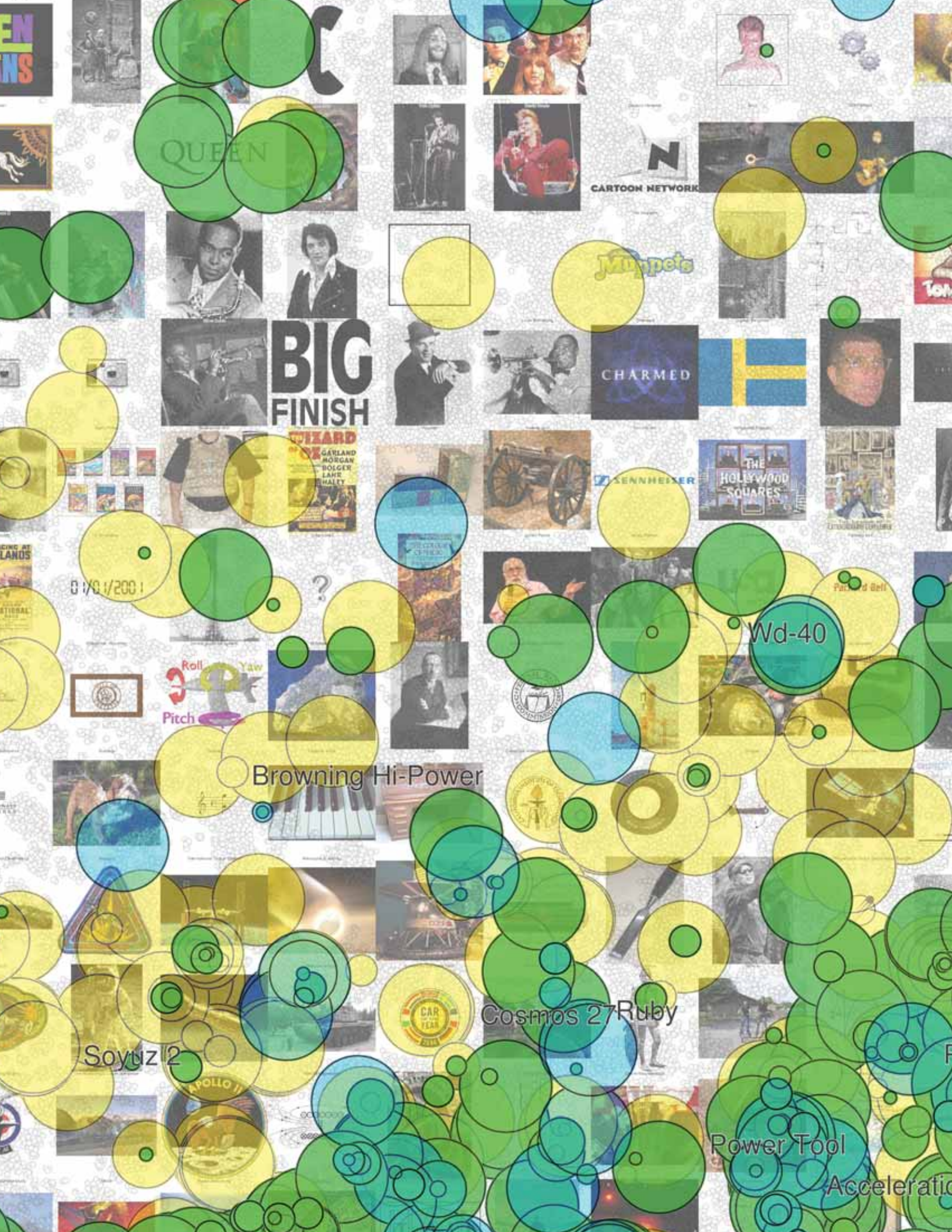
The evolution of smart grid technologies could allow the introduction of meaningful numbers of electric vehicles, but this process, too, will be slow. The big hope is that electric vehicles can act as roving batteries to the grid, thus reducing the need for new system capacity. But this outcome is unlikely anytime soon, because current electric batteries are technically not well suited to power system storage and their prices are extremely high. Still, effective coordination of smart grid policy and policy support for electric vehicles could help accelerate smart grid development.

Smart grid implementation is also not likely to reduce energy use enough to provide meaningful greenhouse gas emissions reductions. The reason is that the primary link between the smart grid and greenhouse gas emissions is not within the power sector—enabling renewable power or reducing demand—but rather outside the power sector by enabling the use of electric vehicles, something that adds rather than detracts from power usage.

Finally, the pace of smart grid implementation will probably be slowed by consumer privacy and cybersecurity concerns. Many privacy advocates are concerned that smart grid data could provide a detailed profile of consumer behavior.

Policy implications

Policy designed to support smart grid investments should avoid setting unrealistic expectations, especially the belief that smart grid programs will reduce power bills. The long-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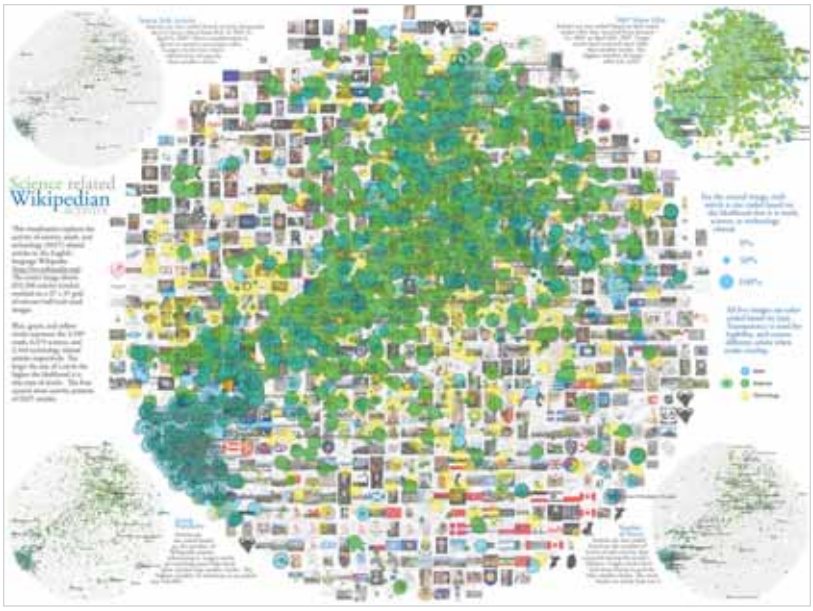


Science-Related Wikipedian Activity

Bruce W. Herr II, Todd M. Holloway, Elisha F. Hardy, Kevin W. Boyack, and Katy Börner, 2007

AIM

Wikipedia (http://wikipedia.org), created in 2001 by Jimmy Wales, is growing fast. In 2007, it included 7.4 million articles in more than 250 languages. About 9,700 new articles were added every day. The English Wikipedia had more than 276,000 contributors. According to the Alexa Web-ranking service, Wikipedia was the 37th most visited Web site. While the structure of editorially controlled encyclopedias like Encyclopaedia Britannica or MSN Encarta is well known, nobody has ever seen the evolving structure of Wikipedia. What major areas does it cover? How much of the content relates to math, science, and technology? How are those areas interlinked? Which topics are growing, declining, merging, or splitting, and how fast? The activity of the thousands of Wikipedians might be even more interesting: What are the hot, most discussed articles? Are today's bursts of editing and linking activity an indicator for tomorrow's growth?

INTERPRETATION

This map shows the structure and activity patterns of 659,388 articles in the English Wikipedia, based on a network constructed in early 2005 and full history data from April 2, 2007. In the middle is a base map of all English Wikipedia articles, each represented by a small gray circle. A 37 x 37 half-inch (about 1.2 centimeters) grid was overlaid, and a relevant image was downloaded for each grid area and rendered underneath the network of articles. The data overlay consists of articles tagged as Math, Science, and Technology—drawn as blue, green, and yellow dots respectively. The sizes of the dots represent the certainty that these articles are in fact related to one of the three categories. The top 150 math, science, and technology articles are labeled by title.

The four corners show smaller versions of the base map with articles size-coded according to the Article Edit Activity (top left), number of Major Edits made in 2007 (top right), Number of Bursts in edit activity (bottom right), and the Article Popularity, measured by the number of times other articles link to it (bottom left). These visualizations serve to highlight current trends, predict future editing activity, and estimate potential increase in Wikipedia articles related to math, science, and technology. *Courtesy of Indiana University.*

run success of smart grid policies hinges on delivering what has been promised. Policies that fail to meet expectations will lead to disappointment, a search for a scapegoat, and a political backlash that will impede progress in the years ahead. One way to manage expectations is to stop using the term smart grid because it implies a disruptive technology investment. It would be wiser and more accurate to speak of the evolution toward a smarter grid as just business-as-usual grid automation and modernization.

The smarter grid rollout should start first with consumers that meet the profile of those most likely to benefit from smart grid programs: electric-intensive consumers with significant flexibility in their use of power over time. Because customer characteristics, particularly the flexibility to cost-effectively shift power use, are so varied from one place to the next, we can expect the implementation of smart grid capabilities to be geographically uneven.

The pace of implementation, especially of dynamic pricing schemes, should be phased in based on the political tolerance of consumers for power price increases. The move to real-time prices should begin with mildly time-differentiated prices that move gradually toward real-time price signals over the long run. Education of consumers will be necessary, but policymakers must recognize the limits of education in divorcing consumer preferences from underlying pocketbook issues.

A significant role remains for smart grid pilot projects to manage the technology risk associated with the evolving smart grid, although policymakers need to recognize the limits on generalizing the results of these projects. The focus for pilot programs should expand from testing dynamic pricing schemes to experimenting with new applications for smart grid capabilities.

In sum, by resetting our expectations and taking modest, gradual steps forward, we can eventually move toward a more robust, smarter power grid in the United States.

Lawrence J. Makovich (larry.makovich@ihs.com) is vice president and senior advisor, Global Power Group, at IHS Cambridge Energy Research Associates (IHS CERA) in Cambridge, MA, and directs the firm's research efforts in the power sector.

GWEN OTTINGER
with RACHEL ZURER

Drowning in Data

Monitoring the chemical content of the air near chemical plants provides valuable data, but it becomes useful only when it is paired with epidemiological data about the local population.

I was at the most undignified moment of moving into my new office—barefoot and on tiptoes on my desk, arranging books on a high shelf—when one of my fellow professors at the University of Washington–Bothell walked in to introduce himself. Pulling my shirt firmly over my waistband, I clambered down to shake his hand and exchange the vital information that begins academic acquaintanceships: Where had I come from? What kind of research did I do?

I felt my shoulders tense, bracing for the question I knew was probably coming next. I explained that I studied communities living next to oil refineries, especially how residents and refinery experts make claims about the effects of chemical emissions on people's health. My colleague replied with what I'd been hoping he wouldn't: "But is it really the emissions from the refineries that are making those people sick?"

An important question, to be sure—essential, even, to policymakers deciding how refineries and petrochemical plants ought to be sited and regulated. So it's hardly a surprise that in the decade since I started my research, I've been asked The Question scores of times, in settings that range from conference presentations to New Orleans dive bars. Yet it's a vexed question, and I have always been frustrated and often struck dumb with my inability to answer it. "There's a lot of controversy over that," I explained to my colleague in my best anthropologist-of-science manner. "The truth is that we don't really know enough to say for sure."

But as I returned to the solitary work of shelving books, I sought refuge in a place that had recently become my favorite environmental fantasy: A brown, windswept hill at the edge of a refinery in the San Francisco Bay area, topped by a small white trailer the size of a backyard tool shed. In my imagination, the trailer glows in the California sun as the state-of-the-art monitoring instruments inside it hum and flash, measuring minute by minute what's in the air. In my imagination, a cadre of scientists peers at computer screens to turn these data into a more satisfying answer to The Question, an answer that matches real-time chemical concentrations with the health concerns of people living nearby.

My fantasy is set in a real place, though I've never seen it. The hill of my imagination overlooks the town of Benicia, a bedroom community of 30,000, where people who drive tight-lipped to San Francisco jobs all week stroll past the antique shops to First Street for scones and lattes on Saturday morning. It's a charming place, yet Benicia's industrial past persists; a slim smokestack pokes up like a flagpole beyond the trailer, its white plume meandering off toward the Carquinez Strait. Benicia is home to one of the 150 or so oil

These "fenceline communities" are places where people cough. Where they carry asthma inhalers. Where every resident has a handful of neighbors who have died of cancer. Where refinery and government officials insist that chemicals in the air don't harm them, and residents are sure that they know better.

refineries that feed the nation's appetite for energy. Less than a mile from downtown, an Oz of tanks and towers on 800 acres churns away day and night, turning up to 170,000 barrels of oil per day into gasoline, asphalt, jet fuel, and other petroleum products. The Valero facility is the town's biggest employer and the major denizen of Benicia's industrial park. The trailer sits on its southern edge.

Most of the communities I have studied are clustered in the South and are smaller, poorer, and more economically dependent on their refineries than is Benicia. For them, the trailer and the data it offers are even more urgent than they are for Benicia residents. These "fenceline communities" are places where people cough. Where they carry asthma inhalers. Where every resident has a handful of neighbors who have died of cancer. Where refinery and government officials insist that chemicals in the air don't harm them, and residents are sure that they know better. These communities are places where conflict lingers in the air along with the smell of sulfur.

Data that can show how chemical exposures are related to health symptoms could help these communities. It could suggest the kinds of protection they need, could show the real extent of emissions reductions necessary on the part of the refineries, could point the way to improved environmental policies. In my mind, Benicia's trailer gleams with the possibility of new knowledge that helps everyone.

But a few weeks after my colleague's visit, my hopes for the trailer dimmed. As I was putting the finishing touches on a syllabus in my office, by now already messy, the phone rang. It was Don Gamiles, an engineer whose company installed Benicia's trailer. He had been excited about the project in Benicia from the time he first mentioned it to me earlier in the summer.

Gamiles has been involved in air monitoring since the aftermath of the Persian Gulf War, when he ran equipment to detect potential poison gas releases during United Nations inspections of Iraqi facilities. He's invented two instruments that can measure concentrations of toxic gases in real time, both of which are part of the suite of monitors that he pulled together for the trailer in Benicia. But these days, Gamiles's business really centers on mediating conflicts between facilities that release those gases and neighboring communities concerned about them. Affable and unassuming in his characteristic polo shirt and khakis, Gamiles works with both sides to design and install suites of monitors, like the one in Benicia, that incorporate his instruments and produce solid data about what's in the air so that neither side can exaggerate. "Everyone's a little bit right," he says. "The refinery guys tend to over-trivialize what's coming out. But communities want to make them the villain."

Though he's been involved in other projects (one major refiner is even talking about making Gamiles's monitors a standard part of their environmental best practices), the Benicia project is what Gamiles raves about: "The sampling station's the best in the world," he said, reminding me that it can monitor hydrogen sulfide, black carbon, and particulates in addition to hazardous air pollutants such as benzene, xylene, and toluene, all for a very reasonable price tag. And the best part: "Everybody's happy!" He chuckled and I imagined his self-effacing grin. "This is a model of how to do things right."

"There's just this one sticking point," he added. He'd called to ask for my help. The refinery and the community group that pushed for the monitors were having trouble figuring out how to present the data. If the monitors detected chemicals, how could they best explain what that meant to someone looking at that data on a public Web site?

The refinery, it seemed, wanted to avoid alarmism and irate hordes at their gates; on the other hand, it was in no one's interest if they swept real risks under the rug. "Everybody has a valid point," Gamiles said. "What would be helpful to have is a listing of standards for all of this stuff"—all of the chemicals that the monitoring station could be detecting, starting with benzene, toluene, xylene, and sulfur dioxide. Could I work with a student to put together a list?

My heart sank. Here was The Question again, in a more nuanced form. Gamiles was asking, "At what exposure levels do emissions from refineries make people sick?" Worse,

this wasn't the first time I'd been asked to take stock of the available information, and what I'd found the last time had driven me to my fantasies of fancy new monitors in the first place.

Buckets of data

In the summer of 2001, I was halfway through my 20s and a Ph.D. program when I walked into the Oakland, California, offices of a nonprofit organization called Communities for a Better Environment (CBE). After years with my nose in a book, I was dying to do something "real" and antsy about finding a focus for my thesis project. I hoped that interning for CBE, whose lawyers, scientists, and organizers worked with Northern California communities to advocate for environmental justice, might address both problems at once.

No one was at the reception desk, so I hung by the door, fingering pamphlets and newsletters announcing the organization's latest successes, including its work helping refinery-adjacent communities establish "bucket brigades" to monitor air quality with do-it-yourself air samplers made from hardware store supplies. Eventually someone bustled past and directed me to the Science Department at the end of one of the office's warren-like hallways.

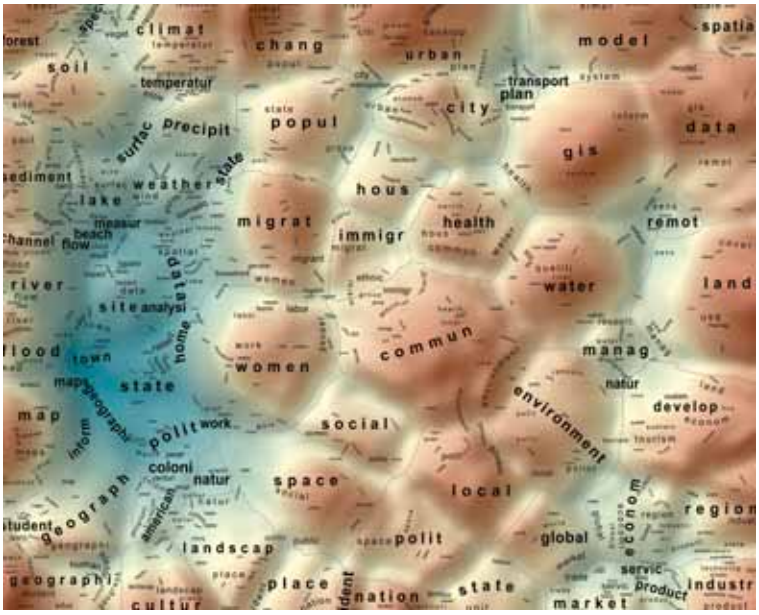
My first assignment seemed simple enough: Communities were getting data with their bucket samples, but they were having a hard time saying what the numbers meant. My job was to compile a list of the state and federal air standards for different chemicals that might show up in a bucket sample. The list would be like a yardstick that citizens could use to put air quality readings in perspective, showing how the numbers measured up to the thick black line that separated "safe" from "dangerous."

As a starting place, my supervisor handed me a second-generation photocopy of a fax containing a table of numbers. The fax was from Wilma Subra, a MacArthur "genius grant"–winning chemist and legend among refinery-adjacent communities in Louisiana. Subra's document listed "levels of concern"; specifically, the regulatory standards set by Louisiana and nonenforceable "screening level" recommendations from the neighboring state of Texas. I was to expand the table, adding comparable standards from other agencies, to give bucket users a straightforward way to know when the concentrations they measured were cause for alarm.

Squinting at a computer screen from the corner of a borrowed desk, navigating through one agency Web page after another in search of air quality standards, I had no problem adding columns to Subra's chart. Agencies such as the Louisiana Department of Environmental Quality (LDEQ), its counterparts in Texas and North Carolina, and the American Toxic Substances and Disease Registry set standards or made recommendations for acceptable ambient air levels of individual chemicals. But each included only a subset of the chemicals I was looking for. The federal Clean Air Act, for example, set limits on total volatile organic compounds, a category that includes these chemicals, but not on the individual air toxins under that umbrella, such as benzene, toluene, and xylene: monoaromatic hydrocarbons known or suspected to cause cancer.

As the table grew, I was surprised to find that there was no consensus on what constituted a safe or permissible level for any of the chemicals. Even after I'd converted the disparate standards into a common unit of measurement, reading across any one row (for benzene, say, or hydrogen sulfide), there were numbers in the single digits, in the double digits, decimal numbers. The lack of consensus was apparent even in the table's header row: One agency set limits on 8-hour average levels, the next on annual averages, the next on 24-hour averages. There didn't even seem to be agreement on what period was most appropriate for any given chemical. I didn't have a single yardstick; I had several of them, each for a different kind of measurement, each with multiple black lines. How would this help anyone figure out what chemical concentrations they should worry about?

At my boss's urging, I made some phone calls to find out how the agencies could arrive at such different standards. A scientist at the LDEQ explained that his agency used occupational health studies—studies of how workers were affected by the chemicals—and multiplied the results by a



In Terms of Geography

André Skupin, 2005

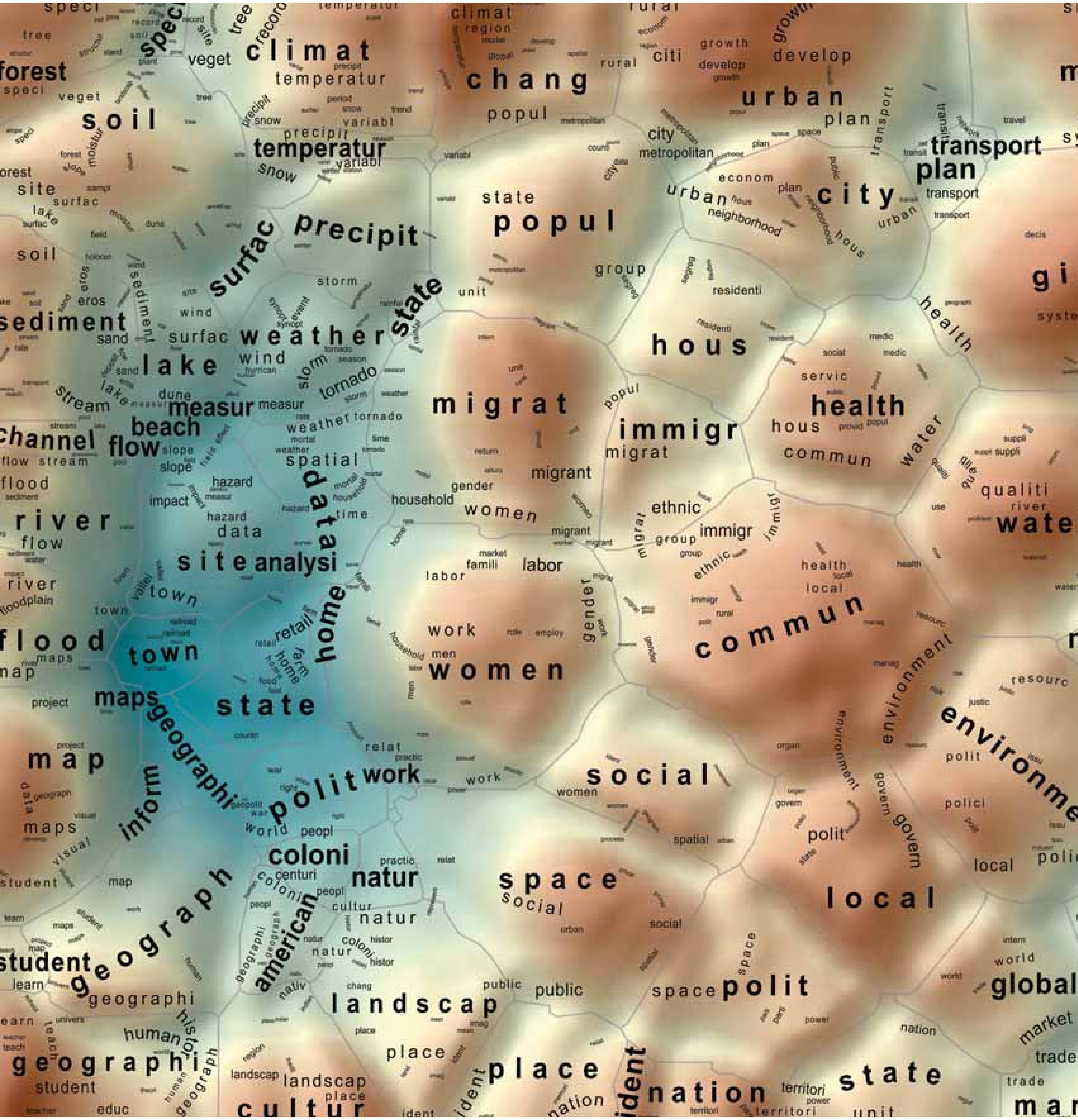
AIM

Many areas of research are extensive in terms of data, published works, scholarly expertise, and practice. Social and intellectual interrelations are highly complex. How can we gain access to broad, global structures of whole research domains as well as to finer, regional, and local structures within subdisciplines? How can we understand major areas, existing and nonexisting connections, and the homogeneity of subareas? Skupin seeks to understand how cartographic design and geographic technology can be applied to map not only geographic space but also abstract semantic spaces.

INTERPRETATION

The map shows the content coverage of geography research for the 10-year period from 1993 to 2002. It was generated from more than 22,000 abstracts submitted to the annual meetings of the Association of American Geographers. Mountains represent areas of higher topical focus, with word stems serving as labels. Community studies are most dominant in the middle of the map. Soil, climate, population, migration, women, social, and health are other major areas of study. Valleys represent regions with less topical focus. One can think of these as capturing information sediments from the surrounding mountains, leading to a mixture of topics. For example, nature and management are valleys surrounded by the major mountains of water, land, development, and environment.

Notice how the arrangement of labeled mountains and valleys replicates major global subdivisions of the geographic knowledge domain. The upper left corner contains topics associated with physical geography, while the upper right corner—including GIS, model, spatial, and data—covers the area now known as geographic information science. Much of the remainder of the map reflects various topics investigated within human geography, including such further subdivisions as economic geography in the lower right corner. Conversely, smaller topical structures within the major mountains are visible, such as the cover and use regions of the land mountain, which reflect documents containing the phrases "land cover" and "land use." *Courtesy of André Skupin.*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scaling factor. I remembered the number from my graduate class in risk analysis: it adjusted risk levels based on 8-hour-a-day, 5-day-a-week worker exposures to numbers appropriate for populations such as people living near refineries that could be exposed to the same chemicals for as much as 24 hours a day, 7 days a week.

A Texas regulator, in contrast, told me that her agency based its recommendations mostly on laboratory studies. I knew about this process from my class, too. Groups of mice or rats or other small animals would be exposed to varying levels of a chemical to determine the highest dose at which the animals didn't appear to suffer any adverse health effects. The agency scientist would have looked at a number of different studies, some of them with incompatible results, made a judgment about which numbers to use, then applied a safety factor in case human populations were more sensitive to the chemical than other mammals. But what neither she nor her counterpart in Louisiana had to work with were studies of what these chemicals did to people who breathed lots of them at a time, in low doses, every day.

In the end, digging into the standards and learning how incomplete and uncertain they were convinced me that we don't really have a good answer about exactly what the chemical levels mean for health. Anyone who professes to know with certainty is operating as much on belief as on data. So by the time Don Gamiles asked me, nine years later, if I could assemble the standards for the chemical that his shiny new monitoring station was detecting, I wanted to tell him that all he was going to get was a whole bunch of yardsticks. What he needed was an additional stream of data, health data that could put chemical concentrations in the context of real people's experiences and, over time, help put those standards on a firmer footing.

But Gamiles is an engineer, not an epidemiologist. I knew that his contract would not have funding for what I was proposing. And explicitly mentioning the health concerns wasn't likely to help Gamiles maintain the collegiality between the Valero refinery and its neighbors in Benicia.

I took a deep breath and agreed to look for a student who would investigate the standards. Maybe, I told myself, if we could show Gamiles and the engineers at Valero the uncertainties in the standards, we could start a richer conversation about what the data coming from the new monitoring station meant, and how to figure it out.

Having that conversation, or at least trying to, seemed especially important since more and more refineries, especially in environmentally conscious parts of the country such as the San Francisco Bay area, have been seeking Gamiles's services, installing their own monitors before an increasingly vigilant Environmental Protection Agency (EPA) can require them to. And yet part of me knew that imagining I could get refiners and communities to talk about the issue was overly optimistic, if not downright naïve. I already knew that petrochemical companies weren't troubled by the limitations of the standards. In fact, years earlier in Louisiana, I'd seen how they use those very uncertainties and omissions to their advantage.

The lowdown in Louisiana

Many of the air monitors in the trailer in Benicia hadn't yet been developed when Margie Richard decided to take on the Shell Chemical plant across the street from her home in Norco, Louisiana, in the late 1980s. But what was in the air, and what it could do to a person's health, were very much on her mind.

Richard's front windows looked out on an industrial panorama: tall metal cylinders and giant gleaming spheres connected by mazes of pipes, all part of the processes that turn crude oil into gasoline, ethylene, propylene, and industrial solvents. Half a mile away, at the other edge of the 3,700-person town, an oil refinery loomed. On good days, a faint smell of motor oil mixed with rotten eggs hung in the air; on bad days, chemical odors took Richard's breath away.

Throughout Richard's eight-square-block neighborhood of Diamond, the historic home of Norco's African-American population, people were getting sick. Richard's young grandson had asthma attacks that landed him in the emergency room on more than one occasion. Two streets over, Iris Carter's sister died in her forties of a disease that doctors told the family they only ever saw in people living near industrial facilities.

Barely five feet tall and bursting with energy even in her early sixties, Richard led her neighborhood in confronting Shell about its plant's ill effects. Every Tuesday afternoon, she and a few other women with picket signs walked up and down the far side of her street, in front of the chain link fence that separated Shell from the community, demanding that representatives from the company meet with residents to discuss a neighborhood relocation. Concerned about their health and safety, she and other residents wanted out.

By 1998, Richard and her neighbors finally started to get some quantitative data to support their claims that Shell's emissions were making them sick. Denny Larson, then an organizer with CBE in Oakland, arrived with buckets. With the low-tech air sampler—little more than a five-gallon plastic paint bucket with a sealed lid and a special bag inside—Richard documented an incident at Shell Chemical that emitted potentially dangerous concentrations of an indus-

trial solvent called methyl ethyl ketone (MEK). She also gathered evidence that residents of her community were exposed to toxic chemicals when odors were inexplicably bad, and even personally presented a high-ranking Shell official with a bag of air from her community at a shareholder's meeting in the Netherlands.

In 2002, Richard and her group triumphed. Shell agreed to buy out any Diamond residents who wanted to leave. But Richard had succeeded in more than winning relocation. She had also put air monitoring on Shell's agenda, where it had not previously been. That fall, even as families in Diamond were loading moving vans and watching bare ground emerge where their neighborhood had been, Shell Chemical and its Norco counterpart, Motiva Refining, launched their Air Monitoring…Norco program.

Good neighbors

One muggy September afternoon, I picked up a visitor's badge at the guardhouse at Shell Chemical's East Site and made my way to the company's main office building. The rambling, two-story beige-and-brown box could have been in any office park in suburban America, except that in place of manicured gardens and artificial lakes, it was surrounded by distillation towers and cracking units.

David Brignac, manager of Shell's Good Neighbor Initiative, which was overseeing the Air Monitoring…Norco program, greeted me with a boyish grin and a slight Louisiana drawl and led me upstairs to his roomy office. We sat at a small round table with Randy Armstrong, the good-natured but no-nonsense Midwesterner in charge of health, safety, and environment for Shell Norco.

Brignac walked me through a printed-out PowerPoint presentation: Surveys showed that Norco residents thought that there were dangerous chemicals in the air and that they had an impact on people's health. Air Monitoring…Norco sought hard data about what really was in the air.

Scribbling frantically on a legal pad, I noted what he left out as well as what he said. There was no mention of the bucket samples; no suggestion that Shell's decision to relocate Diamond residents may have fueled the perception that the air was somehow tainted; no hint at the regulatory enforcement action, taken in the wake of the MEK release, that required a "beneficial environmental project" of Shell; in short, there was no acknowledgement that the monitoring never would have happened if not for the Diamond community's activism.

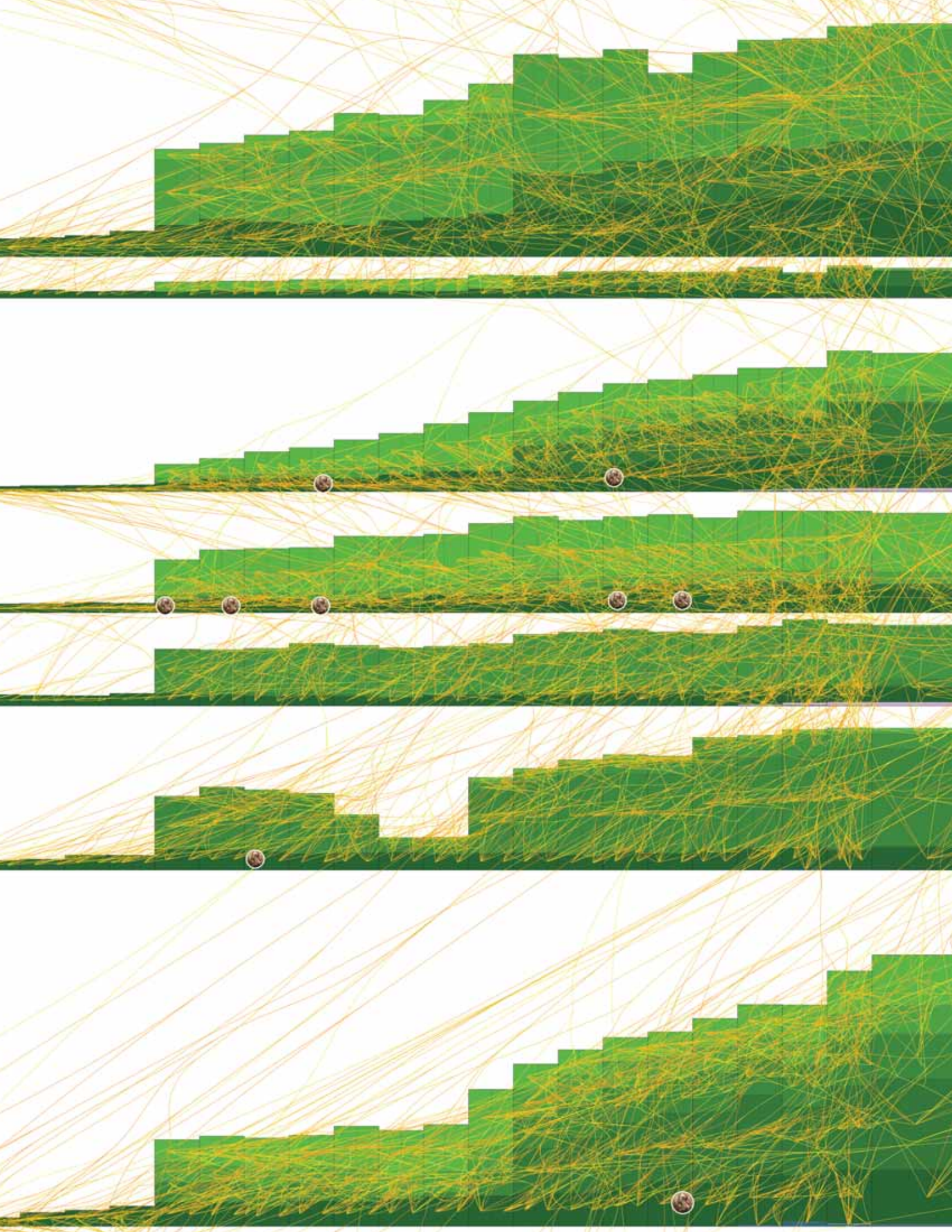
Using their pencils to move me through their talking points, the two engineers described how the data produced by the program would be "objective, meaningful, and believable." Brignac described a planning process that had included not only Shell and Motiva engineers, but also state regulators, university scientists, and community members. Armstrong outlined a sampling procedure that replicated the one used by the LDEQ in their ambient air monitoring program: Each sample would be taken over a 24-hour period, on rotating days of the week (Monday this week, Sunday next), and their results averaged together, all to ensure that the data gave a "representative" picture of Norco's air quality and not anomalous fluctuations.

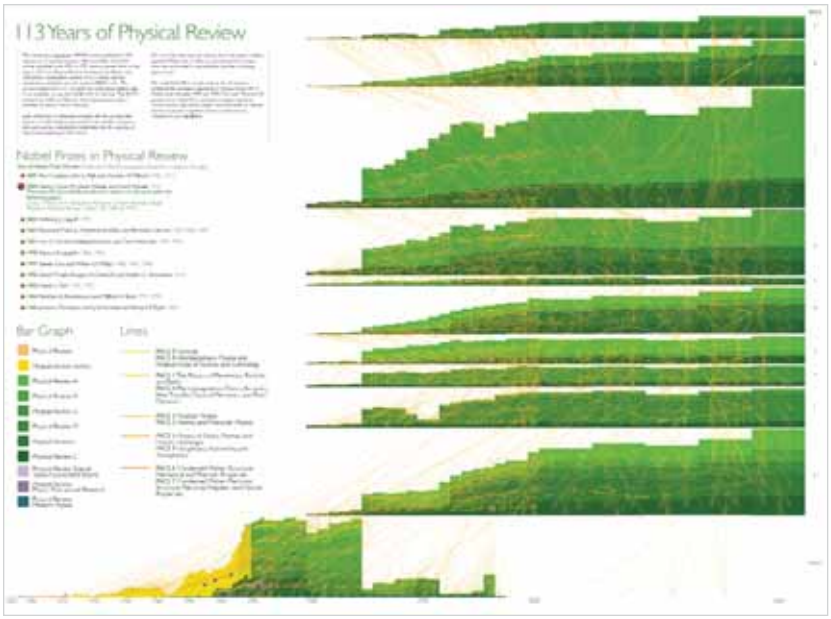
Like all good scientists, Brignac and Armstrong acknowledged that they didn't know what their study would find. They monitored emissions leaving the plant, Armstrong explained, and used computer models to predict how they would disperse into surrounding areas. Those models gave them every reason to believe that the air quality was fine. And the company had done studies of its workers' health, which also gave them confidence that their emissions weren't making anyone sick. But we all knew that models aren't measurements, and the health of adult plant workers may or may not say anything about the health of residential populations that include the very young and very old. So with a slightly nervous laugh (or was that my imagination?), Armstrong assured me that Shell would be releasing the results even if they showed that air quality was worse than they had thought.

Nearly six months later, I followed Margie Richard, now a resident of the nearby town of Destrehan, into Norco's echoey, warehouse-like American Legion Hall. Brignac and Armstrong milled with their colleagues near the table of crackers, cheese, and that unfathomable Louisiana delicacy, the shrimp mold. They greeted us warmly as the facilitator began to usher people to their seats for the presentation of Air Monitoring…Norco's first set of results.

A nervous young African-American man from Brignac's Good Neighbor Initiative team began by explaining the rationale and process of the program, using more or less the same slides that I had seen in September. Then a white 30-something from the independent firm that had carried out the monitoring, less polished than his Shell counterparts and looking uncomfortable in his tie, gave us the results. The headline: "Norco's air meets state standards." They had compared the concentrations measured in Norco, he explained, to limits on chemical concentrations set by the LDEQ, and the measured levels were below the regulatory limits.

Neither the contractor nor the assembled Shell representatives said so explicitly, but the conclusion they wished us to draw was clear: Air quality in Norco met the state's standards, so it was perfectly healthy to breathe. I wanted to ob-





113 Years of Physical Review

Bruce W. Herr II, Russell J. Duhon, Elisha F. Hardy, Shashikant Penumarthy, and Katy Börner, 2007

AIM

How did the field of physics evolve over the last 100 years? When did the many different subfields of physics emerge, die, split, and merge? How are these subfields connected via permanent citation linkages woven by thousands of physicists over the many decades? Can the web of papers their authors interlinked via coauthor and paper-citation linkages be used to identify high-impact papers? Can it be mined to predict the future, or at least the next Nobel laureate?

INTERPRETATION

This is the very first map of a 113-year scholarly data set that captures the structure and evolution of the entire field of physics. The visualization aggregates 389,899 papers published in 720 volumes of 11 journals between 1893 and 2005. Time runs horizontally. In 1975, the Physical Review introduced the Physics and Astronomy Classification Scheme (PACS) codes. In this visualization, the top-level PACS codes run vertically and are labeled from PACS 0 General to PACS 9 Geophysics, Astronomy and Astrophysics on the right. The 91,762 papers published from 1893 to 1976 take up the left third of the map. The 217,503 papers published from 1977 to 2000, for which there are references but no citation data, occupy the middle third of the map. The 80,634 papers from 2001 to 2005, for which citation data is available, fill the last third of the map. Each annual bar is further subdivided vertically into journals, and each journal is further subdivided horizontally into the volumes of the journal. The size of each journal-by-volume area is proportional to the number of papers published. Overlaid on this two-dimensional base map are all citations from every Physical Review paper published in 2005.

Each year, Thomson Reuters predicts three Nobel Prize awardees in physics based on data from its ISI Web of Knowledge, including citation counts, high-impact papers, and discoveries or themes worthy of special recognition. The map uses small Nobel Prize medals to indicate all Nobel prize–winning papers. Correct predictions are highlighted. *Courtesy of Indiana University.*

ject. How could they say that when there were no standards for some of the chemicals that they measured? When Louisiana's standards represented just one version of where scientists drew the line between "healthy" and "dangerous"? I sat on my hands and held my tongue; rabble-rousing at public meetings is not an anthropologist's mandate, especially when she hopes to continue interviewing all sides.

But I wasn't the only one inclined to question the implication that "meets standards" was the same as "safe." In the question-and-answer period, a middle-aged African-American woman, her graying cornrow braids piled neatly in a bun, stood up and asked just how good those standards were. How could we know that they were strict enough? One of the university scientists involved in the project, a public health researcher from Tulane, reassured her that the standards were based on the best available scientific studies and updated as new information became available. Shell's engineers nodded their approval. For them, it seemed, Air Monitoring…Norco had settled the matter: There was no reason to think that emissions from Shell were making anyone sick.

Elsewhere in the audience, Margie Richard pursed her lips. I couldn't tell what she was thinking, but the fact that she was there at all, even after having moved away from Norco, suggested that the Air Monitoring…Norco program had been an important aspect of her group's victory. For years, her group had been calling for hard data about the chemicals they were exposed to, and they had gotten it. But in the drafty warehouse, the victory seemed hollow. Shell had interpreted their data in the context of questionable standards in order to prove what they had believed all along. I wondered if Richard was disappointed. I was.

The story didn't have to end there, of course. Residents of Diamond and other fenceline communities had challenged the industry's science before with their bucket samples. They could likewise have launched an attack on the idea that "meeting standards" was the same as "safe" and insisted on health monitoring to go along with the air monitoring. But their relocation victory meant that Diamond's activists were already scattered to new neighborhoods. Battles over the adequacy of standards were not likely to be fought in Norco.

Yet the question remains for other communities: As more and more facilities set up air monitoring programs to satisfy the demands of concerned neighbors, will community activists continue to push to see that monitoring data are used to get better answers about how chemicals affect their health? Or will they accept comparisons to existing standards that rubber-stamp the status quo? Whether the trailer in Benicia turns out to be the breakthrough I've been imagining it to be rests on what residents do with its data.

California dreaming

When I talked to Don Gamiles in the fall, I had my own favor to ask of him: Would he talk to my colleague, Oakland-based writer Rachel Zurer, and introduce her to the people he had been working with in Benicia? We were working together on a story about monitoring and wanted to know more about the exemplary collaboration that he was involved in. Valero, it turns out, wasn't ready to talk about the project; perhaps they didn't want anyone wondering why the public didn't have access to the data yet. But Marilyn Bardet, the founder of the citizen's group in Benicia that helped pressure the company to install the air monitoring trailer, was more than happy to meet with Zurer.

On a blustery morning in October 2010, Bardet welcomed Zurer into her manicured bungalow on Benicia's east side, then retreated to her office to finish an e-mail. Zurer was left to nose around in the dining room, where Bardet's dual identities were on display.

Bardet, 62, is professional artist who seems to spend as much time as a community activist as she does painting and writing poems. The walls, shelves, end tables, and cupboards of the dining room were decorated with paintings, sculptures, and shells. But the wood of the dining table hid beneath stacks of papers and files relating to Bardet's newest project: a bid to help her town qualify for federal funding to clean up an old munitions site in town, money she said that city employees hadn't known to request.

Bardet assumes that she has a yardstick that shows where "safe" levels of toxins and particulates in the air become dangerous ones, and that there are reliable benchmarks that would tell teachers when they should close their windows and city officials when more traffic would be too much.

Bardet returned in a few minutes, talking quickly. That afternoon she had a meeting scheduled with some Valero officials to keep working out the details of the air monitor's Web site—trying to work through the problem that Gamiles had brought up on the phone, of how to present the data publicly—and she'd been sending them a last-minute memo reiterating her goals for the project. As she gathered her car keys and led Zurer out the door for a tour, she caught her guest up on the details.

Some Benicia residents don't think about the refinery, Bardet explained as she drove under the freeway, past an elementary school, and turned left and uphill just before reaching the Valero property's southern border. It doesn't fit the image of their quaint, comfortable town, and as luck would have it, the prevailing winds tend to sweep refinery odors away from the people, out to sea. The refinery has a good safety record and no history of major conflicts with its neighbors. From many places in town, it's invisible.

Yet Bardet and her fellow members of the Good Neighbors Steering Committee (GNSC) keep a sharp eye on Valero. Keenly conscious of the toxic problems other fenceline communities such as Norco have faced, they are wary of the industrial giant in their midst. The air monitoring station is a product of their vigilance. In 2008, the company made changes to some construction plans without going through the full environmental review that those changes required. Dexterous in navigating the intricacies of bureaucratic requirements, Bardet and the GNSC used Valero's mistake to require the refinery to pay for environmental benefits in Benicia. A single letter Bardet wrote detailing Valero's missteps, plus many hours of work by the GNSC, netted the community $14 million. The monitoring trailer was part of the package.

Bardet parked the car at the end of a residential cul-de-sac and escorted Zurer to a spot under an ash tree in the vacant lot between number 248 (white picket fence, a baby-blue Volkswagen Bug in the driveway) and number 217 (single-story ranch with gray siding, two boats, and a satellite dish). She pointed toward the minor white bump on the horizon, curtained by tall stalks of thistles atop a small brown hill a hundred yards across an empty field. It was the monitoring station that I'd been conjuring in my imagination since Gamiles first mentioned it.

"You wouldn't know that this is a big deal," Bardet said. And it was true. In person, the trailer looked like nothing special. But back in the car again, through lunch at a restaurant in town, all the way until Bardet zoomed off to her meeting with Valero, Bardet shared with Zurer her vision of what the monitors might mean for her community, and for her future as an activist.

"It's not just the refinery," she explained. She pointed out that, for example, while Benicia's elementary school is less than a mile from Valero, it's also near a corporation yard, a gas station, a highway cloverleaf, and the major road through town. The air monitors and weather station could expose exactly which pollutants are infiltrating the school, from where, and under what conditions.

"With that information, you can give a school district an idea of how to improve their site, so you can mitigate it," she said. Teachers could avoid opening windows during rush hour. Or community activists like Bardet would have the data they'd need to evaluate the effect of a new development that would add more traffic to the road. "Policy needs to be evidence-based," Bardet explained to Zurer. "That's what we're after."

Scientific realities

Zurer called with her report on her meeting with Bardet as I was answering a flurry of e-mails from students worried about their final papers. Hearing Bardet's vision for the monitoring station, my hopes sank further. It wasn't that they weren't going to use the data; indeed, it seemed that the information that the monitoring station produces will be something that Bardet can leverage in her myriad projects to improve her community. But in her pursuit of evidence-based policy, Bardet takes for granted the same thing that the engineers at Shell did and that Gamiles does. She assumes that she has a yardstick that shows where "safe" levels of toxins

and particulates in the air become dangerous ones, and that there are reliable benchmarks that would tell teachers when they should close their windows and city officials when more traffic would be too much.

Maybe my pessimism is ill-founded. Maybe the ongoing struggle between Valero and residents over how to present the data will ultimately open the Pandora's box of questions surrounding air quality standards—how they're set, how good they are, how they could be improved—and convince Bardet that she needs a better yardstick. Maybe an enterprising epidemiologist will be seduced by the vast quantities of exposure data that this monitoring station, and others around the Bay area, are producing and persuade Bardet and her group to institute complementary health monitoring in order to create a better yardstick. Maybe the Centers for Disease Control's National Conversation on Public Health and Chemical Exposures, which acknowledges the importance of environmental health monitoring, will help convince government agencies to sponsor such a study.

Maybe, in the end, it was just the stack of grading on my desk that had sucked my hope away. But despite the piles of new information that Benicia's monitoring station will produce—is, indeed, already producing—I couldn't convince myself that any new knowledge would be made, at least not in the absence of more fundamental changes. I wandered off to the faculty holiday party conjuring a new daydream: The National Institute of Environmental Health Sciences would call for proposals for studies correlating air monitoring with environmental health monitoring; the EPA, making ambient air toxics standards a new priority, would demand that data from fenceline communities be a cornerstone of the process; and Marilyn Bardet would seize on the new opportunities and make her community part of creating a better answer to The Question.

Recommended reading

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Gwen Ottinger (ottinger@u.washington.edu) is an assistant professor in the Interdisciplinary Arts and Sciences Program at the University of Washington–Bothell. Rachel Zurer (rachel@zurer.com) is an Oakland-based writer and radio producer.

This article is part of the New Voices, New Approaches series in which young scientists team up with professional writers to produce policy articles with a narrative structure.

REAL NUMBERS

BARNEY COHEN

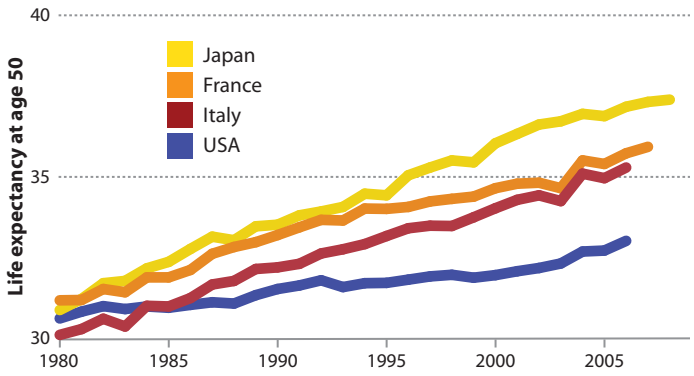
Why Don't U.S. Women Live Longer?

Over the past 25 years, female life expectancy at older ages has been rising in the United States at a slower pace than has been achieved in many other high-income countries, such as France, Italy, and Japan. Consequently, the United States has been falling steadily in the world rankings for level of female life expectancy, and the gap between the United States and countries with the highest achieved life expectancies has been widening. International comparisons of various measures of self-reported health and biological markers of disease reveal similar patterns of U.S. disadvantage. The relatively poor performance of the United States over the past 25 years is surprising given that the country spends far more on health care than any other nation in the world, both absolutely and as a percentage of gross national product. Concerned about this divergence, the National Institute on Aging asked the National Research Council to examine evidence on possible causes. The panel concluded that a history of heavy smoking and current levels of obesity are two factors that are playing a substantial role in the relatively poor performance of the United States. All of the data in the following figures comes from the panel's report *Explaining Divergent Levels of Longevity in High-Income Countries* (National Academies Press, 2011).

Barney Cohen (bcohen@nas.edu) is director of the Committee on Population at the National Research Council and study director of the report Explaining Divergent Levels of Longevity in High-Income Countries.

U.S. women trailing in life expectancy

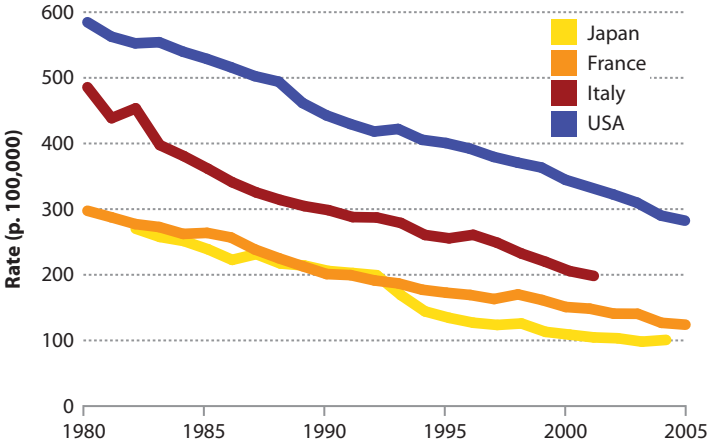
In 1980, women in the United States, Japan, France, and Italy who reached the age of 50 could all expect to live an additional 30-31 years. Today, women aged 50 in Japan can expect to live an additional 37 years, whereas women in the United States can expect to live only an additional 33 years.



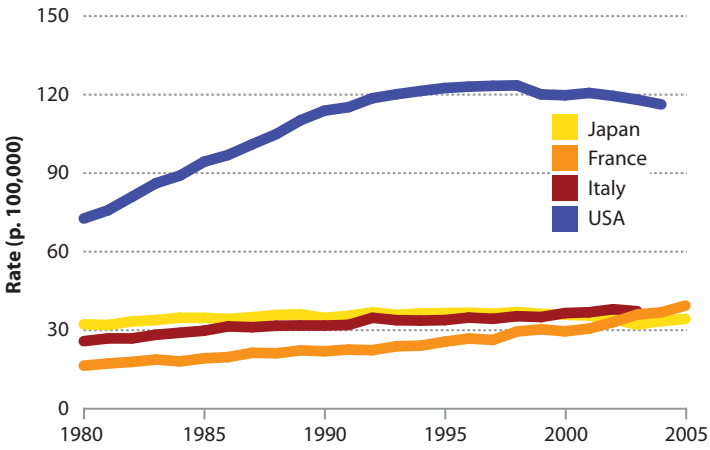
Heart disease and lung cancer are leading culprits

International comparative analysis of cause-of-death data is complicated by variation in coding practice across countries and over time. Nevertheless, it is clear that all four countries have made significant progress in reducing certain leading causes of death such as heart disease over the past 25 years. In contrast, deaths due to lung cancer—a reliable marker of the damage from smoking—have been increasing in the United States.

Heart disease



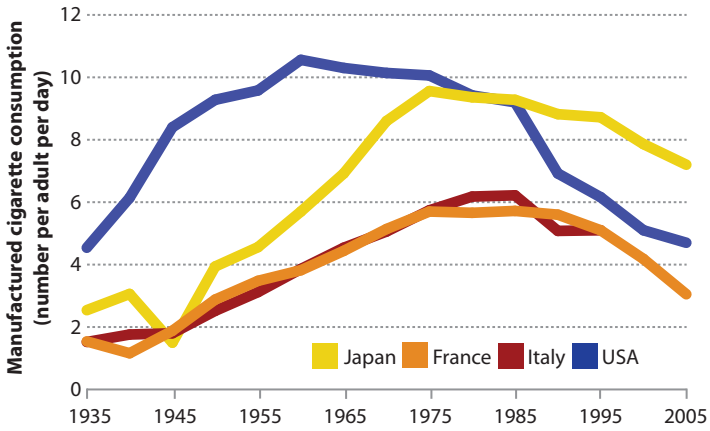
Lung cancer



U.S. women finally foregoing smoking

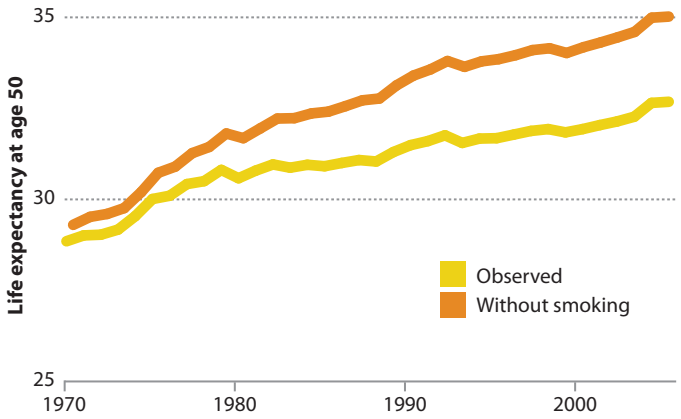
Three to five decades ago, smoking was much more widespread in the United States than in Europe or Japan, and the health consequences of this prior behavior are still playing out in today's mortality rates.

Per capita consumption of manufactured cigarettes



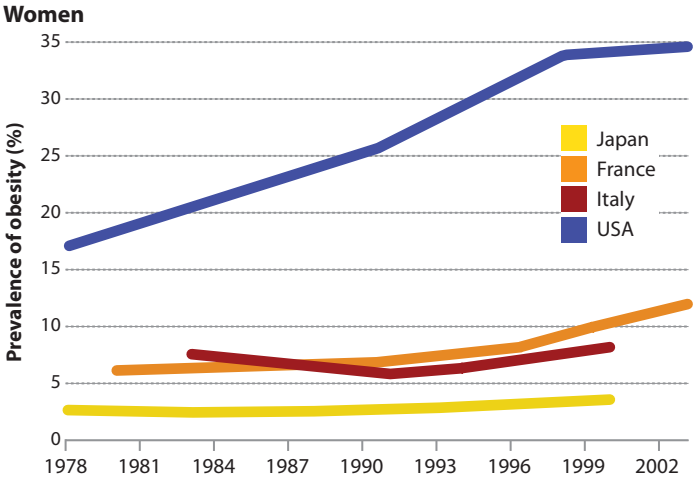
It's the cigarettes, stupid

The yellow line shows the actual trend in female life-expectancy, and the orange line represents what the trend would hypothetically look like if smoking-related mortality were removed. The difference between the two trend lines remained small until around 1975, when it began increasing rapidly. By 2005 it had grown to 2.3 years.



Obesity, the next cause for concern

Other factors, particularly the rapid rise in the level of obesity in the United States, also appear to have contributed to lagging life-expectancy in the United States, but there is still a good deal of uncertainty about the mortality consequences of obesity and how it is changing over time.



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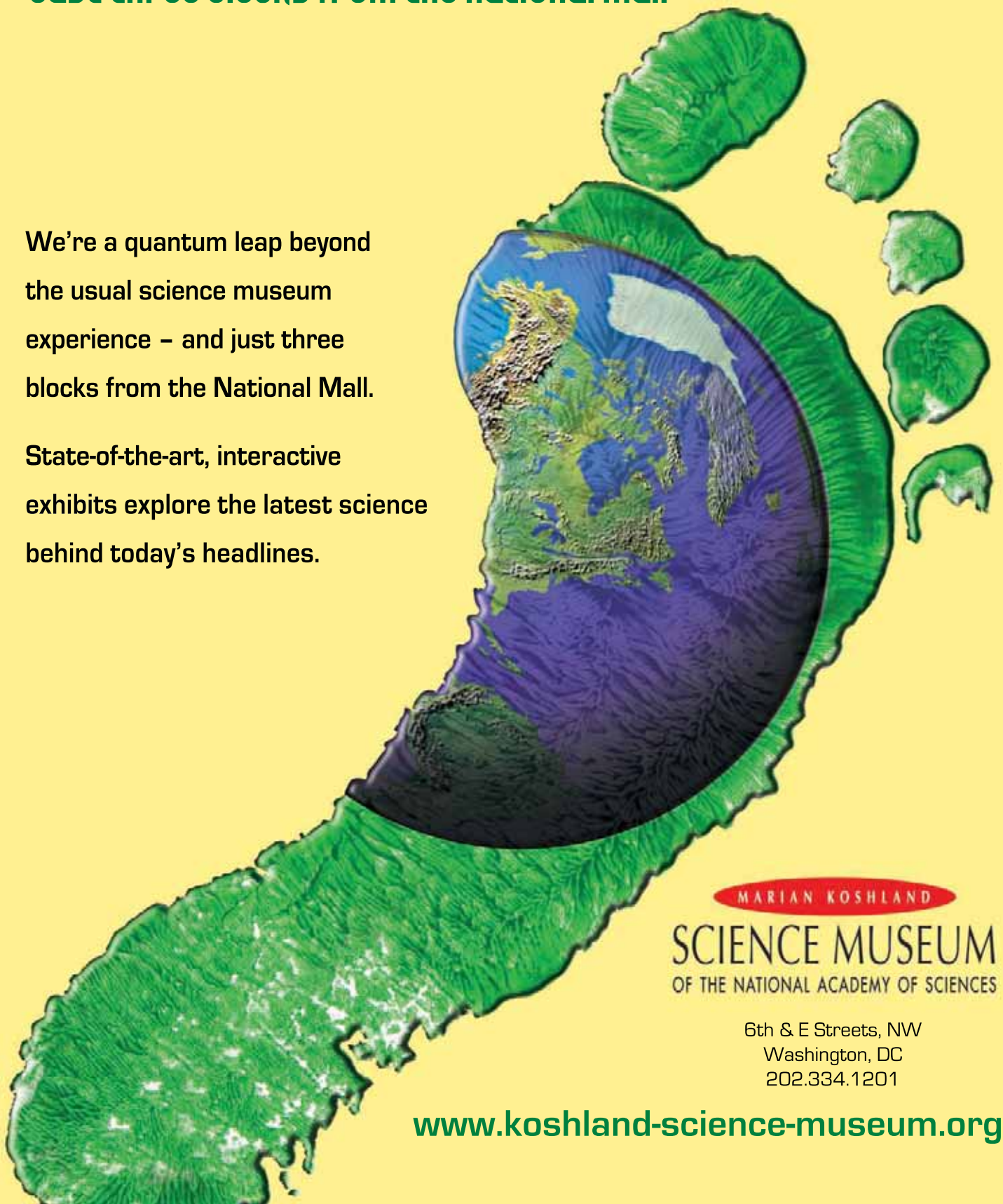

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BOOKS

Climate politics

The Climate Fix: What Scientists and Politicians Won't Tell You About Global Warming

by Roger Pielke, Jr. New York: Basic Books, 2010, 276 pp.

Mark Sagoff

Energy and innovation were major themes in the 2011 State of the Union Address. Barack Obama called for investment in "clean energy technology" to "create countless new jobs for our people." The terms "innovate," "innovative," or "innovation" occurred 11 times in his speech. The president did not mention "global warming" or "climate change."

Last year, Senator John Kerry (D-MA) defended climate legislation in similar terms: "It's primarily a jobs bill. And an energy independence bill and a pollution reduction–health–clean air bill. Climate sort of follows. It's on for the ride."

In *The Climate Fix*, Roger Pielke Jr. faces this political music. He acknowledges what he calls "the iron law of climate policy." According to this iron law, "economic growth and environmental progress go hand in hand." Pielke reasons from the "deeply held global and ideological commitment to economic growth" that "when policies focused on economic growth confront policies focused on emissions reductions, it is economic growth that will win out every time."

How can the world meet the inexorable increase in demand for energy, which conservative estimates put at 1.5% a year, and not destabilize its climate? Pielke uses nuclear energy to illustrate the magnitude of the problem. To meet the demand for energy and still bring carbon dioxide emissions down by 2050 to half of their 1990 levels, the world would have to put more than 12,000 new nuclear generating stations online, and these would not suffice to make electricity available to the 1.5 billion people who now lack access to it. "How many nuclear power stations is 12,000?" Pielke asks in one of many wonderful visualization exercises. "It is, in round numbers, about the same as one new plant coming online every day between now and 2050."

Pielke examines currently available technologies that might be used to stabilize the climate and demonstrates that these stabilization "wedges" do not begin to address the problem. According to Pielke, "we simply do not have all the technology to allow for realistic deployment and displacement of existing infrastructure." Pielke does not expect (although he hopes for) breakthroughs, such as in nuclear fusion, that would lead to fundamentally new sources of power. He believes that enormous progress is possible in lowering the cost of alternatives to fossil fuels, such as wind, solar, biomass, and nuclear, to make them provide abundant sources of inexpensive energy. Technological advance, Pielke argues, is the prerequisite to making progress in decarbonizing the global economy. "The greater the rate of innovation, the greater the potential pace of decarbonization."

It is a short step conceptually and politically, when one follows the mathematical analyses Pielke provides, from the iron law of climate change to the call for innovation. If innovation does not provide the abundance of energy the world demands, adaptation to climate change becomes inevitable. Pielke advises that we should plan for it: "Effective climate policy will necessarily require a combination of mitigation and adaptation strategies."

To encourage innovation, Pielke endorses a proposal by Isabel Galiana and

According to Pielke, "climate science is today a fully politicized enterprise, desperately in need of reform if integrity is to be restored and sustained."

Chris Green of McGill University that governments impose a modest carbon tax to raise billions of dollars to subsidize relevant R&D. The point of a small tax is not to change behavior or to restrict economic activity but "to raise revenues for investment in innovation."

The fix is in

The term "fix" in the title of the book can be understood in three different senses. First, Pielke in many graphs, illustrations, and arguments describes the depth of the difficulty we face—the fix we are in. Second, he calls essentially for a technological fix: innovation in energy technology. The most searching and subtle chapters, however, ask whether climate science has been "fixed" in the sense that a boxing match may be fixed. Pielke accepts the central findings of climate science, but he argues that it has lost its honesty and integrity nonetheless. According to Pielke, "Climate science is today a fully politicized enterprise, desperately in need of reform if integrity is to be restored and sustained."

Pielke bases his indictment on examples he describes in which climate scientists have cherry-picked data, favored interpretations, and downplayed uncertainties in order to create fear, indeed hysteria, in the service of the political programs they advocate, such as the Kyoto Protocol. According to Pielke, leading climate scientists regard climate politics and with it their science as an "us-against-them" Manichean struggle for public opinion. Pielke finds that climate scientists inhibit or punish dissent in their ranks even where uncertainties exist (for example, in the relation between current weather conditions and climatic change), because they regard climate science as "the ground on which battles over climate politics are waged." These experts, Pielke says, rise to high dudgeon in condemning those they call "deniers," a term Pielke believes was "coined to evoke comparisons with Holocaust deniers." Pielke regards what he sees as self-righteous posturing among climate scientists as all the more regrettable because "the battle for public opinion has essentially been won."

The battle for public opinion has been won in the sense that a "majority of the public has for many years accepted that humans influence the climate system and . . . has strongly supported action on climate change for at least a decade." The question is: What action ought to be taken? The "naturalistic fallacy," the principle that one cannot get an "ought" from an "is," implies that climate science qua science cannot tell us what we ought to do. Science cannot tell us what to value; for example, how to balance the interests of future generations against our own. Yet according to Pielke, climate scientists present themselves as policy authorities and with other partisans "selectively array bits of science that best support their position."

There is a lot of common sense in this book. For example, Pielke questions the relevance of the debate over targets: whether the goal for carbon dioxide concentration in the atmosphere should be 450 parts per million (ppm), 350 ppm, or some other level. Choosing a long-term goal is analogous to a middle-aged person deciding whether to aim at a life span of 87.5 or 97.3 years. The goal is not important because the prescription—diet, exercise, visits to the doctor, etc.—is the same. Pielke quotes Myles Allen, an Oxford University climate scientist: "The actions required over the next couple of decades to avoid dangerous climate change are the same regardless of the long-term concentration we decide to aim for."

According to Pielke, the politicization of climate science has created a bias against adaptation. This is because although climate science can say something about what levels of greenhouse gases will destabilize the climate, it can say nothing about how the world should cope with a destabilized climate. Even if governments set ambitious carbon-reduction goals, they are unlikely to fully meet them. Policies for adaptation are therefore at least as important as policies for mitigation.

If one were to offer a criticism of this book, it might be to ask why Pielke is shocked, shocked that scientists dissemble to create alarm, to offer themselves as saviors, and to increase their funding. In an informative chapter centering on "Climategate," the leaking of

e-mails from the Climate Research Unit of East Anglia University, Pielke castigates the scientists involved for trying to manipulate the peer-review process of scientific publication "by managing and coordinating reviews of individual papers, by putting pressure on journal editors and editorial boards, by seeking to stack editorial boards with like-minded colleagues," and so on. Pielke quotes a columnist for the *Financial Times* who commented on the ho-hum response of the scientific establishment: "It said that this is how science is done in the real world."

This may be how a lot of science is done in the real world. It is hard to identify a policy-relevant science, in particular an environmental science, in which participants have behaved better. The scholars who contested Malthusian predictions in the 1960s and 1970s, when Cassandras confronted the Cornucopians, similarly fought political battles on scientific grounds. Today, social and life scientists engage in a great deal of research to "price" or "valuate" ecosystem "services," to measure "existence values," and to quantify "benefits" in order to extract an "ought" from an "is." It is never easy to distinguish between the political and the empirical in the environmental and other policy-related sciences.

Pielke persuasively argues that the work of climate science, as far as its policy relevance is concerned, is essentially complete because its basic ideas are established. A "commonsense approach to climate policy requires no more agreement on climate science than on such very basic ideas." The political consensus for pushing technology is plain, as the president made clear in his State of the Union address. The way forward lies not with climate science but with technology, with physics and engineering. How can we innovate, how should we adapt? The great achievement of *The Climate Fix* is to make the obvious obvious. No small feat in these confused times.

Mark Sagoff (msagoff@gmu.edu) is professor of philosophy and director of the Institute for Philosophy and Public Policy at George Mason University in Fairfax, Virginia.

Green urbanism

Urbanism in the Age of Climate Change

by Peter Calthorpe. Washington, DC: Island Press, 2011, 225 pp.

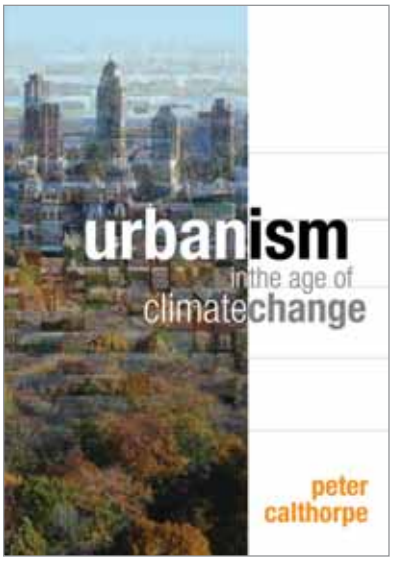
Christopher B. Leinberger

There was a stunted debate in Washington and the country in 2009 about climate change that ended the way many debates do these days: with a hung jury and no action. Yet at some point the United States will have to seriously address climate change. As the

THUS, BRINGING DESTINATIONS CLOSER TOGETHER WHEN DEVELOPING THE BUILT ENVIRONMENT IS A SIMPLER, MORE ELEGANT SOLUTION THAN ASSEMBLING A FLEET OF ELECTRIC CARS AND THE ACRES OF SOLAR COLLECTORS NEED TO POWER THEM.

highest per capita emitter of greenhouse gases (GHGs) by far, the United States must lead on this issue. Time will force action, and the longer policymakers wait, the higher the economic, social, and environmental costs the country and the planet will be forced to bear.

When the debate resumes in earnest, let us hope that the supply-side argument—energy efficiency, renewable energy, and alternative fuels—



will not be the dominant thrust. Instead, demand mitigation should be the number-one means by which we will meaningfully address the issue, as Peter Calthorpe compellingly argues in *Urbanism in the Age of Climate Change*. To quote the immortal Mr. Miyagi in the 1984 movie *The Karate Kid*, when advising the teenage Daniel on how to avoid being beaten up by his high-school chums: "Best defense, no be there." The best way of emitting fewer GHGs is by living in a place that does not require the burning of fossil fuels. That is a walkable urban place where nearly all daily trips from home are reached by walking, biking, or short car or transit trips. Although demand mitigation alone will not enable the United States to achieve the required 90% GHG emissions reduction (from the 1990 base) needed by 2050, without demand mitigation, the supply side will be insufficient, as Calthorpe points out.

There has been a crying need for this short, richly illustrated, cogent book to demonstrate the connection between the built environment (buildings and the transportation infrastructure used to travel between those buildings) and energy use and GHG emissions, and Calthorpe is the ideal author. He is the president of an international urban planning firm, one of the founders of the Congress of the New Urbanism, and the author of some of the most important books on architecture and urbanism of the past three decades. These include *Sustainable Communities* (1986, co-written with Sim Van der Ryn); *The Pedestrian Pocket Book* (1991, with Doug Kelbaugh), in which he introduced the concept of transit-oriented development; and *The Regional City* (2001, with Bill Fulton). With his track record of consistently being well ahead of the curve, one can understand why *Newsweek* named him one of 25 innovators on the cutting edge.

To solve the climate change challenge, Calthorpe writes, we need to focus on ends, not means. For example, the goal of transportation is access, not movement or mobility; movement is a means, not the end. Thus, bringing destinations closer together when developing the built environment is a simpler, more elegant solution than assembling a fleet of electric cars and the acres of solar collectors needed to power them. Calthorpe calls it "passive urbanism."

To Calthorpe, where and how we live matters most. The energy use of an average U.S. single-family household (living in a detached home and driving to work) totals just less than 400 million British thermal units per year. If this family bought a hybrid car and weatherized its home, it could cut its energy use by 32%—not bad for what Calthorpe dubs "green sprawl." In contrast, a typical townhome located in a walkable urban neighborhood (not necessarily in a center city but near transit) without any solar panels or hybrid cars consumes 38% less energy than the green sprawl household. Traditional urbanism, even without green technology, is better than green sprawl. Greening that city townhouse and improving transit options results in 58% less energy use than an average suburban household, Calthorpe calculates. A green in-town condo is even better: 73% less in energy use than the average sin-

gle-family home in a distant suburb.

Calthorpe argues that a supply side–only approach will not lead us to the most cost-effective, socially rewarding, or environmentally robust solutions. Combining supply-efficiency and demand-mitigation strategies will reduce demand for travel through urbanism, reduce oil consumption through more efficient cars, and reduce electricity use through intelligent building design. New energy sources and technologies, the supply-side approaches, can be deployed in more modest doses, ultimately at less cost.

Calthorpe demonstrates that those who create the built environment have the number-one means of reducing energy use and GHG emissions. "Urbanism is, in fact, our single most potent weapon against climate change, rising energy costs, and environmental degradation," he writes.

His logic is as follows:

- The built environment is responsible for more than two-thirds of U.S. energy use and GHG emissions.
- The spectrum of options by which the built environment is constructed can affect energy use and GHG emissions dramatically.
- Building "green urbanism," which today achieves a tremendous per-square-foot market price premium, thereby showing its market appeal, will move the country to where scientists say it needs to be in order to avoid irreparable climate change.

Calthorpe does not stop by making his case for green urbanism; he also demonstrates how green urbanism can be implemented. In doing so, he makes use of his pioneering work in "scenario planning" for metropolitan areas, envisioning how the built environment will evolve over coming decades. It links the many direct and indirect effects of the built environment: land use and conservation, transportation and other infrastructure, water and air pollution, economic growth, net fiscal effects, health, and so on. Calthorpe is currently using the tools he and his colleagues developed to help California implement its own sweeping vision of the future. In my view, metropolitan scenario planning should be the foun-

dation for the next federal transportation bill.

Perhaps the most persuasive example of the value and power of scenario planning is Calthorpe's work during the past decade in the Salt Lake City metropolitan area. This politically conservative and fast-growing area essentially decided to embrace a green urban future. For example, it has invested in an extensive light rail and commuter rail system. The reason the area chose this path was because the total infrastructure cost would be far lower than for continued sprawl, and economic growth was projected to be greater.

Urbanism in the Age of Climate Change could prove to be the most important book of the year regarding the built environment, the most important book in the environmental movement, and the most important real estate business book as well—quite a hat trick.

Christopher B. Leinberger (cleinberger @brookings.edu) is a visiting fellow at the Brookings Institution; president of Locus, a real estate political advocacy organization; a professor at the University of Michigan; and a developer. He is the author of The Option of Urbanism, Investing in a New American Dream *(Island Press, 2008).*

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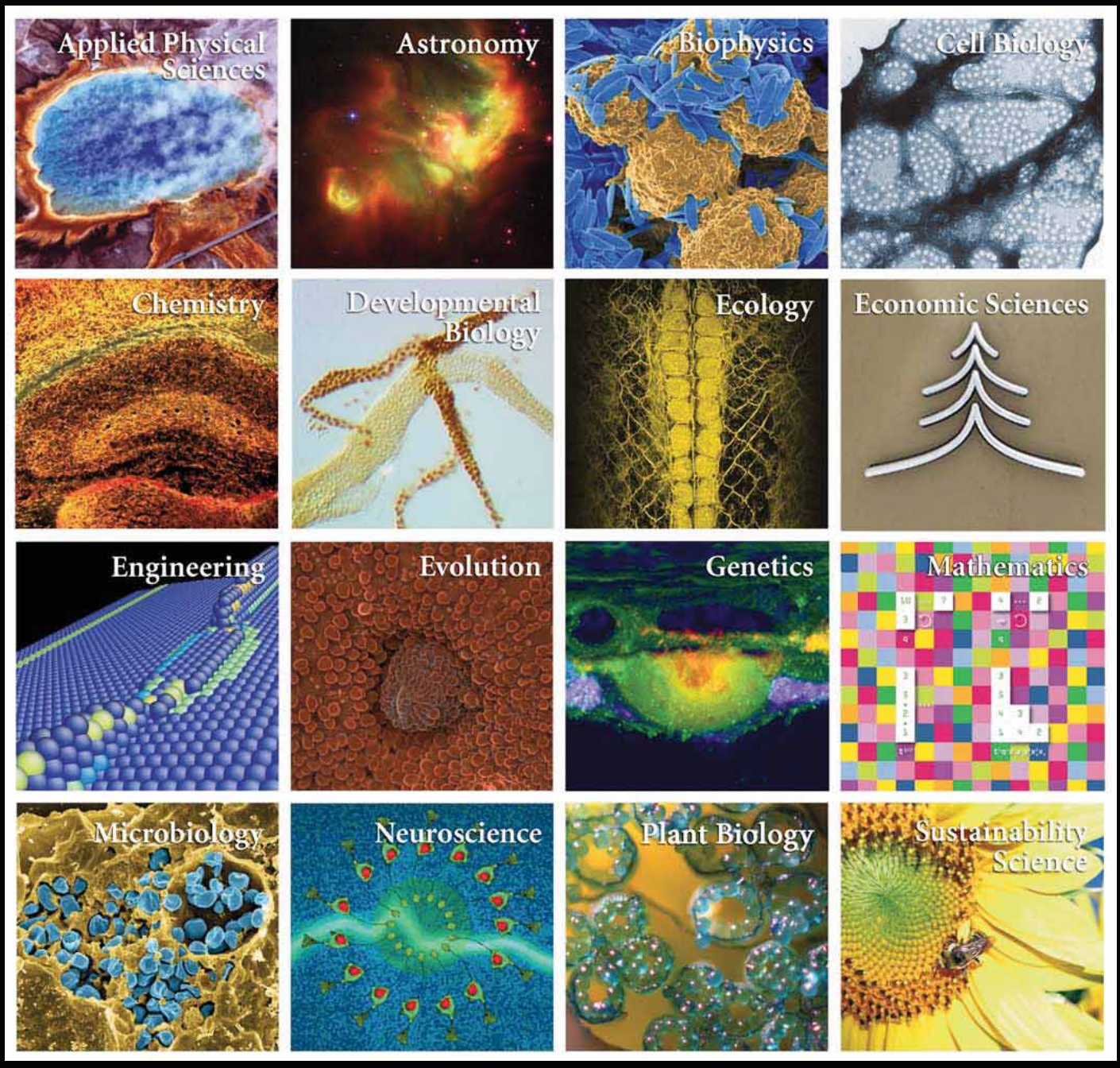

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ARCHIVES

ROBERT HUFF, *Stack Suite #8*, Acrylic, oil, pencil, and gold leaf on paper, 29 x 67 inches, 1994.
Collection of the National Academy of Sciences.

Stack Suite #8

This work by Robert Huff was included in an exhibition of his work at the National Academy of Sciences in 1995. Combining an interest in nature and architecture, the artist reveals an interest in the relationship between humans and their environment.

There are cottony patches of clouds reminiscent of the cumulus clouds in the sky over Miami, where the artist lives. The architectural details imaginatively evoke a sense of space with convex towers of grids, which are sheared by great fan-like shapes of orange and red. Writer and critic Elisa Turner observes about his work, "The artist builds his wonderfully varied and rhythmic compositions, all the while teasing viewers with the illusion of deep space, only to slice that depth into resolutely flat planes of shimmering color."