Smart Energy: Technology, Institutions, and Politics
Presented at University of Vermont

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As I pondered the theme of smart energy and contemplated the work of engineers, ecologists, entrepreneurs, and others, my thoughts kept shifting to broader context. Behind the pursuit of smart energy looms a larger central question—how can communities maintain and enhance quality of life?

That question presents multidimensional challenges that include meeting human aspirations for shelter, heating, cooling, convenience and leisure, personal mobility, and economic dynamism. Worldwide, the question raises issues about how to meet the energy needs of a projected 9 billion people by 2050 in an increasingly urbanizing world. The challenges include enhancing health, of which environmental quality is an important link. Environmental quality also requires preserving, protecting, and maintaining natural landscapes, flora and fauna—the places that sustain us spiritually, socially, and economically.

The search for "smart energy" is a quest to fulfill those aspirations in better ways. By smart energy, I refer to energy sources and related infrastructure that are reliable, resilient, and responsible—the three R's. Smart energy also requires institutions and laws and information systems that incentivize "smart use."

The quest for "smart energy" is not new. As one writer on energy has observed: "Neither humans nor animals like hard work." We are always, he added, "finding easier ways to get work done." "The wheel," he concluded, "was an early advance in energy conservation."

Yet that quest has become more complicated—and its emphasis has evolved. We are no longer—as in case of the wheel—just seeking to minimize our own exertions. We are now seeking to find cleaner ways to provide energy, better ways to lighten our environmental footprint, more efficient ways to illuminate, cool, or heat homes and power computers.

Each and every minute, we pay in the United States nearly $200,000 for imported petroleum. Our energy production and uses are implicated in greenhouse gas emissions and climate change. Our energy production is transforming landscapes. Energy production, use, distribution, and energy conservation, thus, are universal concerns.

Discussions about smart energy have moved beyond the realm of manufacturers seeking to reduce costs to the realm of policy, politics, and society as communities and nations seek to meet broad social, environmental, and economic goals.

Energy guru Amory Lovins summarizes the current imperative: We need, he says, to "wring out the losses in converting, distributing, and especially using energy." But such efforts confront opportunity costs, raising the central relevance of cost-effectiveness.

Energy usage falls into three sectors. A third of the world's energy is consumed in buildings. Another third is used in factories and plants that produce materials, goods, and equipment. The final third is used in transportation

In each realm lie opportunities to do things differently and opportunities to broaden the energy portfolio beyond the era of fossil fuel predominance.

As we think about energy and its relationship to this quest to lighten our environmental footprint while meeting human needs, I see three primary components.

- First is the conservation theme—let me define this as "doing more with less." I am reminded of words of Alfred, Lord Tennyson: "The Earth is so huge, and yet so bounded." But our imaginations are unbounded and therein lies hope for the future of conservation.
- Second is a supply theme—the need to ensure adequate, dynamic, and diverse supplies of energy.

- Third is an environmental protection theme—vigilance to reduce the environmental footprint in energy development, use, disposal or reuse of byproducts.

Before addressing the political economy of where we are going, I'd like to reflect on where we are. Looking at the past 30 years, despite increases in total energy use, energy efficiencies of individual products are significant. For example, today's refrigerators use one-third less electricity than 30 years ago. From 1973 to 2001, the U.S. economy grew 126 percent, while energy use increased 30 percent. During the 1990s alone, manufacturing output climbed 41 percent, but industrial electricity consumption grew 11 percent. From the dawn of the industrial era to the present, we experienced continuous efforts to do more with less—dematerialize, climb up clean fuel ladder, and conserve energy.

We see technological wonders that use far fewer resources—and less energy—to do familiar tasks. A single CD-Rom holds 90 million phone numbers, which replaces—at a telephone company—five tons of phone books. Or consider fiber optics—64 pounds of silica yield a communications network that carries 40 times the messages carried by a cable made from one ton of copper. These innovations yield phenomenal savings in both resources and energy. Or consider trucking—the advent of GPS allows one trucking firm to avoid 4 million miles of driving per year. Through basic truck rerouting, Wal-Mart has reduced delivery route distances by 100 million miles. What is the result of this change? Transportation costs decreased some $200 million, energy use declined, and GHG emissions were reduced more than 10 percent.

I call these innovations the viridian verge—the linking of economic action with environmental benefits. What is the bottom line of this brief technological tale? We have made progress in energy conservation, but conservation is a journey not a destination. There is still much untapped potential at the intersection of energy, the economy, and environmental values.

These opportunities unfold along two dimensions—technological innovations and institutional innovations. The role technological innovation plays in adding value in the marketplace is well recognized. But even with technologies, environmental opportunities lie anywhere and everywhere, to adapt a concept from management expert Peter Drucker, rather than in a few "green" categories.

"Green energy" is not simply "renewable energy." "Green energy"—or, using my term of "Smart Energy"—includes all endeavors that reduce impacts and enhance efficiency.

But let us focus on institutional innovation—an oft-neglected dimension of entrepreneurship, economy, and environmental progress. For environmental entrepreneurship, new institutional arrangements that improve environmental and energy performance fall into several categories. These arrangements include new relationships between manufacturers and suppliers through "green performance contracts." Consider an example of raw potatoes supplied to potato chip manufacturers. A study of the carbon footprint of potato chips revealed that prices were set by weight. Responding to the price signal, farmers controlled humidification to produce moister (and thus heavier) potatoes. Despite strict moisture content specifications set by chips manufacturers, farmers still added a few extra grams of water weight per potato. The total additional weight was significant—and extra moisture required extra cooking to burn off the moisture.

In a life cycle analysis of the potato chip carbon footprint, this extra cooking turned out to account for an unexpectedly high percentage of the chips' energy consumption. This extra cooking actually dwarfed greenhouse gas (GHG) emissions and energy used in transportation of potatoes to the factory. The solution to this challenge was straightforward: change the procurement contract to provide farmers with an incentive to produce potatoes with less moisture.

The growing focus on energy use and supply chains is driven by several factors. First are high energy costs. The supply chain is one of the most pervasive places to find energy savings within industry. Anticipation of regulations—mandated GHG reductions or other emission regulations—affect cost calculations. A second driver is customer pressures. And the final driver is interest, within a competitive marketplace, in enhancing productivity and reducing costs.

But let us turn to different set of relationships and opportunities for innovation. Consider interactions between producers and customers. Within this context, we have seen the emergence of "green building" management contracts—payments to builders or Energy Performance Companies for energy saved. Sometimes referred to as Energy Performance Contracting, energy performance service suppliers provide customers with comprehensive measures to achieve energy efficiencies, expand use of renewable energy, and use distributed electricity generation. Often these services are accompanied by guarantees that savings produced by a project will cover the full project cost.

Energy performance providers do energy audits, design engineering, construction management, long-term project financing, and monitor and verify energy savings. Estimated revenues in this energy performance contracting sector exceed $5 billion—and continue to grow.

A third arena of institutional innovation is the emergence of new relationships among multiple producers through waste exchanges or development of byproduct synergy contracts. Through these relationships, one company's waste becomes another's feedstock. In Texas, for example, a mini-steel mill generated fly ash as waste that was then sold to a Portland cement company as a feedstock. But these byproduct synergies also can result in energy savings. Consider Dow Chemical Company. Forty manufacturing units of Dow took part in a byproduct network within the company, looking for ways to reuse chlorinated wastes. Each unit generated over 1 million pounds of this waste per year. Through the byproduct synergy assessment, participants at Dow identified over 27 potential synergy opportunities using six different technologies. These opportunities translated into $15 million in savings. And—here is the bottom line for energy—these synergies would result in potential energy savings of 900,000 BTU/year.

These new institutional and market contracting arrangements are significant because they affect incentives. They affect motivations of energy and materials users to seek out ever-more efficient technologies and practices that reduce environmental impacts.

Opportunities abound to better meet this Nation's energy needs—through conservation and lower-impact technologies and through new management techniques. But energy challenges require that we "think big"—and differently about our relationship to the world around us. A couple years ago, celebrated author Thomas Friedman dubbed 2008 as the year the Great Disruption began. Eying years of economic growth, eying disparities between rich and poor nations, and eying so much consumption of stuff, Thomas Friedman opined that "We can't do this anymore."

He recycles a theme that recurs—for different reasons at different times—since Malthus first warned of too many people consuming too many resources. While other pundits judge the world's economy in terms of banking and credit and access to capital, Friedman talks of even bigger cataclysms of economy and the environment. We are, he says, simply running out of stuff—depleting the "natural capital" of the planet.

I think Friedman offers the wrong diagnosis for today's profound economic woes. He misses the dynamic processes in a competitive marketplace that enable us to "do more with less."

As far back as Henry Ford's first assembly lines, engineers have measured and tinkered to reduce costs by reducing waste. Even something as prosaic as a coke can has gone through multiple evolutions, so the once hard to crush metal can now, by me, be squashed and torn in two. Why? Because by the 1990s it took just 28 pounds of metal to make 1,000 cans where, 40 years ago, 1,000 cans required 168 pounds of metal.

Friedman's diagnosis may be wrong. But he ends with an important admonition—or perhaps it is a cheer. He cheers for economic assessments that see opportunity in nurturing what Gretchen Daily at Stanford University calls Nature's Capital. Natural landscapes—wetlands and sea marshes, watersheds of free-flowing rivers and streams, forests, grasslands, even urban parks and roadside tree canopy, have multiple benefits for human communities. These natural systems purify water; moderate temperatures, absorb pollutants from the air; provide habitat for bees that pollinate crops; and protect coastal communities from storms.

Yet the connection between these services and the natural world around us is not transparent and, thus, neglected. That neglect affects energy consumption within cities. This neglect results in underinvestment in environmental protection and increased impacts from land, water, and coastal transformation.

With ecosystem degradation come corresponding losses of natural system functions and their benefits to human communities. These losses carry hidden energy costs. Natural systems provide for the most basic of human needs—services that enhance safety, health, and economic opportunity. The City of New York invested over $1.5 billion to protect and restore the Catskill Mountain watershed, a web of natural systems purifying the city's water supply, rather than spending up to $9 billion on filtration plants. Investing in Nature's Capital saved the city money and enhanced habitat, but also translated into avoided energy use that mechanical water filtration systems would have required.

American Forests Foundation evaluated the extent of tree canopy in cities such as Houston, Roanoke, and Atlanta. Houston lost 16 percent of its tree canopy over the last three decades, translating into a loss of annual air pollution "removal services" pegged at $38 million and an annual loss of stormwater management services with an estimated value of $237 million. This loss also meant increased energy usage. Consider figures for one city—San Antonio. Lost tree canopy in San Antonio over a 15-year period is estimated to equate to a $17.7 million increase in residential summer energy costs per year.

These examples highlight the significant services natural systems provide to human communities, their health, safety, and prosperity. Failure to recognize these services results in decisions that diminish, degrade, and even destroy natural assets. The result of this destruction can be increased environmental harm. But it can also mean higher costs to provide services such as water filtering through mechanical engineering alternatives and foregone benefits of energy savings and community safety.

The 20th century was a time of paving over our cities. The 21st century will, I believe, be a time of re-creating natural landscapes, natural urban streams, and other permeable landscapes. These opportunities highlight the intersections of biology and engineering. They highlight the relevance of materials innovations in infrastructure and buildings.

Buoyed by the expanding academic research on ecosystem services, some recent public policy initiatives have begun to acknowledge the economic value of natural systems through the health, safety, and other resource benefits they provide to communities.

The 2008 *Farm Bill* required that the Department of Agriculture develop a framework for measuring the environmental service benefits from conservation and land management, anticipating possible participation by farmers, ranchers, and others in ecosystem service markets.

The Environmental Protection Agency has allowed watershed permits through which wastewater treatment plants may enter into trading arrangements with farmers. To achieve permit requirements for temperature, rather than installing high-cost and energy consuming refrigeration systems, one trade in the Tualatin River Basin resulted in payments to farmers of

$6 million to plant shade trees in riparian areas, avoiding $60 million in costs to construct refrigeration systems at two wastewater treatment plants.

Let me make one thing clear. Investing in Nature's Capital offers economic opportunity. But it also is, I believe, a central foundation of 21st century environmentalism and an important part of a "smart energy" strategy for the Nation. Tree cover in urban areas east of the Mississippi has declined 30 percent over the past 20 years, while the urban footprint has increased 20 percent. An estimated 634 million trees are "missing" from urban areas across the United States as a result of urban and suburban development. This loss of trees and associated permeable surface area has cost cities an estimated $100 billion in increased stormwater management needs—and the accompanying energy use associated with water treatment facilities.

Researchers at many universities have explored technological opportunities for energy efficiency in lighting, computing, and building design. Some have examined energy sources beyond fossil fuels. Several states, including Vermont, are pioneering efforts to shift to Smart Grid infrastructure. That shift may be part of a Smart Energy future. Smart Grid is a concept, not a prescribed set of technologies. Rather, the concept refers to a suite of options to enhance grid reliability, resilience, security, efficiency, and nimbleness. It includes increased reliance on digital information and controls technologies to optimize grid operations and promote and enable user efficiencies. The price tag is high but the long-term pay-off may be significant in some cases.

But let me turn to a political dimension of a "smart energy" future—a dimension shaped by context and challenges. I'd like to highlight three elements of that context that, I believe, will affect energy politics and economics.

First is water—yes, water. Moving water from where it is to where it is wanted is a major part of energy use in the western United States. Consequently, a significant opportunity to affect energy consumption resides in rethinking water infrastructure and technology.

And many energy sources require large amounts of water—or can affect water quality. Energy production is linked to water. Consider ethanol and the 2012 legislated target of 7.5 billion gallons per year, which is estimated by the U.S. Geological Survey to require 30 billion gallons of water to process—equivalent to the total water needs of Minneapolis. If a quarter of the corn crop needs irrigation, corn ethanol would require nearly a trillion gallons of water per year—equivalent to combined water usage in all cities of Arizona, Colorado, Idaho, and Nevada.

Much energy production and use are linked to water, yet water constraints loom large. A National Science Foundation report concluded that abundant supplies of clean fresh water can no longer be taken for granted—not just in the West, but across the United States.

Complicating this picture are the burgeoning populations in some of this Nation's driest areas. Moreover, climate change is altering the availability and timing of water flows. Off-stream water withdrawals in the United States are estimated at 408,000 million gallons per day, or three times the average flow over Niagara Falls, and enough water to fill the Houston Astrodome every 2 minutes. How sustainable this usage is will depend on trends in available supplies and demand and how water is managed—and priced.

Energy strategies are linked to water strategies. As we think about energy efficiency, I believe we cannot do so in isolation from contemplating water supply and quality. Are there technologies to reduce energy requirements for supplying water to communities and farms? As we supply energy—whether bio-fuels, fossil fuels, nuclear power, other fuels—how might we minimize water requirements?

New technologies to access shale gas have opened up enormous new supplies of natural gas. But debates are already surfacing about the effects on water quality (and water supplies) of tapping this shale gas using hydraulic fracturing techniques. How will this scientific and political debate unfold?

But let me turn to a second contextual concern—climate change. A key driver of economics of energy will be politics of climate change. Any climate policy will affect relative costs of different energy options. But the devil is in details—therefore, the shape of energy futures is partly linked to the shape of the climate policy future. Prospects of international climate accords or national legislation are highly unlikely in the near term.

But climate action is not at a standstill. Many cities have climate action plans that are re-shaping urban environments—and will affect energy choices. Some 30 states have renewable portfolio laws requiring specific percentages of renewable energy sources in electricity generation. However, tight budgets and economic duress could soften these requirements if costs become a significant issue.

Beyond climate change issues, there is a third contextual element that affects energy production and distribution. That element is the relationship of land and energy supplies. Many alternative energy sources—photovoltaics, wind, ethanol and other bio-fuels—are very land transforming. So, as we pursue clean energy, we need to broaden consideration of what's green. Yes, the carbon footprint matters. But the landscape footprint and wildlife impacts are also important. To anticipate the challenges of land transformation, one might turn to the Mojave Desert and the current scramble to site solar and wind projects. There, energy, recreation, species habitat, military training, and water issues all intersect on this desert landscape. There is an old Chinese adage that observes that in our challenges reside opportunities. The challenge to land managers in this desert setting is how to minimize the broader environmental footprint of energy on landscapes while, nonetheless, securing opportunities for energy development.

A smart energy future also confronts other challenges. Among those challenges is the marketplace itself—and institutional procurement practices. Sometimes, energy efficient technologies and practices generate lifecycle savings—but cost more upfront. Many firms and governments acquire goods calculating the relative purchasing costs, not the long-term or life cycle costs. Success, therefore, of energy efficient technologies may hinge as much on changing contracting rules as on the merits of the technology itself.

But the marketplace also is a tough taskmaster. Expectations of price premiums for green technologies often are unfulfilled. Consumers want performance and competitive prices.

I offer a final caveat of wariness toward legislated technology prescriptions. Mandating one good idea may preclude other new ideas. The EPA currently has a *pot pourri* of voluntary and mandatory energy efficiency standards for appliances, lighting, and other products. EPA and others also have promulgated many certification programs. Regulations, standards and certifications can stimulate results—but they can stifle creativity, too.

Yogi Berra opined that: "the future ain't what it used to be." Perhaps in a more sophisticated—and less ironic—way, scholar Richard White made a similar point when he wrote that: "All the context in the world doesn't explain tomorrow, which is where you always end up."

I have offered some context. I have summarized some current circumstances, challenges, and trends. Yet "stuff happens." So I offer these thoughts not as Cassandra peering into a crystal ball. But as a perennial optimist that human ingenuity will lead us to a better future.