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For a hearing on

Efficiency: The Hidden Secret to Solving Our Energy Crisis

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SUMMARY

This testimony responds to an invitation from the Joint Economic Committee of the U.S. Congress to explore the potential contribution of cost-effective energy efficiency investments to solving the current energy crisis.

This hearing comes at a propitious time. By July 2008, the acquisition cost of imported crude oil to the U.S. had increased eleven-fold in inflation-adjusted terms from its most recent low in December 1999 (based on Energy Information Administration data), and other energy prices have been increasing as well. We depend increasingly on oil imports from unstable parts of the world, and the world's fossil fuel consumption is (with more than 90% probability) warming the globe (according to the latest reports from the Intergovernmental Panel on Climate Change). Various analysts and political leaders have advocated increasing the supply of energy through expanded offshore oil drilling, more construction of power plants, and increased production of alternative fuels, some of which surely is necessary to meet the joint challenges of oil dependency and climate change. But there has been remarkably little focus (relative to the vast potential) on America's secret energy surplus, "energy production" from innovation in the efficient end-use of energy.

In the three decades since the energy crises of the 1970s we've learned a great deal about the potential for energy efficiency and the means to deliver it cost effectively and reliably. Back then, many analysts still held to the now discredited "ironclad link" between energy use and economic activity, which implied that any reduction in energy use would make our society less wealthy. Now we know that there are many different ways to produce a dollar of GDP using current technologies, some energy efficient and others not. We know that the available efficiency resources are enormous and largely untapped. We know that markets, while generally the best way to provide goods and services, can fail in ways that can be fixed by clever policy choices and business incentives, resulting in lower energy use and a total cost to society (including the implementation costs of those efficiency policies and programs) that is less than that of preserving the status quo. We also know that making efficiency profitable for business is one of the fastest ways to make it happen, although sometimes incentives, government mandates, and other programs are required. Finally, we know that increasing energy efficiency is a question of innovation, not just in technology but also in institutional arrangements and incentives, and if we're fast and smart about it, that innovation can result in direct economic savings to our economy and products and services that we can sell overseas, generating even more economic activity right here in the U.S.

INTRODUCTION

My name is Jonathan Koomey. I'm a project scientist with Lawrence Berkeley National Laboratory and a Consulting Professor at Stanford University. This testimony represents my own professional opinion and in no way represents the views or positions of Lawrence Berkeley National Laboratory, the Department of Energy, or Stanford University.

Given the title of this hearing and recent events, I take it as a given that we are experiencing an energy crisis. The question is: what can and should we do to address this crisis?

What I'd like to make clear today is that energy efficiency is an essential part of the solution. It is the fastest, cheapest, cleanest way to address the problems of oil dependency and climate change.

Since the energy crises of the 1970s we have learned a great deal about the potential for energy efficiency and the means to deliver it cost effectively and reliably:

First, energy efficiency is the key to growing our economy while using less energy in the process.

Second, the available efficiency resources are enormous and largely untapped.

Third, while markets are generally the best way to provide goods and services, they can fail in ways that result in the waste of (or the inefficient use of) our energy resources. Clever policies and programs can fix these failures and reduce energy use at a cost that is less than that of doing nothing.

Fourth, making efficiency profitable for business is one of the fastest ways to improve energy efficiency, although sometimes incentives, government mandates, and other programs are required.

Finally, improving the efficiency of energy use depends on innovation, not just in technology but also in institutional arrangements and incentives. If we're fast and smart about it, that innovation can result in products and services that generate increased economic activity right here in the U.S.

In short, we can use our country's ability to innovate to substitute for using and importing energy resources – an effort that will leave our economy and the environment richer in the end.

BACKGROUND AND EXPERIENCE

I led the energy forecasting group at Lawrence Berkeley National Laboratory for more than eleven years (from 1991 to 2002) and I've been working on evaluating alternative energy futures for more than two decades. I was a central participant in five of the most important and comprehensive energy policy studies to be conducted during the past twenty years:

1) The *Energy Policy in the Greenhouse* study of European options for reducing carbon emissions, conducted by the International Project for Sustainable Energy Paths for the Dutch Ministry of Environment, with books and reports released over the period 1989 through 2001 (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11).

2) A detailed multi-year analysis of the economics of reducing carbon emissions in the New England electric utility sector, conducted by Lawrence Berkeley National Laboratory and completed in 1992 (12, 13).

3) The first "Five labs" study completed in 1997, conducted by five Department of Energy National Laboratories (Argonne National Laboratory, National Renewable Energy Laboratory, Lawrence Berkeley National Laboratory, Oak Ridge National Laboratory, and Pacific Northwest National Laboratory). This study focused on options for reducing U.S. carbon emissions (14, 15, 16).

4) The second "Five labs" analysis, completed in 2000-2001, known as the "Clean Energy Futures" Study, which still stands as the most detailed, authoritative, and comprehensive scenario analysis ever undertaken of U.S. energy futures (17, 18, 19, 20, 21, 22, 23, 24).

5) The "Winning the Oil Endgame" study conducted by Rocky Mountain Institute and released in September 2004. This study focused on options for reducing and eventually eliminating oil dependence in the U.S. (25)

Energy efficiency played a central role in all of these studies, as did energy supply technologies. We'll need both if we're to reduce oil dependency and greenhouse gas emissions significantly.

WHAT DO WE MEAN BY EFFICIENCY?

People don't care about energy use, they care about the services that energy delivers, like warm rooms, cold drinks, and well-lit garages. Efficiency means delivering the same services using less energy. Cost-effective efficiency means that the total societal cost for delivering those services with the efficient technology installed (including all capital, operating, pollution, and program implementation costs) will be less than that for keeping things the way they are now.

Cost effective from society's perspective is not the same thing as cost effective from the individual's perspective. The transaction costs and information costs associated with a consumer buying an efficient product instead of an inefficient one are real societal costs. But just because consumers face those costs doesn't mean those costs can't be reduced or eliminated by policy action. For example, the Energy Star label, which is awarded by the U.S. Environmental Protection Agency and U.S. Department of Energy to products that will both save money and reduce pollution, is a voluntary collaboration between government and industry <http://www.energystar.gov>. That label helps consumers, who no longer need to do any calculations to figure out which products are worth buying—they just look for the label. And minimum efficiency standards overcome the transaction costs issue by simply eliminating the inefficient products from the market, doing so in a way that does not apparently reduce features or affect costs significantly, at least for refrigerators, one of the earliest products to be regulated in this fashion (26).

As long as programs are based on rigorous cost/benefit analyses (as these are) then society will become more efficient as a result, both in energy and economic terms. And that is the goal of increasing efficiency—to improve societal well being while also improving environmental quality.

HOW COME PEOPLE DON'T BUY EFFICIENCY ANYWAY?

An economist and an engineer are walking down the street. The engineer sees a $20 bill and says "Look, a $20 bill!" The economist says "That's impossible. If a $20 bill had been on the street, somebody would have picked it up already." That joke more or less frames the historical debate on this topic.

People have known for a long time that consumers and institutions don't invest in efficiency options that seem to be cost effective, creating what is known in the literature as "the efficiency gap" or "the efficiency paradox" (2, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45). This issue has in the past been portrayed as a conflict solely between engineers and economists, with the engineers arguing for the existence of cost effective efficiency based on their experience with technologies in the field, and the economists arguing against it based on economic theory. That characterization is no longer accurate. The conflict is really among economists (with the engineers supplying supporting data and evidence), with many economists now realizing that the simple models on which their initial skepticism is based do not accurately characterize the phenomena they claim to describe.

Some of the most interesting recent work in economics has focused on transaction costs, information costs, information asymmetries, misplaced incentives, cognitive failures, differential risk aversion, principal-agent problems, path dependence, and increasing returns to scale (2, 39, 40, 46, 47, 48, 49). These issues dominate people's choices about energy efficiency, and they are in many cases amenable to policy action, which in my view is where the answer to the paradox lies.

So that $20 bill on the sidewalk might be better characterized as 2000 pennies, as Florentin Krause points out. And the policy instruments like Energy Star labeling are equivalent to giving the engineer better glasses to help her to see the pennies and a broom and dustpan to help her sweep them up. But just how many pennies are there, and what will it take to put them in the bank?

THE SIZE AND COST OF THE AVAILABLE RESOURCE

It is no longer credible to claim, based on economic theory, that there is no cost effective efficiency to be tapped. The real questions are "Just how much efficiency can be cost-effectively captured, and how much will it cost?" These questions are ultimately empirical ones that can only be answered precisely by actually attempting to implement efficiency and evaluating the results, but the findings from analytical and evaluation studies of previous programs are encouraging.

In a world in which perfect markets prevail, the business-as-usual or base-case forecast includes all cost-effective efficiency improvements. If there are market imperfections that inhibit the adoption of energy efficiency (as there often are), then an additional potential for savings may exist. This potential can be characterized in a "technical" or "techno-economic" fashion. The techno-economic potential gives the costs and savings possible if all possible and cost-effective options are implemented starting immediately, gradually replacing existing equipment through the end of the analysis period (50). It captures the dynamics of stock turnover and generates reasonable upper bound efficiency potential estimates for end-uses where the technologies and dynamics are well understood.

Estimating such potentials requires detailed knowledge of how energy is used in particular end uses, as well as the cost and effectiveness of different technologies to reduce that energy use. The techno-economic potential is characterized by calculating a cost of conserved energy (CCE, in cents per kWh of electricity, dollars per barrel of crude oil, or dollars per gallon of gasoline) and an energy savings for each measure, relative to the base case.

In the real world, policies and programs are imperfect, so the techno-economic potential must be adjusted downwards to reflect those constraints (51). We then estimate what is termed an “achievable potential” that captures some fraction of the savings from the techno-economic potential. This “achievable fraction” is a function of the aggressiveness of policies and the time horizon of the analysis. For a longer time horizon, more equipment is retired naturally and more of the efficient devices can then be installed, thus increasing the potential savings.

There are few recent studies of the potential for efficiency in the U.S., but assessments of efficiency potentials have been conducted for more than three decades (7, 12, 14, 17, 25, 50, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66) They generally find significant cost-effective efficiency potentials in a wide variety of end-uses, although they differ on methods and exact results.

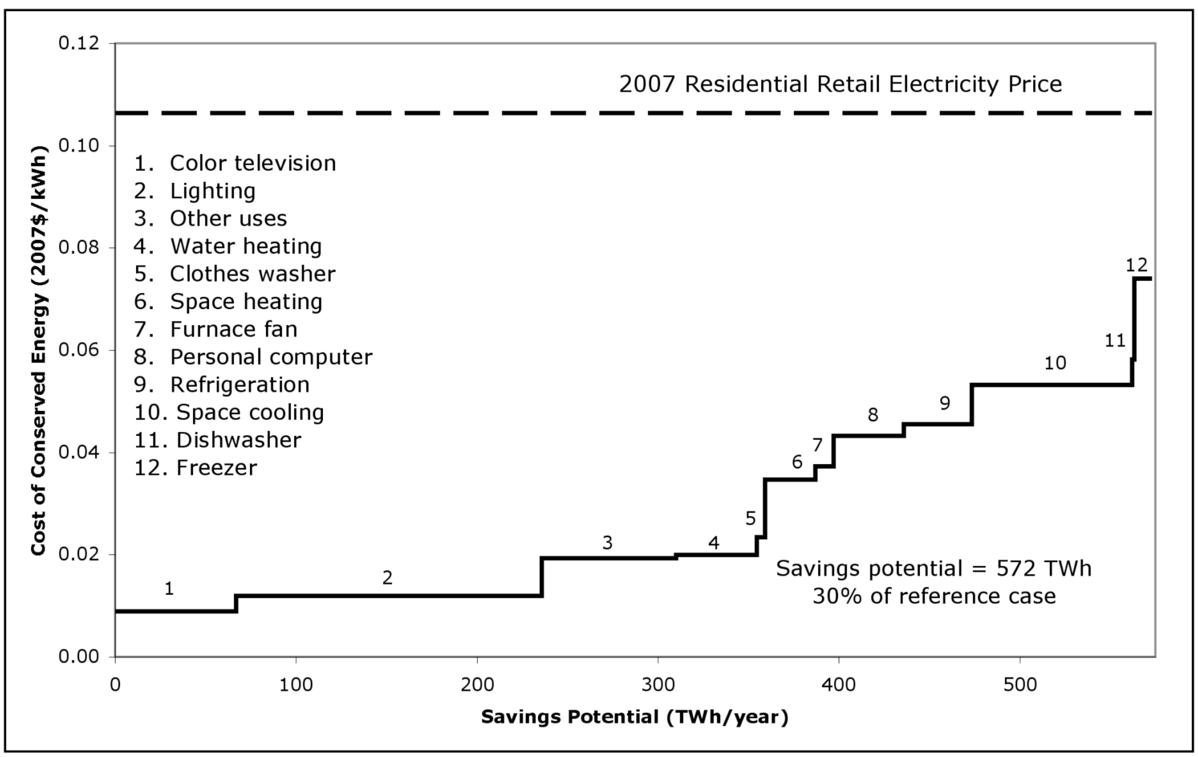
A recent analysis by McKinsey and Company (67) draws from previous energy research to focus on the potential for reducing greenhouse gas emissions in the U.S. This study estimated a significant contribution to emissions reductions from efficiency, but the report itself does not allow easy estimation of the technical details associated with those efficiency potentials.

The most detailed study of efficiency potentials for buildings in the past decade was the Clean Energy Futures study (20), which estimated technical and achievable efficiency improvements by 2020. Brown et al. (68) used the CEF analysis and some simple assumptions to estimate techno-economic potential savings to 2030 relative to the Energy Information Administration’s *Annual Energy Outlook 2007* (69). The Brown et al. study found that the techno-economic potential was about one third of the base case electricity use for both residential and commercial buildings in 2030.

How much of that techno-economic potential could reasonably be captured by 2030? The original CEF study made explicit assumptions about the adoption rates for specific policies, programs, and technologies. In the CEF moderate case (which assumes only modest changes in policies and incremental improvements in technology) the achievable savings were a little more than one third of the techno-economic potential savings by the end of the analysis period, yielding a total achievable savings of about 10% relative to the base case by the end of the analysis period. In the advanced case (which included more and more aggressive programs, policies, and technologies), the achievable savings reached about half of the techno-economic potential savings by the end of the analysis period, representing a total achievable savings of about 15% of the baseline at the end of 20 years. Given a longer time horizon, much more of the techno-economic potential could be captured (and the techno-economic potential could actually increase as innovation improves the capabilities and reduces the costs of efficiency technologies).

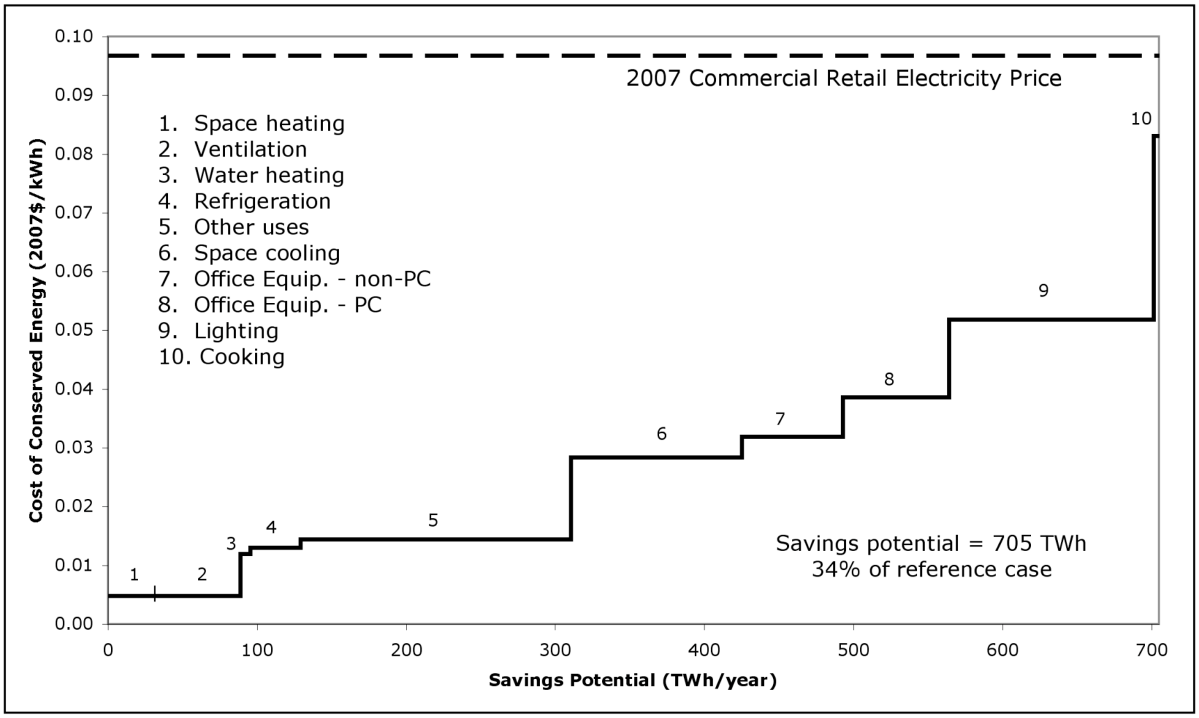
Brown et al. (68) also assessed the economics of the efficiency investments from 2010 to 2030, based on the CEF analysis. The benefit/cost ratio for these efficiency options is about 3.5, meaning that every dollar spent on efficiency returns 3.5 dollars of savings to the economy. On average, these investments would pay for themselves in 2.5 years.

Figure 1: Residential Techno-economic Savings Potential for Electricity, 2030



Source: Brown et al. (68).

Figure 2: Commercial Techno-economic Savings Potential for Electricity, 2030



Source: Brown et al. (68)

The most detailed recent assessment of efficiency improvements affecting oil use is contained in Lovins et al.(25). This study estimated potential savings in U.S. oil use for two cases. The first case was termed "conventional wisdom", representing the potential savings from incremental changes using "off the shelf" technologies for all types of oil using equipment. The second was termed "state-of-the-art", which assumed "clean slate, whole systems redesign" of automobiles, trucks, planes, and other vehicles, using technologies that had been at a minimum demonstrated in prototypes by around the year 2004 (and accounting for the time needed to design and build production vehicles based on those prototypes). The conventional wisdom case showed techno-economic potential savings of about 25% compared to the 2025 baseline oil use in the Energy Information Administration's Annual Energy Outlook 2004, at a cost of conserved energy of about $6/barrel of crude oil. The state-of-the-art case showed techno-economic potential savings of about 50% compared to the base case forecast, at an average cost of conserved energy of about $12/barrel of crude oil.

At the time the "Oil Endgame" analysis was published the Energy Information Administration predicted crude oil prices in 2025 of $26/barrel in year 2000 dollars. Now, of course, that prediction looks low, and the EIA has adjusted its forecast to about $48/barrel of crude oil (2000 dollars). In either case, energy efficiency is a terrific bargain, saving society a great deal of money while also reducing oil dependence and emissions of greenhouse gases.

The historical policy experience in California (70) and the U.S. (71, 72, 73, 74) yields similar results, as does the program evaluation literature. Program evaluations are conducted by electric utilities to understand the impacts and costs of their efficiency programs (75). Two exemplary reviews of such studies in the mid-1990s found that commercial sector utility efficiency programs were generally quite cost effective when evaluated from society's perspective (76, 77). Another analysis of commercial lighting addressed challenges to such evaluation results from the economics community and concluded that the societal cost-benefit analysis for the efficiency programs evaluated had indeed been conducted correctly (78). More recent evaluation work for California is available at <http://www.calmac.org>.

The most important point to take from these studies is that there are many untapped options available to improve efficiency of energy use, and that this energy efficiency costs a lot less than buying energy, be it oil, electricity, or natural gas. Procuring efficiency also avoids the costs and risks of oil dependency, local air pollution, and climate change in the bargain, and is faster to implement than most supply side options. The exact size of the efficiency resource is ultimately a function of how much we invest in research and development and how successful our policies and programs are at breaking down barriers to cost effective efficiency, but we know there's a lot of efficiency that's ours for the taking. So what do we need to do to capture it?

CAPTURING COST-EFFECTIVE EFFICIENCY

There are many summaries of the policies and programs needed to capture efficiency, but two of the most comprehensive ones are *Scenarios for a Clean Energy Future* (17, 18) and *Winning the Oil Endgame* (25). The *National Action Plan for Energy Efficiency* (79) gives broad recommendations for successful energy efficiency implementation, and Skip Laitner of the American Council for an Energy Efficient Economy gave some very specific recommendations recently in testimony before the U.S. Senate Committee on Natural Resources (80). There are many other reports with similar lists and I won't describe their recommendations in detail, but I summarize them here. They include both energy pricing policies (in the form of emissions trading or carbon taxes) and non-price policies, including increased effort on labels like Energy Star, minimum efficiency standards, incentives to consumers for the purchase of efficient products (positive, negative, or revenue-neutral feebates), incentives to utilities for promoting efficiency, demonstration projects for innovative technologies, prizes for achieving efficiency goals, business plan competitions for promoting startup companies, government and business procurement of efficient products, and greater research and development spending, which has fallen to historic lows from the late 1970s (81).

Pricing policies are useful in promoting supply side fuel switching, but are much less so for efficiency. A simple calculation demonstrates why. A carbon tax of $50/metric tonne of carbon (which is the level considered in the Clean Energy Futures study that led to very substantial changes in electricity supply side investments) would raise gasoline prices by about 12 cents per gallon, barely enough to notice in a world of $4/gallon gasoline. And 30-40% of building sector energy use in developed nations is afflicted by the so-called principal-agent problem, where the person buying and operating the equipment is not the same one who pays the energy bills, making those users impervious to price signals (48, 49).

So getting prices right is not enough. To achieve large efficiency improvements–that is, to stop installing wasteful designs of buildings, equipment, appliances and lighting–we'll also need non-price policies as described above, and other innovations, as described below.

WHAT KINDS OF INNOVATIONS ARE NEEDED?

The central organizing principle for research, development and incentive policies should be what Amory Lovins of Rocky Mountain Institute (RMI) calls "clean slate, whole system redesign". Instead of promoting incremental efficiency improvements, as is so often done, institutions should redesign energy intensive products from the ground up. Most technologies are the result of an evolutionary path that is heavily dependent on history. Instead, the focus should be on delivering the services that people demand with products that are just better in every way (not just more efficient, but also more desirable for their other attributes).

And innovation needs to come to institutions as well as technologies, to harness the power of business in the pursuit of efficiency. One reason why Energy Star is so successful is because the program helps make efficiency profitable—it gives companies that produce efficient products a marketing advantage over those producing the less efficient devices.

Modern companies are brilliant at replicating a proven business model on a large scale, which is one example of what economists call "increasing returns to scale" (82). Imagine if a large retailer (like Costco or Walmart) decided that they would only stock Energy Star products from now on (for those products for which a label is available). This action would create a large market for efficient products, making them widely available and turning them from niche products to those with large market share. It would put pressure on the producers of those products to reduce their prices, which would be justified because of the larger production scale that orders of that size would enable. And the markups that companies up and down the value chain formerly applied to these niche products would shift overnight to markups appropriate to products that are widely used, further lowering the price to consumers. That example shows the power of increasing returns if properly applied. We're only at the beginning of understanding and using this concept to our advantage in promoting efficiency.

Two other important institutional innovations relate to electric utility profits, which for 45 states and the District of Columbia are directly tied to electricity sales: every kilowatt-hour of electricity saved means a reduction in profits for the utility. According to the Natural Resources Defense Council, only five states as of July 2008 (CA, DE ID, MD, NY) have adopted legislation to decouple electricity sales from profits. And only five states (CA, ID, MN, WA, WI) have implemented profit incentives for efficiency investments by utilities. We know from the history in California that utilities are enthusiastic and productive efficiency investors when they make money at it. These two institutional innovations (decoupling and profit incentives for utilities) should go nationwide.

Information technology (IT) is one of our most powerful allies in the quest for efficiency (83). IT helps because moving bits is much less energy intensive than moving atoms, because it allows us to collect more and better data, and because it, more than any other technology, allows us to tap into increasing returns to scale.

Amory Lovins of Rocky Mountain Institute says "Move the electrons, leave the heavy nuclei at home". So instead of traveling to Bangalore for a planning meeting, an engineer can use modern "telepresence" technology to meet with his colleagues virtually, saving a great deal of energy, but also avoiding the wasted time, money, and human cost of international travel (84). If you've seen such a system recently (as I have), you know just how far this technology has come since the early days of video conferencing. Significant energy savings accrue because the nucleus of atoms is thousands of times more massive than the electrons carrying the information over the network.

IT also lets us collect more data and better data, which helps us make better decisions. In data centers, the high density computing facilities upon which all companies now rely, the advent of cheaper sensors and ever more powerful computing is helping people manage their costs and energy use more effectively than ever before. And more accurate data allows companies to more effectively identify and eliminate misplaced incentives that inhibit efficiency (85), because the consequences of such institutional problems become manifest more quickly.

Since the 1990s, commercial enterprises have developed and utilized computer analysis tools to manage a wide variety of risks. In contrast, investments in energy efficiency are not typically evaluated in a risk analysis, but treated much more conservatively, usually by using a simple payback analysis. Those enterprises that explicitly analyze the opportunities for energy efficiency and implement cost-effective options will benefit their bottom line (86).

IT also helps users manage data more effectively, particularly when data are released in a standardized format. For example, electric utility rates, which are now almost exclusively printed on paper, are difficult to manage for large companies with facilities in many states. The rates are complicated and they vary state-by-state and over time in unpredictable ways. If the federal government were to promote the development of a standardized electronic format for utility rates it would allow greater efficiencies in the design and energy management of facilities owned by multi-state and multi-national companies. The Lawrence Berkeley National Laboratory tariff analysis project made a first pass at creating a database of such tariffs manually <http://tariffs.lbl.gov/>, but that's a far cry from having such data released and updated automatically by each utility. A nice side effect of such standardization would be that web-based energy analysis tools could more easily evaluate utility bills for residential and smaller commercial customers as well.

One of the main reasons companies are now so good at replicating business practices is because of the scalability of IT infrastructure. There are terrific returns to scale with these systems, and once a new business model has proven itself in one store, a large company can very easily roll it out to all its other stores in a matter of days (82). The power of this technology puts increased economic and resource efficiency within our grasp, and we can improve efficiency much more rapidly now than we could in the past.

RECOMMENDATIONS

Some have called for an Apollo project to attack the current energy crisis (87), but I think a better analogy would be what happened after the Russians launched Sputnik (88). The U.S. invested massively in science and engineering education, in technology, and in research and development, across the board. The whole society was mobilized to meet the challenge, and the Apollo project was just one manifestation of that effort. Meeting the current energy challenge will require mobilizing our entire society again, this time to promote energy innovation.

Congress can aid that effort in several ways.

First, I suggest that the National Academies and the National Science Foundation be commissioned to evaluate

(1) the need for additional research and development (R&D) and the effectiveness of the current R&D portfolio across the entire federal government, with particular emphasis on the potential for clean-slate whole-systems redesign as a central organizing principle for these efforts.

(2) the need for increased funding for science and engineering education from kindergarten through post graduate work

(3) the current portfolio of energy efficiency standards, focusing particularly on standards that have been passed by the state of California that have not yet been passed by the federal government, on end-uses where significant cost-effective energy efficiency potential remains (89), and in enduses that are affected most strongly by the principal-agent (landlord/tenant) problem (49).

(4) the use of prizes (like the X-prize for space travel) to promote breakthrough innovations in energy efficiency and alternative fuels

(5) the use of revenue neutral "feebates" for promoting efficiency in light vehicles, given that this policy has the potential to promote efficiency and increase the profitability of domestic automobile companies (25).

(6) the use of new information technologies (such as improved video conferencing, electronic tolls for roadways, radio frequency identification (RFID), and wireless sensor networks) to improve the overall resource and energy efficiency of technological systems both within and outside the federal government..

Second, the U.S. Department of Energy and the Federal Energy Regulatory Commission should be asked to assess the benefits and costs of promoting standardized electronic formats for utility rates.

Finally, the relevant agencies in the Federal government should collaborate with the utility industry and the National Association of Regulatory Utility Commissioners to promote the adoption of decoupling of utility profits from electricity sales and the implementation of direct profit incentives for utility investments, both of which have been successful in California in making utilities enthusiastic advocates for energy efficiency. Adopting those institutional innovations in the states that do not now have them is one of the largest single steps we as a society could take to promote energy efficiency on a large scale.

CONCLUSIONS

Efficiency is the cheapest, cleanest, and fastest source of new energy "supply"—it can both save money and improve environmental quality. This insight is not a new one, but the U.S. has been reluctant to fully embrace it. There have been some notable historical successes with CAFE standards for automobiles, minimum efficiency standards for appliances, Energy Star labeling, and utility efficiency programs, but we have not yet tried a "full court press" for energy efficiency. The name of the game is innovation in technologies, policies and behaviors, and we as a society need to make that innovation occur more rapidly, more broadly, and more effectively than it ever has before.

Our choices today affect the choices we will have tomorrow. Continuing to install inefficient products will strand investment and delay the transition to using – and marketing to the world – efficient alternatives. If we choose to invest in research, development, demonstration and implementation we can have a much more efficient future than we would have otherwise, with co-benefits in energy security, economics and the environment. This future is within our grasp—we just need to reach for it.

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