



THE JAMES A. BAKER III  
INSTITUTE FOR PUBLIC POLICY  
OF RICE UNIVERSITY

ENERGY AND NANOTECHNOLOGY: PROSPECTS FOR  
SOLAR ENERGY IN THE 21ST CENTURY

OUR ENERGY CHALLENGE

A LECTURE BY

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THIS STUDY IS PREPARED AS PART OF THE RICE ENERGY PROGRAM INITIATIVE ON  
ENERGY AND NANOTECHNOLOGY

THE JAMES A. BAKER III INSTITUTE FOR PUBLIC POLICY  
CENTER FOR NANOSCALE SCIENCE AND TECHNOLOGY  
ENERGY AND ENVIRONMENTAL SYSTEMS INSTITUTE  
SHELL CENTER FOR SUSTAINABILITY

RICE UNIVERSITY - DECEMBER 2005

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THIS STUDY WAS MADE POSSIBLE THROUGH THE GENEROUS SUPPORT OF

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## **Our Energy Challenge: A Lecture by Dr. Richard E. Smalley**

I have been on a personal journey for the past year and half in a search for terawatts to find some happy answer to the energy problem. I believe the problem is, simply stated, that we have to find a new oil. Oil was, unquestionably, the basis for prosperity for this country and the planet in the last century—particularly the last half of the century. But it is very clear to many of us, including leading scientists and policy makers, that if oil remains the basis for prosperity for the world throughout this century, it cannot be a very prosperous or happy century. There are two reasons for this. First, we will certainly peak in worldwide oil production sometime in the earlier part of the century, perhaps much sooner than we would like to see it; and second, there are vastly more people on the planet who do not currently consume energy to speak of, that unquestionably will be consuming it in the future. Billions of more people, as the century unfolds, will be consuming energy at the rate that the top billion do right now. As this energy consumption rises worldwide, we will create a huge wall of carbon with immense negative impacts. Should we not find some way of getting around it?

So we need to find an economic alternative to oil. We need a new basis for energy prosperity. Ten billion people on the planet—that is our challenge. I believe this challenge is vastly greater than we admit. Between where we are right now and where we need to get to, we really have to find a new oil. I do not mean a liquid; I mean a technology that makes us energy rich again in an environmentally acceptable fashion for 10 billion people. Between here and where we need to be, there is something like ten miracles. The good news is that miracles do happen. I have been involved in physical sciences long enough to see many of them happen: lasers, high temperature super conductors, and so forth. But at the rate that they have been happening, over my lifetime, I am beginning to appreciate the magnitude of the breakthroughs that need to happen. I am not by any means convinced that we will get there soon enough. That is the reason I feel strongly that we ought to get much more intense about this issue than we have in the past and launch a major new energy research program to get this problem solved.

I know many people have heard me talk about this so I also wanted to take this lecture a step farther. In May 2003, we had a wonderful conference here at Rice University on energy and nanotechnology. We took DVDs of all the presentations, and I have looked at these five times over, listening to everyone talk, again and again. And even the people that I thought I understood

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what they were going to say, even the moment they stood up, I find that even on the fifth time I am learning new things. I have walked around trying to imagine at least one acceptable scenario for new energy by 2050. I was looking for a scenario that seemed consistent with the way the problem was described by the leading energy science experts who participated in our conference. There are certainly three or four different scenarios, but I find one particular approach a very interesting one, and I thought I would just talk about this one and then sit down.

Imagine by 2050, we have hacked away at this energy problem. What could it look like? When we leave oil as our prime energy driver on the planet, not only would we leave the best, cheapest, primary energy source, this great gift from mother nature, but we also have to give up the best possible way of transporting energy over continental and transoceanic distances. Now that we are looking for an alternative way of storing hydrogen, remembering the experience we have when we drive up to a Shell station and gas up with 300-400 miles of gasoline, we realize what a magnificent beauty gasoline has given us. So when about a hundred years ago we found gasoline (or at least the unrefined predecessors of it) self-propelled coming out of the ground, it was quite an event. We got crazy rich on that. Now, we try to find some way of storing hydrogen and there just isn't anything as elegant as our current gasoline system. When we go to get primary energy from the Middle East or somewhere else and bring it across the ocean to the United States, the actual cost of doing so is really quite small. When we leave oil, we have lost that. Already, we see a future where we will be bringing liquefied natural gas across the ocean, and that is not nearly as efficient, and it is going to be terribly worse when we try to bring hydrogen across the oceans. So we have to ask ourselves, how do we transport energy over long distances in the world of the future?

Well, when I think about the answer to that question, I am imagining a scenario where the dominant way we transport energy over long distances is as energy. We do not cart it around as mass and then reconvert it, but we cart it around as electrical energy. And so if you have one word in this scenario to describe this new oil, it would not be "oil," it would be "electricity." It would not be hydrogen, it would be electricity. That is the key conceptual insight that makes things work.

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Imagine for North America, for example, a continental electrical energy grid--all of Canada, the United States, Mexico and even down to Panama--which connects on the order of a 100 million local sites. The one characteristic that is most interesting in this scenario about these local sites is that at every site, there would be local storage. In thinking about the next stage, we need to realize that when we abandon oil, we not only leave a great primary energy source and the best way of transporting energy from here to there, we also leave one of the best ways of storing it. The biggest single problem of electricity is storing it.

When we are trying to find a way to store electrical energy on a vast scale, as we generally need energy in gigawatt power plants, there are very few options that one can imagine on that large scale for energy storage. But if you imagine attacking the energy storage problem locally, at the scale of a house or a small business, the problem becomes vastly more solvable because there must be many more technologies that are accessible at the smaller scale. As a scientist, I would rather fight the battle of energy storage locally than on huge centralized scales.

It is fascinating to imagine what the impact of this change of approach could have. If every one of those 100 million local sites has its own local storage--which they have locally decided for their own particular sociological, economical reasons to use a particular technology to give them an hour of buffer or a day of buffer, five days of buffer, however long they have decided to do it--then the energy system starts to make a lot more sense. Then the electrical grid can afford to be fairly erratic. The local sites determine what period of time they want to be buffered. Increasingly, the primary energy producers that put electrical power in the world can just simply dump the power onto the grid as the cheapest possible way, and locally, the local storage buys it off the grid when it is cheapest, when it is, of course, most abundant. No longer do you have to have a system as we have currently in the United States, where we have almost twice the generating capacity than we use on average because we have to account for the peaks and the lows of demand. The most interesting part about this scenario is that the local storage aspect to this new electricity-based system means that innovation will be continually and efficiently motivated by free market forces. Because when a decision is made locally: "Well, we made a bad mistake when we bought that energy storage technology from Sears because there's a much better one from GM these days." Customers will agonize over it a bit, but after a couple of

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years, it is not a huge life-changing decision; it is a little mistake. After a while, people sell off their old unit or trash it and bring a new unit in. It is a small thing, but a 100 million times a small thing gets to be very big. So this allows the electrical energy grid to transform itself, with a time period of a couple of years rather than time periods of decades. This gives you tremendously robust energy sources and the possibility to mix locally produced electricity with grid delivered centralized sources.

It is fun to talk about this, but what technology can give you that local storage? You cannot buy it right now from Sears. What technology would be necessary? Here are some of the miracles

### One World Energy Scheme for 30-60TW in 2050: The Distributed Store-Gen Grid

Energy transported as electrical energy over wire, rather than by transport of mass (coal, oil, gas)  
Vast electrical power grid on continental scale interconnecting ~ 100 million asynchronous local storage and generation sites, entire system continually innovated by free enterprise  
Local = house, block, community, business, town, etc.  
Local storage = batteries, flywheels, hydrogen, etc.  
Local generation = reverse of local storage + local solar and geo  
Local buy low, sell high to electrical power grid  
Local optimization of days of storage capacity, quality of local power  
Electrical grid does not need to be very reliable  
Mass Primary Power input to grid via HV DC transmission lines from existing plants plus remote (up to 2000 mile) sources on TW scale, including vast solar farms in deserts, wind, NIMBY nuclear, clean coal, stranded gas, wave, hydro, space-based solar  
EVERYBODY PLAYS  
Hydrogen is transportation fuel

that we need (Figure1). Just providing the local storage does not completely solve the problem, because you have a primary energy supply here that is going to have to come from new sources. I need one other key technology. I need to be able to transform the efficiency of transporting

electrical power over thousand-mile distances, including over continental distances. Instead of taking a hundred megawatts over a thousand miles, I need to take a hundred gigawatts over a thousand miles and do it cheaply so that I can forward the cell power for a couple of pennies per kilowatt hour, 2000 miles away, paying for the entire infrastructure all along the way. If we had an answer to do that, then things start to make sense.

There is a fascinating, wonderful aspect about this scenario. The mass primary power input to the grid from high voltage DC transmission plants can come from existing plants. This is an energy system where you do not have to imagine tearing down everything we have right now and building a completely separate grid. You can start putting this in place right now and have all

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existing plants providing power to the grid. The value is that we can not only integrate residential solar; we can also hook up very remote sources to this same grid, including vast solar farms in the deserts, where you are using the local storage as a buffer supply for when the sun's down; from wind when it is blowing and when it is not in wind farms. You can import vast amounts of electrical power from remote nuclear power sources way out in somebody else's backyard, behind some military fence, where you are absolutely sure there is no nuclear weapons risk associated with plant operations. You can link in electricity generated from clean coal plants, wherever we have found a place for them where we really think that we can strip the CO<sub>2</sub> away cheaply and not have it come back greater than 0.1% leakage per year. With a system such as this, things start to actually make sense to me.

Of course, you still have to solve the transportation fuel problem, and I do not believe there is any clean answer to that aside from hydrogen and plug-in electric hybrid vehicles. But it is fascinating to me to look at this because it tells me the sort of technologies that are necessary to enable a more sustainable energy system. It is not just making the energy initially; it is transporting it around and storing it.

Let me just stop at that point. I have been trying to leave the global climate change argument to one side, disciplining myself only to use my right arm, my pro-energy, pro-business side, and not the part of me that cares about the environment. I believe climate change is a much more critical problem than has been taken into account in our current political debate. And there is just no answer to reducing greenhouse gases, short of a major new program of a magnitude and sustained level of concentration as the Apollo or perhaps actually beyond it. It may take us a whole generation to get this problem solved. Thank you.