KEYNOTE ADDRESS

RENEWABLE TECHNOLOGIES, CLIMATE CHANGE, AND THE LONG WAR: A PORTFOLIO STRATEGY

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I thought I would share with you this morning some thoughts about how we need to respond in energy terms to this long war we are in. I don't believe this is just Iraq or Afghanistan, or just Al-Qaeda, or even just 9/11. I believe we are at war with Islamist totalitarian movements from the Middle East, several of them, and that this will last at least as long as the Cold War did—forty-five years in the Cold War's case—and it will affect all of our lives in many ways for a long time. Some important aspects of it we don't have time to go into this morning, but one important aspect of it is that, in most things that we use in our day-to-day lives, we have choices and alternatives. If there's a shortage of wheat, we can eat corn. If there's a shortage of natural gas for heating, we can use oil or electricity. But in transportation there is not such a choice. 97%, 98% of our transportation is fueled by oil, and although some other uses of oil such as home heating in the northeast can be undertaken with other products, in transportation that's not true. If, for example, Al-Qaeda succeeds this year as they failed last

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year in their attack in Abqaiq, the big production facility in northeast Saudi Arabia, if they take out just the sulfur clearing towers—very easy targets, by the way, through which six to seven million barrels per day of Saudi crude pass—they could take that six to seven million barrels off-line for well over a year and certainly send oil well over $100 a barrel probably heading towards $200 a barrel.

If something like that happens, Brazilians can pull up into the filling station and see the ethanol pump and the gasoline pump and see that gasoline prices have shot up because of what happened in the Middle East, smile, then turn to the ethanol pump—they call it "alcool"—and fill up and drive away. They have a choice. We don't. Yet. So oil has a unique position in that, not only are we dependent on it for a key part of our society's function, but pretty much everything else we buy, such as food, is highly influenced by oil prices because food is transported such great distances, now, very quickly. The Middle East is home to two-thirds of the world's proven reserves of conventional oil. As we move along and find that other fields in other parts of the world are hitting their peaks, that means that production costs increase very substantially. We hit our peak in the lower forty-eight states of the United States about 1970, and other parts of the world are seeing the same phenomenon. If, as a result of that, we find we are more and more and more dependent on the Middle East, we have some even bigger problems than we have today. And when I say "we," I mean the world's oil importers, many of them, most of them democracies. China, though, is an oil importer. All of us oil importers, in a sense, are in this together.

This dependence has some huge pitfalls. Not only could we have terrorist attacks of the sort that I described skyrocketing the price of oil, but simple changes in regime could have similar effects without a revolution of any kind. For example, King Abdullah of Saudi Arabia is someone that we can at least have discussions and sometimes make agreements with. He's a reformer, in Saudi terms. It's pretty easy to be a reformer in Saudi Arabia. King Abdullah is willing at least to talk to someone about the possibility, for example, of women being permitted to drive cars. He appointed a reasonable education minister a couple of years ago, who was trying to reform the extremely hate-filled Saudi education system, and this reforming minister was fired by the head of the Interior Ministry, Prince Nayef, after a few months in the office. Prince Nayef, by the way, was the head of the religious police a few years ago when they shoved the little girls back into the burning school because they were fleeing the flames and didn't have their veils on just right. Prince Nayef is one of two or three men who may be the next king of Saudi Arabia. Dealing with Prince Nayef might not be so easy, in terms of working things out. And if we should end up with a successful coup or something in Saudi Arabia, bin Laden says that his ideal price for oil is about $200 a barrel.

People say whoever runs things in any of the countries of that part of

the world is going to need to sell their oil. Well, they don't need to sell that much of it if they want to live in the Seventh Century. We face, in the Middle East, a complex set of circumstances that leaves us every morning waking up hoping that the night before Al-Qaeda had not succeeded in taking out the sulfur clearing towers at Abqaiq. There are some other aspects to this dependence that are extremely important. We are in the business of borrowing today over $300 billion a year—nearly a billion dollars a day—to import oil. It is far and away the largest share of the trade deficit, much bigger than our trade deficit with China. And that $300 billion-plus a year, part of it, goes to the Gulf, of course, and some of it goes to Saudi Arabia, which makes about $160 billion a year selling oil. Several billion of that goes to the Wahabbi sect of Saudi Arabia, which has essentially the same ideology as Al-Qaeda.

Al-Qaeda and the Wahhabis of Saudi Arabia agree on their genocidal approach to Shiite Muslims, Jews, homosexuals, apostates, and agree on the degree of repression, near total, that everyone else, particularly women, should live under. What they disagree about is who should be in charge. They disagree about whether one should exert all one's efforts to support the Saudi state or whether one should feel free to go flying airplanes into buildings whenever one wants. And they hate each other. Just because they agree on the underlying doctrine doesn't mean they don't hate each other. They loathe each other; they kill each other—very much like the Trotskyites and Stalinists in the '20s and '30s agreed on the underlying value of Communist dictatorship, but just disagreed whether you should be able to do it freelance fashion or only at the service of the Soviet Union. So when any of us pulls into the filling station, it's probably a good idea, if you have a second, to turn that rear view mirror before you get your credit card out and look at yourself just a second, because if you want to know who is paying for those madrasses in Pakistan that teach little Pakistani boys to be suicide bombers once they're ten years old, you are.

This long war is the only war the U.S. has ever fought, I guess except for the Civil War, in which we paid for both sides. This is not a good long-term strategy. If $300 billion a year is something of a burden for us, since our trade deficit makes people less willing to hold dollars—in a crisis the possibility exists of interest rates rising sharply—think what a problem it is for a developing country in, say, Africa. They're trying to pay for $60 per barrel of oil by exporting textiles and foodstuffs. Everybody knows that the biggest problem they've got is debt, and that debt is very heavily driven now by $60 a barrel-plus oil. We've got a problem with our debt. They have a tragedy.

Another aspect of this increasing dependence on the Middle East is that the largest share of oil reserves in the world, and the ones that are most accessible, are in Saudi Arabia, and they're also accessible to OPEC to manipulate. They can turn on the Saudi reserve capacity, increase the supply of oil, drive the price down, and bankrupt their competitors. They

did that in 1985. One of their competitors was the Soviet Union, and it helped bankrupt them, and that was good. But one of their competitors was the Synfuels Corporation of the United States, established in the late '70s—a particularly expensive undertaking to create synthetic fuels. It was not accidental that, a year after the Saudis drove the price of oil down to $5 a barrel, the Synfuels Corporation went bankrupt, thereby helpfully teaching us that one of the stupidest things we can do in order to try to avoid our dependence on the Middle East is have some huge, giant, really expensive way to produce an alternative to oil. Now people will argue that Mr. Simmons is correct about oil peaking in the Middle East, and we're about to reach a situation where Saudi crude prices will go up—that Indian and Chinese demand are going to be so huge in the years to come because their middle classes are beginning to buy cars and so on, that the price of oil will stay up—and that the Saudis would not be able to drive the price of oil down and bankrupt their competitors they way they did in the mid-'80s and, to some extent, in the late '90s. But the dependence is at the back of everyone's mind, and it's one of the things that deters investors in things like cellulosic ethanol and other alternatives to oil—this nagging concern that somewhere, somehow again, these alternatives may be bankrupted by the price of oil being driven down.

What can we do about all of this? If this set of problems I've set out is as serious as I've described and has as wide a set of dimensions, isn't there something we can do? Well, let's start with what we should not do. What we should not do is replay the Synfuels Corporation. And the effort for the last several years, five to ten in the U.S. anyway, the recipient of much of the government money—state level as well as federal—has been, in fact, a replaying of the Synfuels Corporation. It's called the hydrogen highway. Hydrogen fuel cells are very useful devices for stationary use, for space, for a number of special applications. To use them for automotive propulsion for the family car, burning hydrogen is one of the single worst ideas that has come down the pike with respect to transportation and energy in a long, long time.

First all, you have to bring the cost of the cells themselves down by a factor of forty to fifty, and that may be doable. There are smart people working on this, and that may be the easiest part of it. The second part of it is that there needs to be a national distribution system for hydrogen, in which you put, say, natural gas in every filling station, reform it into hydrogen, figure out how to store explosive hydrogen, and figure out how to run the pumps so people can drive up and pump the hydrogen into their cars. I've been figuring that was a multi-hundred billion dollar investment in infrastructure. I talked to a former Secretary of Energy the other day about it, and he said, "No, Jim. I've been looking at it, and I think it's closer to a trillion dollars of infrastructure."

Now these, first two steps I've described, fuel cells and hydrogen distribution structures, are not as big a problem if one has a large vehicle, if

one is talking about, say, a bus, because a bus could be refueled at a central facility and not have to go to a neighborhood filling station. But even then, one still wonders why one would take natural gas, reform it into hydrogen, put the hydrogen in the bus, turn it into electricity, drive the bus on electricity, and lose over a third of the energy in the process, when all you have to do is put natural gas in the bus in the first place. There are natural gas buses running around in a number of cities around the United States. Natural gas works fine in an internal combustion engine with some modest changes.

The other—and really far and away the stupidest thing to do—would be to take electricity; do electrolysis—as everybody did their high school experiment: electricity into water, hydrogen and oxygen out—get the hydrogen, put the hydrogen in the filling station, store it, pump it into the vehicle, and turn it into electricity again, losing in the process over half of the energy. Why not put the electricity in the car in the first place? Into its battery? Hydrogen for passenger vehicles, for family cars, would, I think, replay the Synfuels Corporation debacle in spades.

What we have to stay away from is single solutions, huge investments in infrastructure, and an attitude that says unless one thing provides the full answer, it's not worth doing. You can find in the literature, everywhere now, condemnations of ethanol saying, "look, if you tried to replace every drop of gasoline with corn-based ethanol, look at all the land you'd need, look at this problem, look at that problem." The answer is sure, yes, it would be a dumb thing to do trying to completely replace gasoline with just a corn-based ethanol. Corn-based ethanol needs to use good agricultural land; you've got to fertilize it. That drives up global warming gas emissions. It's dumb to think it's a total solution. There's a place for corn-based ethanol, but there's no place for any complete substitution of one type of system, or one type of transportation feedstock or fuel for oil. We need to look at a portfolio. We need to do what any reasonable investor does and say, "I'm not sure where all of these technologies are going, but this one looks good to me; this one looks good; this one looks like maybe we'll put a little less than a full effort, but a little something into it." And you end up with a portfolio of a number of approaches, some of which are going to work out better than you think, some not as well. That is the mindset we need to think of in terms of moving away from dependence on oil.

Now what might some elements of that portfolio be? First of all, electricity: off-peak electricity in the United States. Some public utilities sell electricity cheaper off-peak at night than they do during the daytime since there's less demand then. Off-peak electricity, in many parts of the country, can be sold profitably for four, five cents a kilowatt hour. Now if you have a battery in your hybrid that has about six times the energy, six times the kilowatt hour capacity that batteries in today's Prius' have—nine kilowatt hours instead of one and a half—if you plug it in overnight, you

buy several kilowatt hours for a nickel each. The next day, you drive for twenty, thirty, forty miles, wholly on that overnight charge before you become a regular hybrid and go back and forth between liquid fuel and electricity. You will be getting over 100 miles per gallon.

Everybody knows, I trust, that when you run out of your overnight charge in a plug-in hybrid, it's not nearly as serious as running out of a charge on your cell phone. You don't have to plug it in again. You just become a regular hybrid. So instead of getting 120 miles per gallon, you're only getting fifty miles per gallon. Okay. We're plugged in overnight, and we're driving on off-peak electricity, roughly a penny a mile. A penny a mile has a number of attractive characteristics to it. Not only is it one-tenth the cost of what you are spending now in terms of your outlay for transportation fuel, but for most vehicles, it's going to be sufficient for a very large share of their driving. Half the cars in the country drive twenty-five miles a day or less. So if you have a thirty mile charge on your battery, you may go, on the average, months before you go to a filling station. And forty miles a day includes three-quarters of commuters. So if you have a forty mile battery charge, which is what General Motors is advertising on its now-announced Chevrolet Volt, even if you are a commuter and drive a substantial commute—fifteen, twenty miles a day—you still are going to be able to do it all-electric.

When it all comes out, as I said, because of the low cost of off-peak electricity—and if you have to buy at peak level you're still in the ballpark of two, maybe three cents a mile—you are in a world in which nobody, in my judgment, is going to sit over there in the Middle East and say, "we're really worried about this cellulosic ethanol and some of these alternative liquid fuels the Americans are working on; so let's turn on the pumps, the reserve capacity, and drive the price down to $5 to $10 a barrel." Why don't they do that? Because $5 a barrel still loses versus penny-a-mile electricity. They would have to drive the price down to under $5 a barrel to compete with penny-a-mile electricity. And I think that means that having plug-in hybrids makes it much less likely that we will see the aggressive tactics that we saw in the '80s and '90s in terms of trying to bankrupt other alternatives. I think the low cost of electricity helps protect, not only plug-in hybrids, but $30 to $40 a barrel cellulosic ethanol or even tar sands oil from Canada and so on. So plug-ins, as far as I'm concerned, are what make a lot of the other things possible. By the way, from an environmental point of view, studies that are cited in these materials I've distributed indicate that you would have to have about 85% of the cars in the country be plug-in hybrids before you would need to add any baseload. You don't need to add any new power plants. You're using essentially un-used nighttime capacity.

And secondly, because what comes out tailpipes is so dirty compared even to what is produced by the whole electricity grid in generating electricity—dirty in CO_2 terms—on the average, moving from a regular

internal combustion engine to a plug-in hybrid reduces global warming gases for that vehicle by something in the ballpark of 30%. It's around 95% in California. It's around 30% average for the country as a whole. It only reduces CO_2 5% in states like Ohio and West Virginia that have very coal-heavy grids. But you are, with plug-ins, moving into a world in which you're making substantial improvements in emissions and global warming gases and not adding to the requirements for baseload. As the grid gets cleaned up—as we move more and more away from dirtier forms of coal and into IGCC coal with carbon capture and sequestration, or into solar, wind, even nuclear—methods of producing electricity that do not substantially increase global warming gas emissions will be used. You are cleaning up not only the grid, but you're also cleaning up, essentially, the vehicles because these would be heavily dependent on electricity.

Biofuels are another important piece of this puzzle, but I don't believe more than fifteen billion, maybe twenty billion gallons maximum a year will come from corn. Enough corn ethanol probably can be produced in this country without putting a huge stress as the land use and the systems move the country entirely to E-10 gasohol—10% ethanol. But if you want to do much more than that—and I think you should, to move to biofuels from other feedstocks than corn—then comes the production of ethanol from cellulosic biomass using genetically modified biocatalysts; the production of butinol. British Petroleum and Du Pont have announced that they are now producing butinol from sugar beets and, I think, looking to do it from cellulose. Butinol is an alcohol-like substance that has more energy in it than ethanol and can be used in pipelines, where ethanol has a hard time being used. Biodiesel and renewable diesel from all sorts of waste products represent another possibility.

All of the technologies are useful and interesting and important, and they are useful and interesting and important for two big reasons: one is that they can be done almost anywhere. There can be prairie grass almost everywhere, or some variety of grass that can be used as a feedstock for cellulosic ethanol. There is waste every place there are human beings, every place there are farms, so distributed generation of the fuels is an important feature. The fact that all of them are essentially simply releasing CO_2 back into the atmosphere that's going to be released anyway is important. Plants fix CO_2 in the photosynthesis process. If the plant dies, at some point the CO_2's going to waft back into the atmosphere. If the plant is cut and turned into cellulosic ethanol, the same CO_2 is going to waft back into the atmosphere. In neither case are you digging down into the Earth and pulling out CO_2 from dinosaur bones and ferns and turning that loose in the atmosphere. So you're essentially just recycling the CO_2 with these alternative biofuels.

And the third thing is that there are some very exciting new possibilities: for example a Cargill plant north of Omaha producing polylactic acid from corn and, soon we're told, from cellulose. Polylactic

acid is the principal ingredient in a large share of plastics. We are on the edge here of being able to begin a movement from a hydrocarbon to a carbohydrate-based society, not just for transportation fuels, but much of our production of chemicals. And what that means is that people who are getting into the business of renewable diesel or biodiesel or cellulosic ethanol or butinol may well be able to get up on the step more quickly because they can produce specialty chemicals from things like cellulosic biomass, which have much higher margins, probably, than fuel, and get their business going in a sensible way with something that's essentially a bio-refinery—not just a facility that produces a single type of fuel.

The fourth and final area I'll mention is fuel economy from fundamental changes in the vehicles themselves. I've been looking at the Defense Department's needs. 70% to 80% of its energy needs are for aviation fuel. If you look at the design of helicopters, which are gas guzzlers that make SUV's look thrifty by comparison, much of the technology is thirty, forty, fifty years old. With what one could do with new types of lightweight technologies, new engines, and so forth, you can have improvements of a factor of five or six in the fuel efficiency of helicopters and probably double efficiency for long-range transport aircraft. For cars, some of the same technologies are relevant. For a number of years, we used carbon composites, some of it initially very secretly, in the construction of things like stealth aircraft. Then it moved to being utilized in other types of aircraft. Now Boeing is beating the pants off Airbus with its 787 in part because of its fuel economy, and its fuel economy is in part driven by the fact that about half of the airframe of the new Boeing aircraft is made out of carbon composites. Formula One racers are made out of carbon composites, and the reason is clear, if you ever see on a film a wreck of one at 220 miles an hour. It will hit something and bounce and roll and roll and the driver will walk away because he's air-bagged and strapped in, and there are one or two little dents in the car. Why aren't there more? Because it's made out of carbon composites, and carbon composites are ten to twelve times more resistant to crashes than steel. And they're about half the weight. About half the weight means approaching double the mileage. So if we start looking for improvements in vehicle efficiency by expanding into the commercial vehicle market what's already in the commercial aviation market and the racing car market, we have some other fuel economies that are quite plausible.

Well, if you take it together—moving toward plug-ins, moving toward biofuels, and moving toward carbon composite construction of vehicles—you can make some fairly dramatic progress. I hasten to say none of these technologies is pie in the sky, and they have all been invented for other reasons and are being used all the time in the market, commercially, for other purposes. You don't need a Manhattan Project. You don't need a bunch of people standing around in white coats thinking up something for the first time. These three technologies are here. They require some

sophistication in application; they require some manufacturing technique improvement; they require getting up on the learning curve so that the manufacturing is efficient; but they're not new ideas. The batteries that you need for the plug-in hybrid already exist because most of us don't want to charge cell phones every fifteen minutes. The reason the charge lasts all day is the lithium ion batteries. Millions of them are shipped into the U.S. every week. You've got four or six in your laptop. The cellulosic material and the chemical processes, particularly for things like cellulosic ethanol, are made possible because of genetic engineering of the biocatalysts so that we can be as effective as cows. Cows turn cellulose into sugar in their stomachs easily by secreting enzymes that break the cellulose down. With genetic engineering, we can be almost as effective as cows, which is good. Genetic engineering has been boosted for many years by the pharmaceutical industry because it had all sorts of reasons for utilizing it. We don't have to invent genetic engineering. And the composite construction, as I've said, has been around aviation for nearly decades and is now in the vehicles market, but for race cars, not yet for commercial cars. If we put these together, a fifty mile per gallon Prius with the right batteries becomes a 120 mile per gallon Prius, running at a penny a mile for the first thirty, forty miles. If what's in the tank is E-85, let's say 85% ethanol from cellulose and 15% gasoline, and the car is made out of carbon composite materials, the fact that it's running on 85% cellulosic ethanol means that it is getting something in the ballpark of 500 miles per gallon of gasoline because it's running mainly on electricity and ethanol. And because of its carbon composite construction, it has something approaching double the mileage of a largely steel-based Prius. It is up there somewhere in the ballpark of getting a thousand miles a gallon of gasoline. It'll take a few years. It's not next year, but I don't think it's as many as five away before you could start seeing vehicles in showrooms with those kinds of characteristics.

One thousand miles a gallon. That ought to make a Wahhabi frown. Thank you.