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Challenges and Opportunities of Unconventional Oil and Gas Production

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I'm very pleased to be here. I'm very pleased to be the third distinguished president's lecture. I want to leave you with a couple of facts about what associates me with [previous speakers in this lecture series]. First, Norm Augustine and I have exactly the same birth date; we were born the same day. Secondly, John Holdren wouldn't be where he is now if he hadn't passed the chemistry course I taught him at MIT.

I want to speak to you about four aspects surrounding unconventional oil and gas in this country. The first is the staggering changes it has brought to the energy outlook of this country in just a very brief period of time. That's highly unusual. In the 50 years that I've been following energy matters in this country, it is certainly the most abrupt and massive change in energy outlook that I have experienced.

Second, I want to speak to you about the economic and geopolitical consequences of this revolution in unconventional oil and gas production. Third, I want to speak to you about the one single serious matter

A video of Dr. Deutch's lecture, which includes his slide presentation, is available at: **www.stevens.edu/lecture** that can derail the prospects of unconventional oil and gas for both the United States and for the rest of the world—and that is, how are we going to manage its very, very serious environmental impacts? And finally, I want to spend a few minutes about the lessons that this recent history of a complicated science and technology issue has for universities, especially for universities such as Stevens or MIT that have a strong technical character. So those are the items I want to cover with you, and let me begin by asking you to go back five short years, the beginning of the Obama administration, and remind you what was on the energy agenda of the country at that time.

First and foremost, it seemed like the United States was hopelessly dependent on imported oil. It had been for decades. It looked like this country was going to be dependent on imported oil as it was growing in expense and with all of the geopolitical implications that had for the foreseeable future. Moreover, the drop in production of conventional natural gas in the United States indicated that we would have to import natural gas at increasing quantities. And the Energy Information Administration of the Department of Energy projected that by the year 2015 we would be importing 25 percent of our natural gas from abroad as liquified natural gas in tankers at very high expense at a range of $10.00 to $15.00 per million British thermal units (BTUs).

Secondly, the United States had embarked upon a major legislative initiative to adopt a greenhouse gas policy for the country. It was discussion about introducing a rather complicated esoteric cap and trade system to reduce the emissions of greenhouse gases, particularly carbon dioxide, through a legislative proposal of setting a market for the amount of emissions that could be managed, and if you couldn't do that, you would have to pay a fine and pay that to the government. It was assumed that that regulation would establish a policy for the United States on greenhouse gas emissions.

Third, there was an accompanying expectation of a renaissance for the nuclear industry. The nuclear industry looked like it was on a promising track both in this country and elsewhere, especially because it was a carbon-free, electricity-generating technology.

And finally, from the money that was raised by the government for selling permits for the emission of CO_2, $15 billion a year would be available for research and development and demonstration of renewable energy technologies.

That was the outlook and the agenda of the country five years ago. What is the outlook today and how has it changed?

First of all, there has been no progress on carbon legislation in this country since that time, and no one expects that the Congress of the United States will enact legislation to control the emissions of greenhouse gases or to address climate change. Indeed the president has indicated his intention to rely on environmental regulation by the Environmental Protection Agency under authorities provided under the Clean Air Act.

Secondly, nuclear power is off the table. It is not going to happen. It'll happen in a few countries. It'll happen in China, happen in Korea, maybe one or two other places but not in Europe or the United States or elsewhere for two reasons. First of all, the Fukushima accident, which once again raised in the public's mind and in our political leadership questions about the safety of nuclear power, but also its cost, have continued to elevate relative to the alternative of other electricity-generating technology.

Third I note that the budget outlook is such – in the absence of sale of permits for CO_2 emissions – that there is not that $15 billion a year for renewable energy R&D that was anticipated five years ago.

But the big news is something else. The big news has to do with the huge and unexpected growth in unconventional oil and gas production and resources both in this country and in North America generally. Instead of anticipating imports of natural gas, we now anticipate that by the year 2015, 25 percent of natural gas consumption in the United States will come from unconventional gas production. During the same period of time in the five-year period, the price of natural gas has dropped from $8.00 to $10.00 per million BTUs to $4.00 or even less per million BTUs—a drop of a factor of two. The low cost of natural gas has pushed into the electricity sector, so natural gas is a technology of choice for generating electrical power in this country and in many other countries for the foreseeable future. Coal has reduced its presence in the electricity sector by 20 percent. Nuclear power is gradually, as the plants decline and their lifetimes expire, becoming less and less of a presence. And the low-cost gas has always also prevented renewable electricity-generating technologies like photovoltaics to enter the market.

So all of this has been a tremendous change—a tremendous change which has benefited, had economic benefits and geopolitical benefits, from the presence of considerable additional resources that were anticipated, especially of gas but also of oil. Let me talk about said economic consequences of this great prosperity that was unanticipated. First, as I mentioned, there was the low-cost price of gas from a wholesale value of $8.00 to $4.00 per million BTUs, meaning that U.S. consumers, especially in the Northeast, were spending less for heating their homes, electricity costs were going down, and the price of producing chemicals in this country was going down. Secondly, there has been an enormous increase in jobs in the domestic oil and gas industry across the country from North Dakota to Pennsylvania from the great, great generation of drilling that has taken place in unconventional oil and gas, and no longer are we importing those resources which would represent jobs in some other country.

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There is an enormous incentive now to look at natural gas technologically to introduce it as a replacement for liquid fuels wherever they may occur, because liquid fuels such as motor gasoline are so much more expensive. And even though gas is going into the power sector, the big opportunity, which hopefully will come with time, is the introduction of natural gas either directly as a fuel for light-duty vehicles, transportation vehicles, cars, or perhaps through conversion of the gas to liquids to some other fuel—even methanol as a fuel for automobiles. So this is a tremendous change and a tremendous set of economic consequences which have been a benefit to the U.S. economy in almost all respects.

What about the international consequences? These are equally important. For a person of my background, energy has always had an important element of international and international political implications that deserve and require attention from our country's leaders. First point to note, and it's an important point—this is not a U.S. revolution. It is a North American revolution. Canada has been a joint partner all along the way in the production and the resource development of these unconventional oil and gas resources. Mexico has huge resources itself, and the current president of Mexico indicates that he wants to modernize their oil and gas industry to take advantage of these opportunities as well. And another thing which points to the strength of the U.S. industry is we really have an integrated oil and gas market through Canada, the United States and Mexico, an integrated North American market not caused by government, not caused by Washington, D.C., but the importance for businesses of making sure that they can move this resource which powers so much of the country, oil and gas, around the country. So it is a victory for North America and North American integration, a very strong example.

"These resources are present throughout the world, and it has changed the circumstances from an expectation that all the oil and much of the gas is in the hands of a few major resource holders to a much broader range of countries and of people. That's terribly important in terms of the geopolitical relationships between consuming countries, such as our European allies and ourselves..."

Why has it happened here and not elsewhere? The good Lord did not put down unconventional oil and gas resources just in North America. They're all over the world, but they happened here first for two reasons. One is the enormous energy, controversial as it may be, of private ownership of oil and gas resources under your land that you own. In almost every other country of the world, if there are oil and gas resources under your property, the government owns it, and therefore there is not a harmony between exploiting those resources on your land or in your community and your community and you making money. And the second point is there is an enormously greater intensity of drilling rigs and drilling rig resources and drilling know-how in the oil and gas industry here in the United States, which is simply not matched anywhere else in the world.

If you leave out China, the United States has something like 70 percent of all the world's drilling rigs, and as I will show you momentarily, those drilling rigs are the key to the technical advances that permitted hydraulic fracturing to take place. Two features: one was the ability to have rotating steerable drilling, which allows you to put the drill bit where you want it to be, four kilometers from where you started to within a distance of a very few meters—unbelievable control over drilling. And the third was this active hydraulic fracturing that by perforating the well along the way and injecting huge amounts of water into the surrounding rock, you fractured it and released the oil and gas that was present in tight sands or in shales particularly, much more being present there than had been expected, and you could do this in a very economical way. Those technical advances occurred in this country from the industry in this country, not only big companies but small companies as well, and that's why it's not happening as rapidly elsewhere in the world although the resource is present.

So you can expect that over time this unconventional oil and gas activity will spread to Latin America, for example in Argentina and Colombia, to North Africa, Indonesia, and Algeria, and Morocco, to Europe where there are vast deposits, in the UK, France, eastern Europe and Poland and Bulgaria, in Russia, in Asia, particularly in China and India. So these resources are present throughout the world, and it has changed the circumstances from an expectation that all the oil and much of the gas is in the hands of a few major resource holders to a much broader range of countries and of people. That's terribly important in terms of the geopolitical relationships between consuming countries, such as our European allies and ourselves, and our producing countries, not all of whom are the greatest friends of the United States around. So this has been a tremendous benefit to U.S. foreign policy.

The U.S. is going to be much more influential with global energy markets, and many of the countries that we're concerned about have faced a huge adverse wealth effect from realizing that their reserves no longer have the value that they used to have. Iran is the largest holder of conventional natural gas reserves in the world. Suddenly the value of their gas is much less than it was before. Russia was exporting gas to western Europe at $10.00 per million BTUs while the price in the United States is three to four [dollars per million], and companies are talking about exporting our gas from North America, if not from the United States, and exporting our oil to these countries to bring them the benefits of diverse source of supply at lower costs.

So all of this does put instability into these countries; it may be countries like Saudi Arabia, Iran, Kuwait, Venezuela. We'll see falling revenues from their resources, falling wealth effects. It may put strains in their country and instabilities that may even lead to conflict. But the fact of the matter is the balance of power has shifted from those supplying countries that were most undemocratic supplying countries, which were of such concern to us, to other parts of the world, which are of greater interest to the United States and its allies, to Europe, to Japan, the large importing developed economies, but also to rapidly emerging countries such as India and China who need energy for their growth, and it has shifted the balance in their favor compared to what it was five years ago.

Well there are some huge uncertainties, huge uncertainties that should be of interest to engineers because it is also opportunity. The first is the world today consists of three gas markets: one in the United States where you can buy your gas at $3.00; one in Europe where you have to negotiate with Russians, get it for $10.00 or $12.00; and a third in Asia where it's really substituting for diesel oil, not for coal like it does in the United States in the power sector. In Shanghai or in Singapore or in Tokyo, you have to pay $15.00 to $18.00. Will that diversity in those three different geographic markets continue, or will there be a gradual, not sudden but a gradual moving, through longer and longer pipelines, through more and more LNG tankers? Will there be a gradual harmonization of that to a single global price for natural gas ex-transportation? That would have a tremendous implication on what has been a division of the world into three different markets—huge, huge.

Second point is at the present time the cost of gas in the United States, $4.00 per million BTUs, compares to oil at $100.00 a barrel and somewhere in the vicinity of $15.00 or $18.00 per million BTUs. There's the greatest disparity between natural gas and oil costs today in this country that has ever existed in history, and that means that there's a tremendous economic incentive for technology to find ways to make that natural gas substitute, whether it's in the transportation sector, whether it's in the chemical industry, anywhere to substitute for petroleum as a feed stock. So those are the two big uncertainties, which are out there, uncertainties which also provide opportunities for technology innovation.

But the largest question has to do with, will the public agree to seeing this kind of exploitation go forward because of its environmental impacts? And I'm sure everyone here in the audience knows that the controversy in the United States over this use of unconventional oil and gas is extremely strong, very equally divided, and by no means decided. So the question about how we manage those environmental impacts going forward is key to whether we'll be able to enjoy these opportunities I've spoken about, and also key for other countries, because other countries will look to the United States on how they've managed these environmental impacts and how they've managed the stewardship of the resources.

Now at this stage, I wasn't going to do this but I do think I have time, I hope I have time, to show you a few slides to underscore some of the points I've made. So here is a map which just shows you where these resources are located, and it underscores the point I want to make to you. This is not happening in Texas, Oklahoma and Louisiana. This is happening everywhere, North Dakota being in the Bakken up there. Secondly, you can see that it is everywhere in North America; in Canada, in the United States, and in Mexico. And every time they draw this graph, there are more places which are located on it because there's been more exploration. So it's a North America phenomenon. Here's a chart as it exists today for the world, and again you see the whole world has this pattern of unconventional resources. It's no longer in the Middle East. It's no longer in the Persian Gulf. It's no longer in Venezuela, which doesn't seem to have any; I'm sure that's not right, but there's none reported. So this is a worldwide blessing which is available.

Here's the one chart that I want to show you about how hydraulic fracturing is done. There at the top on the surface you see a drilling rig, and it goes down in a vertical length one or two kilometers. And then they put a side passage on it, which goes out as far today as three or four kilometers. And along the path through a complicated way of using pegs to block the way and perforating the side and injecting water, they make these sides—at every point they inject into the side of the formation, create these fractures by putting in the hydraulic fracturing fluid, and that's the way they cause the production to happen. This is not a mom and pop drilling operation; this is a very large and sophisticated technical operation.

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Okay, this is really, you know, not responsible for me to show this. This is what a site looks like when it is getting prepared for hydraulic fracturing, drilling and perforation. And what I want to point out to you is there's one—in this particular older slide—there's one well being drilled here and hydraulically fractured. Today there's been a lot of progress. There's several wells drilled from one pad. But what I draw to your attention is the number of trucks around that well site. Now I want you to imagine living in a place like western Pennsylvania, beautiful part of the country, where the roads are narrow and the communities are small. And one day 60 hydraulic tank trucks loaded with hydraulically fractured fluid come up with Abilene, Texas license plates on. This is not a happy circumstance for that community. And while the person who owns this piece of property is likely to make a fortune from this operation, the people who live around them may not. So again, the slide here stresses the magnitude of the operation, the impact that it's going to have. And I want to tell you when this country starts producing this in broad numbers, 10,000 of these wells will be drilled a year, and they're gonna be drilled everywhere. They're not just gonna be drilled in you know – I personally don't have the same concern about a well being drilled in Texas or California that I do in Massachusetts, but people can differ. It's everywhere.

So it started off on a bad foot, and it started off on a bad foot—I hope I don't offend anybody in the audience—principally because of lobbyists and Washington lawyers who said oil companies, our clients, do not need to tell you what is in this fracturing fluid that we are injecting underground. So first of all, I want to tell you that here is what the character is of fracturing fluid. It's about 90 percent water. It has one percent sand, and here are the kind of additional agents that are added to this for a variety of Julia Child's purposes for having this fluid do what you want it to do. But the idea that a company or a company's representative could take the view—we're going to inject this in your county, in your farm, in your community, a place which has had no oil drilling before, and not tell you what the content of that—it's just goofy. It's like shooting yourself in the foot. Well, they've backed off of that, and they know that that's not gonna work, and now all of the companies tell everything that is in their fracturing fluid. And they do it for two reasons: because their argument that there was intellectual property in the composition of the fracturing fluid was phony, and they saw that the public simply wasn't going to accept it. So that is a very important bad start. And still if you look at the single thing which bothers people the most about hydraulic fracturing, they say the hydraulic fluid will go into our drinking water.

So here is a chart of a lateral in the Barnett Shale, and here you see, carefully done, every possible fracking that has occurred and how far the fracks through the perforations went into the formation at the different depths. These are 8,000 feet, so that's what, a mile-and-a-half or more than a mile-and-a-half. And you can see how far these injections went. Now notice the distance from the surface, and there it shows the depth of the water table everywhere along the surface along this lateral distance. So you can see that there are thousands of feet of difference—very unlikely. In fact, there is no way that that fluid which has been injected down there is going to find its way to the surface. So that whole issue, as emotional as it is, has been so terribly mismanaged. But it also shows you something else. What if we got better at directing each one of those fractures and knew that they were going in the most productive way, how much less water would we have to use if we could be more intelligent about making those fractures in order to do production? And the answer is a lot. There can be a lot less high utilization of water in the hydraulic fracturing, and that goes to show you that the industry over time with field experience will make the advances so as to make this a much more efficient operation.

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How could some of this fluid get to the ground water? Certainly it's possible, because when you finish the well, you close it up, but you begin to open it up for production. The first thing which happens is that you have a flow back of water that you injected in it now coming back carrying some of the minerals which are present in the earth, and if you don't have a good completion at the top of your well, you could have a spill and that could find its way into somebody's neighboring property in some neighboring place. So good engineering completions here are critical, and while it is true that there's not much risk from this in-depth injection, it is also true that there is a significant water risk if a completion is not done right. If the cementing job in the well or the casing of a pipe along the well is not done properly, there can be surface leaks, which can go into the water table.

My last point is another point about technology. This chart says there's a lot of difference in how productive wells are—big variability. That says with engineering knowledge making sure that you use best practice, best management on a well, there is a tremendous opportunity for much greater productivity per well, again indicating that you could have better effectiveness here with less environmental impact. That's it for the slides.

So there are five environmental impacts I want to draw to your attention here in this when it's done at scale. The first is air emissions. The air emissions are of two types. They're from all of the power equipment, which is on the surface when you are operating the drilling and injection equipment. There's a small very important issue about the leakage of natural gas from the well completion. You will know that natural gas is – all of you I'm sure are as competent as John Holdren in chemistry—it's methane, but methane is a much more potent greenhouse gas than carbon dioxide, so even small leakage of methane is a matter of some concern here. So the air quality consists of the traditional controlled regulated pollutants but also special attention to the volatile organic compound of methane because of its great greenhouse gas characteristic.

Second is water. You have to purchase the water, acquire it. You have to get it to the site. You have to inject it. When you inject it, the first thing which happens is flow-back water, which brings back some of the hydraulic fracturing fluid. You have to capture that water. You have to put it into a holding pond. The holding pond may service many different wells or many different paths, but after that for the remainder of the lifetime of this well, which is 20 years, there will also be flow-back water from geology itself. And I should mention somewhere along the way these geologies are quite different. The effects are the same. The opportunities are the same. But the particular geology affects its water content. Very different between the Eagle Ford in Texas and the Marcellus in Pennsylvania. But that water will also come back, and it will have some of the minerals which are in there. There's a curious chemical fact that the Marcellus actually has a tiny, tiny, tiny bit of radium in it, the water in the Marcellus. The Utica, which is underneath the Marcellus, doesn't have any.

So the geochemistry is different here, but that water has to be held and then something has to be done with it. Well what can you do with that water, because it's not drinkable, it's not usable. Well, you can do one of three or four things. One of the things you can do is use it as injection water for the next one. That works fine as long as you're in a geometrically increasing world. But if you're not, if for some reason you're not always increasing, eventually you have more produced water than you have need for injection, particularly at a certain region.

Secondly, you can go and inject the water, this produced water, into very deep wells, injection wells, which are regulated by the Environmental Protection Agency under a water disposal regulation, and you can do that. That means you have to transport the water by truck and then inject it, and in fact in places like Pennsylvania they have no injection wells. So they transport it by truck and put it in injection wells in Ohio. How long Governor Kasich will allow them to do that is an open question, or when he'll start charging real money. Or the third thing you can do is just let it go and fall in the fields, in the streams, but then you really are polluting those streams and that's unacceptable I think in any part of the country. And finally, you can send these huge amounts of water to treatment plants, which have been built for an entirely different purpose, and ask them to clean the water out.

I go through this because the Environmental Protection Agency is responsible for this but so are all the state regulatory agencies, and they are in each other's throats; they are in each other's throats. The Environmental Protection Agency and many people in Washington, as expected, believe that one national authority is best. The state regulators who have more real experience on the ground know that there's a difference between the land in Arkansas and in Pennsylvania and in Colorado and in Wyoming, where in Wyoming they're much more worried about the effects on visibility, dust and visibility. There's a huge quarrel about how this is best regulated, and let me tell you that's not a good thing. Moreover, the Environmental Protection Agency goes at this by saying what are the authorities that I have on my shelf that Congress has voted me, and how can I cobble them together to address this problem. I was talking to your distinguished provost a moment ago. He asked a tremendously interesting geotechnical question about how best to manage that water, and let me tell you it's a big deal. We're going to have tens of thousands of these wells. But the Environmental Protection Agency works from the legislation on the shelf. It doesn't work from thinking this is a systems problem; it's not a systems engineering problem.

So there is a big question here about how are we going to give industry the initiative to do better. Where I believe all the prospects are, they will do better and can do better. There's a big question about how authority should be shared on independent regulation between the states and the Environmental Protection Agency. And there's a big question about how this knowledge of regulation should be spread to the other countries who are beginning to use or want to use this technology. So it's a blessing. It has huge economic benefits to the country, huge benefits to the region and eventually the world potentially. It has enormous geopolitical benefits; it doesn't make the world perfect. We are not energy independent, but we're less dependent on imported oil. We are not energy independent. We used to import—North America now, I don't talk about just the U.S.— North America used to import about 40 percent of its oil. When this thing goes up a couple years from now, we're gonna be importing less than ten percent, and we may be even exporting. So it's huge. But, if you don't manage this environmental matter properly, this is not gonna happen; the American people won't accept it.

But what's the story for Stevens? What's the story for MIT? What's the story for universities? There is a lesson here; there are lots of important lessons. And I just want to conclude with spending a few minutes about what this means for a university. First of all, you're gonna wait a long time until you find a more contemporary example of where a technology change in society melds technical advance, economic incentives, regulatory and political challenges. This is an absolutely perfect, vivid, living example of it. Now how well do we do at dealing with our students and carrying out our research in light of such kinds of problems? It's not only this problem; it's not only the energy area. It's in healthcare where I know you do have an initiative. It's in education. It's certainly in the issue of climate change, because none of what I've told you may be momentarily helpful to climate change because you're substituting natural gas for coal. But the natural gas itself produces CO_2. So climate change is not addressed here.

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But it does say to the university, "Are we organized?" Especially those universities who care about innovation, those universities who care about working on their society. And I noticed that you're "the innovation university." MIT's tag line has gotten much use. It's, "making a difference in the community." But my point is how does this look from an academic point of view, and the answer is we're very, I think relatively—I'm talking now from the perspective of an MIT faculty member—we're pretty rigid in our disciplinary structure, pretty rigid. Appointments and promotion go through departments; certainly at MIT they do and conventional departments at that. And we incidentally are living with a 50-year-old history of separating science departments from engineering departments. I don't know what that's all about. I know what it was about 50 years ago.

But I can pull out any random faculty member at MIT and ask them, "Do you know whether this person's a professor of physics or electrical engineering or material science?" Not a chance. So we're still back in those old disciplinary days. I don't even know, your distinguished provost, whether he's an engineer or a scientist. He's assisted on a geotechnical problem. Is he in the earth atmosphere and planetary sciences, or is he in civil engineering? I don't know. But our university organizations are still looking backwards, not forwards on these problems. As far as I'm concerned, we could do more. We don't have to change everything overnight. We could try some experiments to do it.

And I think that the lesson of this, what it suggests for education, is even more evident. First of all, students love this kind of problem. Students that I know love this kind of problem because it combines their knowledge that they have learned in their disciplines properly with the opportunity for making a difference in the real world. But we don't in our curriculum. We don't in the opportunities we offer them to hear and learn skills from people that will allow them to put together the different disciplinary skills that you need to make one of these problems work. We never really do that heavily and certainly not at MIT in their education. Again, I underline the enthusiasm the students have everywhere I go. Of course if they ask me to come and talk about energy, the students who come are interested in energy, but boy do I hear a lot of interested students.

So I conclude by saying a big deal has happened in the United States – a big deal for the United States and for the rest of the world – and that is this explosion of unconventional oil and gas resources and production. It's a blessing, an economic blessing, and it's a geopolitical and foreign policy blessing. It's not a sure thing. How it will develop and if all the opportunities can be realized or not, not a sure thing. But the most important thing is to be sure that you listen seriously to these environmental impacts because they are real, and somehow we organize ourselves to do better at them than just to sit by and wait and say, "Hope it'll get better." And finally, from this story and others like it, it really does say to the universities that there's so much opportunity to do things a little bit differently and really make a difference to our fellow citizens in making the world a better place. Thank you so much. Thank you.

A video of Dr. Deutch's lecture, which includes his slide presentation, is available at:
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