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Session 5: "Energy and the Economy"

Speakers:

Adam Sieminski, Deutsche Bank

Stephen P. A. Brown, Resources for the Future

Donald L. Paul, University of Southern California Energy Institute

David Sandalow, DOE

Christof Rühl, Group Chief Economist, BP

[Note: Recorders did not pick up introduction of panel (see biographies for details on the panelists) or introduction of session.]

Adam: Microphone. So, we've lost a little bit of time because of all of the sessions running a bit over, but here is how we're going to make that up. I had about 12 minutes worth of slides that we're going to abandon. Isn't that great? We get to hear from the panelists rather than me. Now, my name is Adam Sieminski. I'm the Chief Energy Economist for Deutsche Bank. Don't let that intimidate you. I'm really a civil engineer, and, because of that, I wanted to make sure that we had at least a few economists on the panel here with us, and we actually do indeed and I'll be introducing them in a little bit

The introductory remarks I wanted to make really quite simple. The topic of today's discussion is energy in the economy. And ,looking at this from the perspective of energy demand, I think we can make a really simplified conceptual attack at what energy demand is all about by saying that it's really just a function of three things: Population, per capita incomes, and energy intensity which is energy demand as a

function of dollars of GDP. So, if you think about world population, it's been growing actually pretty rapidly, well over 1% growth, from 1950 towards 2000. But the projections from both the United Nations and the U.S. Census Bureau say that global population will slow down, still growing at something like 0.8% or 0.9% over the next 50 years. There are about 6.5 billion people on the planet right now, and, by 2030, when a lot of energy projections are set, we'll probably have close to 8 billion people. So, population is growing and if you wanted to round off the number, you'd say 1%.

About per capita incomes, the average growth in per capita income globally over the last four years has been 2%. A lot of nations have policies on reducing population growth rates, but virtually every country in the globe seeks to achieve faster per capita income growth, yes. So, what is per capita income growth? That's how much you earn, right? Do you want that to go down? No. So, per capita income is likely to go up, and it's probably not going to go up appreciably less than the 2% that it's been doing for the last four years. So, population is growing and per capita income is growing. What about energy intensity?

So, that's the good news from the standpoint of using less energy resources. Energy intensity in the economy, the amount of energy needed to grow GDP, has been falling. The long-term growth rate has been about a minus 1.3% figure. So, it's been falling at about 1.3%. A lot of studies suggest that, with an effort on the part of technological development and maybe some government mandates, we might be able to improve that minus 1.5%. What does all this mean? It means that energy demand in general is likely to grow. Population and per capita incomes are growing faster than the ability of improvements in energy intensity, could think of that as being efficiency is not quite the same is going down.

We have a huge number of countries: Brazil, India, China, Mexico, Russia, and others where per capita incomes are low and so also is oil consumption per capita. If China, which uses less than a half a gallon a day per person, were to achieve rates of

oil consumption anything like what's happened in South Korea or Taiwan in Asia or even at the lower rates that we see in many of the countries in Europe, oil demand in China alone would go up by a factor of 4 or 5 and possibly by an order of magnitude.

Now, China is currently burning about 9 million barrels a day. So, that means China in theory, if they had income similar to those in the U.S., for example, could be using 90 million barrels a day. Now, does anybody here want to venture the likelihood of being able to supply 90 million barrels a day to China? Current total global worldwide consumption is running about 86 million barrels a day. So, that would be a huge change. Right, so if we can't really slow down population growth a whole lot and if per capita incomes are going to grow and if that's going to happen in countries like Brazil and China and India, well, what's the other possibility?

Well, we could have another global recession like the one that we had in 2008 and early 2009, and, in fact if you look at business cycle timing and how long the fed has been keeping relatively low interest rates, which were talked about at the last meeting, if the fed starts to raise interest rates at the end of this year — August, September — that might actually trigger another economic slowdown in the U.S. and possibly globally sometime at the end of 2012. So, for those of you who are interested knowing when the next recession is coming, that could be one of the shortest expansion cycles that we've ever had.

Right, okay, can oil prices be either too high or too low? You could argue that back in 1980, 1981, that oil did play a role in the global economic downturn that we had. Steve Brown will talk a little bit about oil's role in the economic outlook. But it turns out that in those two or three years from 1979 to 1981, 1982 that oil accounted for something like 6% of global GDP at then very high oil prices. In the 1990s that's something closer to 2%. In 2008 in the first half, we were back up into that 6% of global GDP range.

I believe that when oil is absorbing 6% to 7% of global GDP, it's priced too high. Consumers, in a sense, can't afford it, and that begins to trigger downturns in demand. At 2% of global GDP, producers can't afford to go out and find the next barrel that's needed and that creates problems. Is there a sweet spot? Yes, I think there is somewhere around 3% to 4% of global GDP. That would be the equivalent actually right now of about $75 a barrel. What would it take to get back to the rates of the early 1980s and the first half of 2008? About $150 oil. So, I'm not going to try to predict where oil prices are going, but let me just say that if oil does go to $150 a barrel, we're going to be in for trouble again.

Okay, with those comments, now I'd like to turn this over to our panelists. We won't be needing those. So, if you up there in the booth, can get a Steve Brown's slides running? And let me just tell you briefly, now, I think you've heard this before today, their bios are in that small booklet, and Steve is a non-resident fellow at Resources for the Future where he also serves as the Co-Director of the new RFF Center for Energy Economics and Policy. Before joining RFF last year, Steve had a 27-year career at the Federal Reserve Bank of Dallas where I first got to know him where he was a Director of Energy, Economics, and Microeconomic Public Policy. And his work there was instrumental in building up the reputation of the Dallas Fed, for his excellent work in energy economics, and Steve, please. Thank you.

Steve: Thank you, Adam. It's a pleasure to be here, and thank all of you. As I was watching some of the presentations earlier today, I was sort of thinking, well, if somebody covers something that I'm going to cover then maybe I should cut it out in interest of speed. And if someone says something that's different than I'm going to say maybe I should cut it out to minimize disagreement. And I realized that, by the end of the day, I actually had nothing to say. So, I'm going to go ahead with what I originally planned to say.

If we look at this chart, what we see is kind of the history of oil prices, basically since World War II shown in combination of blue and red, the red highlighting Jim Hamilton's work or idea about oil prices that have risen sharply. And the gray bars show the timing of our recessions including our current recession. And if you look at these in combination, what you see is what Jim Hamilton said a number of years ago, then he would say, in 7 out of 8 post World War II recessions were preceded by sharply rising oil prices. And now, in fact, we would have to say 10 out of 11 of our post World War II recessions have been preceded by a sharply rising oil price. These prices are adjusted for inflation, so they're real. And even though, you know, we probably wouldn't attribute either the 2001 recession or the current recession to sharply rising oil process, nonetheless, we saw sharply rising oil prices prior to those recessions.

And that's given rise to this view that there's an inverse relationship between oil prices and economic activity, although Adam just talked about the opposite view. And in fact, as some of the presenters in the short-term outlook just got through talking about, there's really a complex relationship between oil prices and economic activity. And there's actually even now research that puts those together. The inverse relationship really is only a characteristic of oil supply sharks. So, this is when we see a disruption in oil supply that pushes up the price of oil that is a characteristic...that is an oil supply shark that reduces the amount of oil available for use in the economy and slows down economic activity.

Now, in fact, we're all well aware of the idea that if we have an expansion of the economy that's driven by, let's say, productivity sharks, that's something that's going to drive economic activity and pull up the oil price. And certainly that's what people...how people characterize the rise in oil prices from about 2002 to 2008. Now, suppose that in fact that productivity sharks happen abroad. A lot of the productivity sharks in the 2000s were actually occurring outside of the United States in places like China, India, and Brazil. And a lot of people...the way a lot of people looked at that if they just sort of said,

well, that's going to give us the same thing as a supply shark because the Chinese will use the oil, they will drive the price up, we will get less oil, life will be like a supply shark.

But it turns out that when we look at countries that are experiencing these kinds of productivity sharks, there're spillovers to other countries of these productivity sharks. And that the favorable productivity sharks experienced in China, Brazil, and India led to smaller favorable productivity sharks in the United States. Now, this is all supported a by growing body of research that has come out in the last few years. Lutz Kilian at the University of Michigan is one of the people who's doing some work in this area...has produced more papers than one can believe.

And I working with a couple of other people — Mine Yücel, Vice President of the Federal Reserve Bank of Dallas, and Nathan Balke at Southern Methodist University — have found similar kinds of results, and there's some people working at the Board of Governors of the Federal Reserve System who have worked like this and people working at the European Monetary Authority who have found work...found results somewhere to this. So, this is something that's kind of a well-documented research now, although not something that's widely known.

So, I want to move to something that Adam talked about now, which is the positive relationship between oil price up...between oil price consumption and per capita income. And you can see here that there's a pretty strong relationship. It's not perfect. Not every country lies exactly on the curve. But what we've seen here happen is that countries like China and India, is they move up. Their consumption of energy moves up. And so what's really been driving energy markets in recent years, in my opinion, is this positive relationship between economic activity and energy consumption. And that's been really increasing the demand for energy worldwide.

I think Adam covered that well enough, so I'm not going to talk about that very much. And that is basically the story between 2002 and 2008 where we saw a strong global demand. Oil supply development really lagged behind, and a lot of reasons have

been given for that including oil peak or oil plateau, the latter being associated with Matt Simmons. Jim Smith has argued that OPEC has been restrained in adding capacity, not very restrained in production but restrained in adding capacity. It's been a fair amount of work identifying national oil companies as being inefficient and lagging behind in investment. And in fact it's rational that there would be less investment in the oil sector if it was lagging behind in terms of productivity gains.

So, not only did we see that, but we saw expectations that demand would grow, which led to the idea that oil prices were going to continue rising. And we saw fears of supply disruptions at a tight market and we saw a weakening dollar, things that have been covered elsewhere today and the possibility of some unrealistic expectations. I don't want to really spend too much time talking about each of these details.

And the other thing I'd point out is that the elasticities of supply and demand in energy markets are extremely low, meaning that a little bit of shortness in the market can lead to very volatile prices. So, the 2008 price collapse is pretty obvious, oil worldwide recession. Capacity additions were starting to catch up. And in fact, in the chart that we've seen in some presentations earlier today, excess OPEC capacity was pretty...is now pretty…large and that led to a lessened impact of supply disruptions in unwinding of speculative positions. And again, we see a pretty strong price collapse because of the low elasticities of supply and demand.

Moving forward, looking at the oil price rebound, I think what the standard story we're hearing is the strengthening global economy is boosting world oil demand even though that strengthening global economy is very uneven at this point in time being led really by China, perhaps with India going along. And I think there is continuing expectations that oil supply development will lag behind. People project how much oil China really could consume and say I can't imagine that supply is going to keep up with them. And some of the earlier presentations notwithstanding, there's a possibility that the so-called oil hedge against the dollar has resumed. Some of the previous

presentations have suggested that that may now have come to an end, so maybe I should take...have that be something that I take off.

So, what's the outlook for the world economy? Well, according to the International Monetary Fund, we're going to be seeing growth pretty close to what it was prior to the recession. In fact, we're in a period where that's already starting to happen just a little bit slower. So, kind of the conventional thinking is, well, this was kind of a temporary financial disruption at the market and now we're going to go back to things kind of the way they were. And the growth is going to be led by the emerging and developing economies. And if we look at industrial production, it's returning back to trend globally.

So that, however, is kind of how the international monetary fund and kind of the standard outlook is. In fact, the roots of the current recessions suggest that the U.S. recovery might be slow. We had a severe financial crisis driven by a financial and real estate bubble, and certainly one could argue insufficient market oversight. And that was probably also contributed to by what one might consider lax monetary policy. And there's a loss of confidence in financial institutions, which led to the financial institutions not really keeping the financing going. However, we are already seeing signs that U.S. housing may be recovering.

Confidence is rebounding as measured by confidence indexes. But financing is not fully restored, and in fact monetary policy, as Adam mentioned, is a risk as the economy starts accelerating. And are we in for a long, hard swag? Well, some work by Reinhart and Rogoff suggest that, in fact, when you're looking at financial crisis that the duration before you really get into a recovery is quite a bit longer than for a normal recession. So, we'd be looking for slower economic activity or slower economic recovery than normal. And I think right now that's the kind of evidence that we're seeing.

And there are a couple of different scenarios for recovery. Previous trend, we turn back to the previous trend. And a lot of, I think, outlooks suggest that we're going to

return back to the previous trend. Another one is that we're kind of not going to return to that previous trend but we're going to return to that growth rate. That could mean slower growth in energy over time...slower growth in energy demand. And then there're people who say we might even see falling off of the pace. My own personal view falls somewhere in between scenario two and three because one of the things that we know is that when we have the economy enter into a recession is that the things that are going to make it grow when we come out of the recession aren't the things that made us grow as we were going into the recession that the economy is reorganizing.

Consequently, I'm not so confident that we're going to see...continue to see...robust growth throughout the world going forward. Now, I just thought it would be interesting to put up the history of EIA oil price forecast. And you might laugh at them but I have belonged to the International Energy Workshop and where they do consensus of experts. And the consensus of experts looks pretty much like you're going to see from the EIA. So, you're laughing at yourself if you consider yourself an expert.

So, let's look at the current outlook and this is the current EIA outlook. This is kind of based on the resumption of world economic growth. Capacity fails to keep pace with the growth of demand. And as our growing reliance on alternatives and heavy to difficult...and heavy, difficult to refine crude, so essentially we're moving away from the use of light oil and oil is going to be harder to produce. There's going to be less of it. But economic growth is going to continue unabated. I'm sorry.

So, let's sort of think about the strong world oil demand growth. Dargay and Gately actually say that the EIA is wrong. They've completely underestimated the growth of demand based upon the income projections that they are using. But I think there're a number of factors that will moderate oil demand growth. First of all, I think we'll see a lot of conservation as a result of higher prices and as a result of evolving technology. And I think we'll also see a movement in vehicles toward electric hybrids where a lot of oil is consumed in electric hybrids, I mean, in the transportation sector

also see a movement toward lighter weight vehicles. And I think that in fact we're going to perhaps see the emergence of new energy use patterns. I don't think the Asians are going to use oil like the Europeans and Americans and I'll tell you why.

Here's everybody's view of how Asians currently use energy. And everybody's view is sort of like they aren't really using very much in their transportation sector. When they get all these ta-tas, they're going to be all in gridlock burning oil. Well, the reality is the Asians are already in gridlock. This is the reality in Asia today. And Lee Schipper, who has been studying transportation in Asia, actually says this is the future of transportation in Asia. This is very low oil use. This is use of coal, perhaps, or natural gas to generate electricity.

So, I would say that I think that, first of all, the economy isn't going to be as robust growing in the future and, secondly, I think energy use patterns are going to be a little bit different. So, I think it's more likely we're going to see softer energy prices as a result of that. Not only that, I think there is a possibility given the resources around the world that we could see a return to abundant oil supply, and that could give us a much lower price range somewhere to what I show here.

Right, so to conclude. I think a weak global economy has depressed oil prices. Economic recovery is boosting world oil demand. The oil hedge against the dollar has unwound or is unwinding and that should keep pressure off of oil for a while. But as oil prices really...as we move forward as recovery takes hold, I really think oil prices in the $70 to $105 range are sustainable based upon economic conditions. I think timing remains a question. We are still at the beginning of a slow recovery. And that's what most people will expect to continue happening here in the United States.

Well, thank you very much for your attention.

Adam: Steve, thanks very much. Our next speaker is going to be Matt Rogers. Matt is the Senior Adviser to the Secretary of Energy for the Recovery Act and...and his role, his responsibility, this is like really cool, right?...he is giving away $37 billion. Well,

our guaranteeing part. And everybody now, up in the front, wants to meet Matt. Before joining the Department of Energy, he was a Senior Partner at McKinsey & Company in the San Francisco office where he played a leading role in developing McKinsey's perspectives on global energy supply and demand and greenhouse gas abatement economics. We're really pleased that Matt could take time out of his very busy day to join us, so Matt.

Matt: Thank you, Adam, for that kind of introduction. This is an important dialogue, I think, that you and Steven have framed very well. The charts this afternoon seem to ask a relatively straightforward but challenging question. Are we destined to see economic growth return, and, just as it returns, run headlong into fossil energy shortages and ever increasing carbon pollution, or do we have the opportunity to deliver higher fossil energy productivity in the future than we have seen in the past?

In my discussion this afternoon, I'd like to make three relatively simple arguments. The first is that innovation is a primary contributor to economic growth and job creation and is essential to addressing this energy productivity question. The only way to accelerate economic growth without accelerating fossil fuel demand and carbon pollution to unsustainable levels is to increase energy productivity through efficiency and innovation. Those two pieces — efficiency and innovation — need to come together. The second point is that the Recovery Act is making a down payment on this journey. We're investing both in current deployment and the next generation technological innovation.

And then one of the things that's been most exciting about my role is to see both the significant potential to deploy existing technologies more widely and economically and the opportunity to accelerate innovation in energy productivity in the United States and globally. Given the rise in global demand for efficient clean energy products, the other key is that U.S. leadership and high technology clean energy markets is creating

good, high-paying jobs today in building the platforms for long-term job creation tomorrow.

And then the third basic point is that if we can structure the market and send this appropriately this year, the U.S. has the potential to capture global leadership and high technology clean energy innovation manufacturing and deployment. What do we need to do that? We need to price our carbon and other pollutants. We need innovation-focused tax policies. We need expanded incentives for middle-class energy efficiency. We need more incentives for manufacturing clean energy products here in the United States. But if we do that, we're actually on the verge of achieving a very significant shift in the curves that Steven was talking about.

The President has been quite consistent since his days on the campaign trail talking about clean energy as a way to create good long-term jobs, to strengthen our economy, to improve the environment, and to enhance national security at the same time. You heard him last week talking at some length about the national security part of that equation.

The Recovery Act was a key initial leg in that argument. It's creating jobs today. It's providing a significant down payment on the nation's energy and environmental future. It was...the first leg of the Recovery Act was a set of tax incentives. The second leg was a set of transfer payment to states to really put a safety net under an economy that was coming apart in the first quarter of last year. But this third leg of the Recovery Act is really focused on building infrastructure and accelerating innovation, and it's both part of the infrastructure and innovation to lay the foundation for long-term economic growth and job creation, and this is where the Department of Energy is really focused.

So, why do we do that? There's a widespread agreement in the financial community that innovation is in fact a primary driver for long-term economic growth and prosperity. This is what Solow won the Nobel Prize for. And it's quite clear that it's that kind of productivity that allows us to grow real GDP per capita, the kind of discussions

that we're talking about earlier. The challenge, of course, is that energy has historically been one of the slowest sectors to innovate. We tend in this environment to talk about long-term forecasts as 20...or short-term forecasts as 20- and 30-year forecasts because it sometimes takes 50 or 100 years for energy technologies to innovate. Coal started taking over from wood in the 1850s, oil started taking over from coal around the time of World War I, and it took between 50 and 70 years for those equations to change.

And what is that? Well, there are three basic differences about energy innovation versus others. The first: Scale. We're talking about scale that is dramatically larger than that in other sectors. The secondary set of system integration challenges come from the infrastructure requirements of energy. And then the third is a challenge about...some might think of it as a behavioral expectations challenge...that comes from the ubiquity of energy. People expect it to perform in a certain way, and changes in that are actually quite difficult to drive through the economy.

Nevertheless and perhaps most importantly when it occurs, energy innovation has a profound impact economically. And what we've seen across the United States in the 20th century was a great deal of our economic growth was actually tied to energy innovation. And so energy innovation is essential for economic growth. And for job creation, it's also essential for us achieving our energy and environmental goals. So, across each major marker, what we're trying to do is invest both in commercial deployment and in next-generation innovation.

As Adam said, I've had the privilege of trying to spend $37 billion of appropriated funds that support about $100 billion of projects over the last year. We've actually now obligated...we've actually now selected recipients where...32 of our $37 billion dollars in funds, and so my popularity continues to decline with every week. Other than that, we've also...we've actually obligated to send out checks for $27 billion of those funds, so that money is out in the economy creating jobs today.

But again, the key for us is that this notion of the competition among clean energy innovation pathways that we've been able to fund gives us a high degree of confidence that cost can come down and performance in these technologies can continue to improve quickly. If you take transportation as a simple example, what we're doing is we're creating a competition between and among biofuels, hydrogen, natural gas, electrification, and conventional internal combustion engines. Each of which have dramatic performance improvement opportunities.

And it's that ability to fund each of those pathways, recognizing that breakthroughs in any of those offer a significant performance improvement that gives us a great deal of confidence about where this economy is heading. We've been able to both invest in the set of current technologies and then in the set of fascinating next-gen technologies like FastCap Systems and Delfia, Envia — a set of companies that offer 10- and 20-fold improvements in what are typically thought of as relatively mature technologies.

We're doing the same thing on the biofuel side. We spent $600 million on 19 pilot and demonstration plants to demonstrate the next generation of biofuels technologies. and then the Defense Advanced Research Projects Agency, for energy, invested similarly in a portfolio of a half a dozen technologies that offer the possibility of taking sun and water and CO2, and producing fuels directly from that. And the analysis that Steven and Adam were talking about, denotes that we may have achieved peak demand for fossil gasoline in the United States, really highlights the opportunity to reach that kind of trend globally. And that, therefore, is the challenge ahead.

We take a similar story. Our investments in grid infrastructure are giving customers lower...more choice, lower cost, greater renewable penetration, and greater ability to introduce electrification into the transportation sector. And that kind of innovation that we're seeing both in the current deployment and then in the next

generation of things like energy storage create the possibility of a very different network than we have today.

So, if you put that all together, the argument that we would make is that the Recovery Act is creating jobs today. But it's also providing a critical down payment on the nation's energy and environmental future. Taking together the projects that we funded under Recovery Act and frankly the oversubscribed opportunities that we haven't been able to fund really highlights the opportunity for the United States to accelerate energy innovation and to accelerate this notion of energy productivity in the global economy. It creates the opportunity for the United States to take a leadership position in clean energy technologies and to lead other countries in terms of how one uses energy in a highly productive fashion. And the thing that again gives us the most confidence is the ability to fund multiple competing pathways. Along each of those pathways, you see the same path to much higher energy productivity.

The other key element here is that long-term jobs stay in industries where there's a high degree of innovative content, in industries where R&D and manufacturing and deployment are very tightly integrated. We've made a major commitment across the value chain to make sure that we're investing in R&D, in the manufacturing, and in the deployment of these technologies. Because unless you do all three, all of a sudden the system actually doesn't rise to the same level of performance and we're just at the beginning of this journey.

Again, our challenge now is to put in place the long-term incentives because all we've done under the Recovery Act is make a down payment. And if we don't create those long-term incentives, the investments that we've made will be hollow. The Secretary talks about this as the next industrial revolution. And if we think about the kind of challenges we have ahead, it's that kind of scale of performance that we need to achieve. And the accelerating rate of clean energy innovation really puts us on the verge of achieving that kind of performance, that kind of productivity expansion that will

take this curve that says somehow energy population plus income equals energy demand, and change the slope of that curve fundamentally over the next 20 years. And with that, I thank you very much.

Adam: Well, thanks very much, Matt. Sticking to this theme of how energy innovation and investment in new energy technology might help transform the economy, I'm very pleased today that Don Paul, who is an Executive Director at the University of Southern California's Energy Institute, is with us. Don has had a very distinguished career at Chevron. He retired in 2008 after a number of years there where he was, at the end, Vice President and Chief Technology Officer for Chevron. I told you that I was a civil engineer and had a...I went on to business school. But even that's a bit of a subterfuge. My degree was an MPA. Matt actually has an MBA and he worked as an investment banker at Credit Suisse.

Somehow or another, I started out with an MPA thinking that I wanted to go in the government service. I had a goal in college: I wanted to run the National Park Service. Given my oil price forecast over the last six months, I wish I would have run the National Park Service. But Don, Don has a PhD but it's not in economics, it's in geophysics from MIT. I think that what Don is going to do is to try to bring into focus some of these issues that Matt has talked about to let you see the scale of effort that's going to be required to get these changes that we all want to see come about. So, Don.

Don: Thank you. Thank you, Adam. And it's a pleasure to be here this afternoon and certainly an honor to be a member of such a distinguished panel and to see many friends today. What I'm going to do in the next few minutes is talk about how technology scales in this transition that Matt talked about perhaps play together. As Adam said, I'm not an economist, but, certainly in my years at Chevron, I both benefited and suffered by their forecast.

But let me start with this concept that I think applies very generally in the energy system but certainly in technology. It is that scale, time, and complexity and that I think

there are many aware of the systems aspects when we talk about energy. But there's a tendency even in the most sophisticated audiences for people to land in one corner, and so I'm going to push on this thing or I'm going to understand this segment when in fact it's always about science and technology, and economics and business, and government society. All of them tie together. And frankly, I think it's one of the reasons why it seems to be impossible to predict price, and that's also one of the reasons why it can seem to take so long for the system to evolve even when there's very high levels of innovative effort.

Another aspect of this, the time. And I think this is particularly important, well understood by many I think in this room, but not understood in many of those I deal with now that I'm on the academic side and startup companies and venture capital firms and so on. That in energy, history, the present, and the future always co-exist. You are always carrying along things that have been in the system a very long time. In Chevron, we were producing from oil fields that were discovered in the 19th century, still are today in California. So we have very, very long-lived infrastructures. You have multiple generations of technology being overlain on this. And I'm going to come back when I talk about Smart Grid and say this is going to be one of the real challenges about that.

But obviously, you also have multi generations of infrastructure at any point in time. So, I say to some of my friends in the venture capital community, it's not software. You don't get to take the system down and reboot with the new one. And this is a particularly important aspect. When we think about evolving the system and innovating at scale as Matt talked about, just the scale issue on trillions. I'm going to cover all of these. But a couple of them, I think, are particularly important.

One is we've used about a trillion barrels of oil since first discovered in the 19th century, actually a bit more than that. There's about a trillion barrels on the books; we call them reserves. We're going to need another trillion barrels. That's about 30 years worth at current rates, so obviously if those rates accelerate, it's even more pressure.

Many believe we could get into an argument about peak oil, but many believe that there's a trillion barrels of new — genuinely new — reserves to be found out there. And I expect the technology will do it. But the cost of this at $20 a barrel for finding a development cost today is a robust amount of money. Although it was, you know, it wasn't that long ago when a trillion was not a household word, but …

Adding another trillion watts of power, at least...at least, even if there are dramatic improvements. And the other one that I think always strikes me is eliminating a trillion tons of produced CO2. That's 25 giga tons a year for 40 years. So, by 2050, you're going to have to take a trillion tons. These are in amazing numbers when you actually think about the challenge ahead of you and innovating at enough scale. But at the same time, there's a certain...in a way it seems a bit of a paradox that 1% pieces matter. And the reason they do and those who have been in the energy business and were in it for many decades like I was is that, you know what, the 1%s add up and it's true for efficiency. It's true for additions.

And so when I...I try to encourage people who are entering the energy system with their innovations and ideas. When I say, boy, you know that's a great 1%. I sort of feel, well, gee the 1% is real money in most places. One percent...to add 1% to global reserves will cost $200 billion of investment. So, if I had innovation it made that processes 10% more efficient, that's a real business as far as I can tell. Two and a half million electric vehicles into the U.S. market, which is a pretty robust number. It's not some of the longest term forecast, but if you think it over the next decade, that's a pretty big number. That takes out 1% of U.S. fuel demand. So, you got trillions, and you get 1% counts. And I think this gives me a sense of how one would evolve the innovation system as it goes on.

Let's talk about some specifics and I'm going to say sort of two trends. They've heard a lot and talked about technology for a lot of people say that this is going to be a cornerstone. We heard it...in the last session we heard it. Again, in this session we

heard it, and certainly this morning by Dr. Chu. But one of the things that's important is to realize that sitting underneath whatever the application technologies that come, the way to improve energy innovation, or what I would call transcendent trends, these cut across all industries, and the three that really stand out in my mind, of course, are universal digitization and computing as people look around handling whatever PDA it is and whatever other device it is. And the amazing thing about this is this we're just at the absolute front edge, the absolute beginning of where this will be.

And the reason why I think this is important when we think about energy, and I'll come back to my talk about specific energy trends that the injection of funding for innovation and research into energy pulls along these transcendent trends too. The most specific example of this is super computing, high-performance computing that has the investments, and computing often done for national security reasons have always pulled oil and gas technology. Seismic technology and oil and gas have directly ridden the curve up on computations. The fact that computers are a million times faster than they were 20 years ago has directly translated into seismic imaging technology inconceivably 20 years ago.

So, that set another example of this transcendent trend which pushes up the ability to do things that energy really couldn't do. The other one that's really, really powerful in my view is the ability to change things at the macrolevel scale whether you do them biologically, thermochemically, physiochemically, the ability to make what you want from what you have. You know, the history of energy is using what you have. But the ability to make things that you want from what you actually have, the whole basis of synthetic fuels is a very, very powerful technology in the long run, but, of course, it transcends beyond energy too. But there, again, the investments and energy are going to pull the whole base up. So, I think these are two areas where certainly the United States, as long-time leaders, will continue to get...the whole base will get pulled up by the investments and energy.

And then the third one, which I'll come back to, that's emerging is how the human beings relate to technology. We all have actually...I know it sounds silly but if you step back and think about...we all have relationships with the technology around you and in a way that you have never done before. And I would argue, you're going to...it's going to be in ways you haven't seen yet. And that will be one of the things that's going to play out in energy. So, if I talk about some specific energy technology, just to mention a couple developing intelligent energy, when I close, I want to talk about Smart Grid. I'll leave that.

Diversifying the feedstock. This ability that diversify feedstock plays directly, I think and ultimately the ability to fill out whatever that fuel demand wedge is going to be because, I think, most of us who have worked in the oil business do believe that in fact conventional oil is, in fact, going to hit the maximum. You can argue whether it's now or 20 years from now as a practical matter that is going to happen and you're going to need to add into that wedge other kinds of fuels and diversifying these for both fuel and powers an important storing energy at scale. And I guess I didn't have up here electrification of transport. But in my view, electrification of transport is a direct will-be, a direct outcome if it's going to be successful at scale of intelligent energy systems and the ability to store energy at scale either whether you do it in one place or across millions of vehicles, that's going to be an essential part of that.

And then the final one is reengineering natural resources at scale. And so what do I mean by this? Well, I would argue that what we're now producing: hydrocarbon resources, shale gas, from things that when I was started life as a geologist, we call them source rocks. I mean, these weren't reservoirs. But in fact the ability to restructure the subsurface — literally cubic kilometers of it — to release molecules or store molecules in the case of CO2, this is a really powerful technology and how that it gets used, I think it's going to potentially alter the supply system as well.

Let me close by talking about two specific aspects, bring it back. This is a...this figure tries to depict R&D to commercial deployment and this is for fuels. So, back in my Chevron days, you're thinking about a new kind of fuel processing scheme. What one would do is demonstrate the science on the bench top, pretty small volumes. You would build a lab plant. This is a miniature refinery, miniature processing plant, but it's got all the parts and pieces that demonstrate that this technology can be delivered day in, day out with consistency in product outputs understanding all of that. These are tens of millions, maybe make half a barrel a day or a barrel a day. That's not enough. And this is this golf. And I think the real golf in energy goes from science to...I got a pilot that works and produces the right things. I've got batteries that function. I can make hundreds or thousands.

How do you get the two orders of magnitude or three orders of magnitude across this boundary? In the oil industry, in the majors like Chevron or Exxon Mobil, we did this. We did this for a living. We would actually build experimental facilities. But in many parts of the energy system today with new innovators entering the ecology, we don't...this is hard to do. And when you think about power, this kind of 10-10-10 scaling and cost millions to do a lab. Tens of millions, hundreds, billions, even in power this applies.

And with utilities, of course, whose primary measure of goodness is reliability. Most utilities do not get points for doing things innovative but they get lots of points for things not going down. So, I think one of the keys that we'll have to figure out in this transformation is in this new emerging energy transformation industrial revolution is how to get across this boundary right in here and how do we do that at scale.

Let me talk for close. I'm talking about Smart Grids. As we heard this morning from the very opening session, I thought a good plot since you're connecting two infrastructures. You're connecting two of the world's largest infrastructures. Now, this is a very interesting one to connect because the time scales of technological change and innovation between the information/telecom infrastructure and the energy one are really

different. The other thing that I think will be interesting to see is the fact that historically, as information systems are wrapped around physical or business process systems, ultimately they dominate. And part of the reason they dominate is they have this high-speed innovation cycle. We've seen that in the financial industry, for example.

So, it has promise of lots of gains and certainly for bringing invariable sources and that would be both production sources and demand sources. It's going to create an enormously complex system. You can imagine a system now with millions and millions of components and a system in which there is instantaneous real-time displays, and a system in which, unless we fix the storage problem, there isn't a lot of storage to buffer things. So, all of these create a system.

And then of course the fourth point that many of us are working on and concerned with is this is a cyber-physical system. But it creates because there's physical, literal physical access to digital nodes. It creates an entirely special form of cyber security. And as we learn in Chevron in the oil gas business, we went through cyber security for pipelines. It is physical entry, materially raises the risk, cyber risk for a system, if you can actually crack something open and get to the chips themselves.

So, this is all and this is recognized by DOE in a program that Matt's funding on Smart Grid, how important cyber security is. All these things are I think a great set of challenges and opportunities for developing intelligent infrastructures, this is...in my estimation it's only one…the intelligent infrastructure. It's a natural one but it's only one of...there are others that one could think about. And I want to close by coming back to that on that transcendent trend. The whole issue about humans and technology and the relationship and how is that going to evolve in a world in which complexity, technological intensity continue to rise.

One thing about the Smart Grid is that's not like the Internet. The Internet, one could already...you can't live without it but in fact some people do. But you can manage your...the extent of your interface. But in fact with power, you have power. You can't live

without it. And now, you put these two together and you've drop them on my doorstep and it's creating interesting reactions. So, I think many people had blanked out and there's no reason to name any particular utility. Every utility has this problem that's been rolling these out. And what is this all about? Why...what's the Smart Grid rebellion about?

And I think part of it is this complexity, do you people...some people just don't want another system to deal with in their life. Some people, perhaps, are saying I do not want to be reengineered into a smarter planet. That's not my goal. So, I think this understanding, the dimensions of this new energy technology world, especially a world that in many parts counts on its ability to provide an alteration in the behavior of the occupants. So the system that people use energy and the way they do it that this behavior, technology, energy linkage, I think, is going to be one of the interesting things to deal with and one of the things that's going to be important. So, with that, thank you for your attention. I look forward to your questions.

Adam: So, Don, thanks very much. You know, I forgot to mention before you stood up that your very extensive public service record. Don has served on presidential panels for Federal energy research and development. He's been on the National Research Council, and I'm particularly thrilled that I had the privilege of working with Don on the National Petroleum Council's study from two years ago with a hard truce which by the way, the National Petroleum Council is an advisory group to the Secretary of Energy. It's not a lobbying group in the report that we came out with a few years ago, I think has been hailed as one of the finest ever done by the National Petroleum Council and Don had a very strong role in that along with his colleagues from Chevron.

So, we started off with the PhD economist, we heard from an MBA from Yale, and then we heard from a PhD in geophysics. This panel is all about energy and the economy and we're going to conclude with another PhD economist who specialized in energy. Christof Rühl is the Group Chief Economist for BP. He manages BP's global

economics team. He provides input into the firm's commercial decisions and many of you have benefitted from the work that Christof is very closely involved in now, the annual publication of the BP's Statistical Review of World Energy.

In other words talk...earlier panels about transparency and energy and statistical availability. Before the government was doing this, BP and Exxon and others actually did provide some pretty valuable information out there to the global community, and Christof is still involved in that. He served at the World Bank where he was an economist under Russian and Brazil Desks, very interesting, two of the brick countries that we talked about so much and were highlighted by Steven Brown, so without further ado, Christof Rühl from BP.

Christof: We already got a bunch of questions.

Adam: Okay.

Christof: Before I even started. Thank you very much for the kind introduction. I have to correct you, Adam. I never managed to finish my PhD. I've always been born to this; it would not get me anywhere.

Adam: Oh, you have the ABD, the All But the Dissertation?

Christof: So, I ended up.

Adam: I think there's probably quite a few in the audience here, Christof.

Christof: When I was teaching, I was...so, I ended up in Energy *[inaudible]* at the end. All along, while you were doing these introductions, I was wondering whether you're going to this *[inaudible]*.

Adam: All right.

Christof: Well, thanks for the invitation. Thank you all for coming. Last speaker, last session, so 15 minutes waking up and then we're done. What I would like to do is to also give you a take on the future, probably a bit more down to earth and a bit more proceeding from things, which I think we have a fairly clear idea about which we know. And I would like to do this in two ways.

I would like to first talk about what we have seen through these years of the crisis emerge in terms of structural issues, and I'll just pick of the markets that's enough, oil and gas. And then also and what I think and what we think internally for our long-term energy outlook will be the biggest change in energy markets, say, out to 2030 and that, in our view is perhaps not withstanding all these government efforts and all these other interesting things where is perhaps nothing which has to do with renewable, that's probably in the area of natural gas, although I would argue that we have to be a bit more careful than just looking at how cheap it is and how technology has helped us so far.

But I would like to start with connecting to what Adam has started from, where this energy demand come from and where we actually are in the long term because I do believe that it makes sense before you go into the business of predicting anything, to have an idea where you come from. And the first very simple approach to that is to just look at this curve and to realize that what has just happened to us over the last few years, this highly synchronized commodity cycle including fuel price cycle is something which doesn't happen every day. We are used in our business to talk about circulate the developments and so on but in fact you have to go back a long time, maybe until the early '70s until you find comparable developments like what has just happened to us.

And as there's a lot you can talk about that, I just want to point out a long period in between, of course, it's not only a period of relatively low fuel and other commodity prices, it is also a period of great stability because all along the economy did in cyclical thing on top of it and what people want to know, of course, at least when you're in the commercial role like me and the first instance is what does all this mean, these two spikes and especially the last one. Where are we going from here? Are we in for another 30 years of, you know, low-case stability or do we have reasons to suppose that something has changed between these two spikes. And the world has changed in a way, actually, to a different outcome. What these two spikes have in common is, of

course, when you look at economic growth as the prime driver of energy demand, you have the, say, five-year intervals, the period of the highest global economic growth. And I'm going to strictly talk global energy from a period of highest economic growth before that spike in the early '70s.

The second highest period of recorded global economic growth, you have before the spike in 2008. And that's where the commonalities sort of ceases to exist because what these two...what distinguishes these two periods of very high global economic growth is something we all know is sort of the composition of that growth, what drove that growth and that brings me to what has always referred to as the emerging market countries, the brick countries, industrializing countries.

In the period during this...leading after the '70s, much of that growth came from the most industrialized countries. Here you see what has happened over the last 20 years or so. On the left hand side, the world divided simply in OECD and non-OECD countries — OECD, the most industrialized countries. Non-OECD is my shortcut for everything else, the developing economies, the emerging market economies — and their contribution to global economic growth rising over that period from around 20% to more than 50% today.

On the right-hand side, you see the contribution of the same country groupings to primary energy consumption growth, and you will see how the contribution of the so-called developing world here increases from around about 20% to more than 90% of primary energy consumption growth over the last few years, and we can put numbers on that, actually we did. If you take market exchange rates, which where you can criticize that, but if you do so then in order to produce $1000 worth of additional GDP in the non-OECD economies, you would need about 3.4 barrels of oil equivalent. To produce the same additional $1000 in the OECD economies, you will need 1.1 barrels of oil equivalent. It's a difference by a factor of three.

As the first observation, and why is that? It's not immediately obvious why poorer countries should use more energy to produce an additional unit of GDP. If you would use PPP exchange rate, the picture changes slightly, but the fundamental difference remains. And the same question, what *[inaudible]*. Of course you have a plethora of reasons. You have inefficiencies, infrastructure programs. You do have this whole issue of subsidies in the emerging market economies distorting the picture. But you have one prime reason. The thing and something everybody knows is just putting numbers on which is that if you compare economic growth in our developed economies with economic growth in these industrializing economies, you're really comparing apples with oranges. Now in the U.S. economic growth, crisis or not, there's something which proceeds gradually where the sector of composition of the economy changes only slowly.

In vast parts of the world where you have this huge process of industrialization, you have a genuine process of transformation with literally hundreds of millions of people over the last few years moving from low-energy intensive activity such as agriculture into high-energy intensive activities such as industry. And that demand for energy, this is primary energy on the right hand side, which comes from industrialization is something we have been through just a few decades, 150 years or so earlier. But that is, first of all, first and foremost a demand for electricity already leaning *[inaudible]* industrialization is electrification.

And therefore, it has more or less been satisfied with coal. The stress sums up the picture here because of that massive demand for energy, primary energy from the developing world. 2008 actually was the first year in which the absolute energy consumption in the non-OECD, the developing countries was larger than in the developed countries. And of course you see across the main components of primary energy demand how that proceeded. First one to cross over was coal, already in 1988,

driven by that demand for electricity. And you see how coal has proceeded since then and how we at BP internally predicted will proceed.

Natural gas crossed over in 2008. And for oil, the crossover point is still a few years ago. This will probably happen in 2015, 2016 that the developed world will consume more oil than the developing world. So, there is a powerful demand for energy which goes a bit beyond the...which Adam mentioned at the beginning only the consideration of per capita which has to do with the structural changes in the economy we operate. And that is the background, the long-term background, against which we have to evaluate the consequences of the economic crisis. And here's not the time to discuss it in detail.

I'm very much the same place, Steve is there, what are seeing right now is a bounce of recovery in 2010, 2011 in my book driven by an inventory cycle and driven by government support, fiscal, and monetary support which will have to be withdrawn, and it is very, very doubtful that after 2011 or so, we will continue seeing high-growth rates as we see in the rearview mirror we have used to for the last few years. We're probably in for a period of sluggish growth, and I'll come back to that.

Now, what are the implications or what do we see changing actually in the oil market first of all? This is what we've talked about...many people have talked about during the day, the rapid rise of oil prices and then the decline apparently, completely unanchored by any sort of future prices. Future prices move very much like the IEA picture, which of the three, as previous speakers have said and so. It's not only the experts. It's also the wisdom of the crowds which hold, paint the same picture.

Well, what I think the first issue to realize when looking at oil markets is that sometimes, indeed, life can be quite simple. And what happened in oil markets, I think this is important to reassure first and foremost, is a simple story of supply and demand disturbed, mixed up by, the existence of a cartel in that market. And I do think that recent price developments really should pay *[inaudible]* to these ideas of prices go up

because of refining shortages, prices go up because of bad speculators and all of that. There is no way in explaining recent oil price development without recourse to OPEC and the production management they have implemented.

Again, we don't have the time to go through it in detail here and see sort of the big picture. The oil price takes off and starts rising early 2007. Then OPEC came back on its own and started to cut production the first time and it went up all the way to $147 for *[inaudible]* at least by the summer of last year after OPEC and Saudi Arabia and had done something very exceptional had in the early...in May, June 2008 unilaterally announced production increases as the oil price sailed through 120 to cool down the market. And I remember the day I did this the first time, the oil price jumped at $6 because everyone was in that frenzy. Nobody believed that Saudi Arabia would do it or nobody believed probably that they could do it. Everybody saw at the market was completely max out.

With the benefit of hindsight, we know that they had increased production exactly as they promised they would. That oil shows up in inventories by the summer of 2008, exactly at the point in time when global demand fell through...fell over cliff. And falling off a cliff, it did. I remember, September 2008 when I still get the dimensions straight. U.S. oil consumption dropped as much as total Indian oil consumption, 2.7 million barrels for that. And that caused the price to fall down until $34 at Christmas last year.

Now comes something interesting. In the first half of 2009, the global economy was still shrinking. Oil demand was falling and energy prices, traded coal or natural gas, were also falling. There are few commodities that are rising and oil is one of them. Within a few months it was back from 34 to twice that in the spring of 2009 in the midst of falling demand. And that, of course, we all know that somewhere is the result of OPEC reacting very quickly announcing production cuts by the end of 2008 and executing them to the tune of about $3 million barrels per day and you can show how they were catching up with falling demand so that at the end, we have a situation where

inventories are full and where the market thinks, (a) The economy is going to stop shrinking at some point, and (b) OPEC discipline looks solid and is going to hold and that stopped oil prices from declining and brought them to the levels where they are currently.

The research in that framework, of course, a role for financial investors and what they do. But they don't determine the direction which the train is going. They jump on the train. They look at this. They are no fools. They look at the same things we are looking at and then react. And I repeat it especially and you can go through the whole story and explain it but we don't have the time here but especially the right half of that price curve together with the supply management of OPEC, there is no way that anyone can explain that without recourse to OPEC and as management of the market.

On the demand side, meanwhile, there's also an interesting development. These are annual figures and then quarterly figures. But what I want to point out here is again this tension between the developing role of the OECD countries and the non-OECD countries. You see that already at the end of 2005 and the end of 2006, there's a whole demand, and the developed economies declines as long before anyone talked about in economic crisis. In 2007, the year of very strong global growth that declined even more and then, of course, through the crisis it fell through the roof. We predict this decline to continue going forward and one of the structural features of oil markets seems to me that the statement that OECD oil demand has peaked, demand and the OECD.

There may be individual countries which are in exception. But as a group, it has peaked. And that, I think, is the first of two structural issues which the crisis...the economic crisis has highlighted but will be with us for the long term in oil markets. OECD demand has peaked and what that means is not trivial. We heard in the previous session on short-term oil demand people complaining rightly and saying how difficult it is to estimate elasticities for the U.S., right? Now, think about estimating elasticities for

the non-OECD economies in places like China or for oil demand positively related to prices such as in the Middle East.

So, we have to decline in the non...in the OECD countries, which will be replaced by the non-OECD but it is not clear to which in the extent that we replace, what this really means for aggregate demand. Why not? First of all because the usage of oil for industrial purposes and developing countries is still much larger, so it's harder to calculate because it's not only transport. Secondly, massively because over...everywhere we have these subsidies for oil production still distorting at the picture. It will be very hard to calculate that as they gradually remove and these countries are removing them.

Of course, they realize they compete at each other and certainly, of course, because the vehicle fleet hasn't yet been built on those countries. And again, I forgot who. It was one of the previous speakers, took the position that maybe life is not that simple, that we shouldn't expect the Chinese exactly to drive that same cars as we do in the U.S. or in Europe. So, in other words that replacement of the non-OECD with...decline with...of OECD decline with non-OECD growth in oil demand mainly to aggregate outcomes where it's for some certain despite this big change in the world that this means is unilateral increased growing markets.

And the structure shift, the second one, of course, is the flip side of the success in OPEC and regulating the market is that amazing degree of spare capacity which we have right now which on the one hand means that OPEC has a problem forcing compliance and everybody who has studied the economics knows that what they say about cartels that they can never last forever. On the other hand in the short term it means, see little red arrow there on the left hand side, that's oil demand growth on average during the good years.

We now have about 6 million barrels a day spare capacity in the system. During the good years, annual demand growth was about 1.1 before the crisis hit. So, in other

words it is kind of hard to say now with the oil price is at 87. But in other words even if the good days were to return tomorrow, it would take more than three years until we're back in the situation as tense as it was before the price peak last summer. In other words, it's unlikely that over the next two to three years we would see similar price spikes as we have seen in the past.

But that picture also becomes important in the medium and longer term because now you think if these projections are right, we'd say that the good years are not to return tomorrow. Demand will probably be slow. Then you think about developments such as the upcoming production in Iraq, such as deep water production elsewhere in the world, such as finally, probably a supply response from the non-OPEC countries. And again, you may have reasons to suppose that at least over the medium term, it's not said and done. It's not clear that we are just sailing through another round of very high oil prices immediately. I'll leave this for discussion. These are the two structural things in oil markets. But what I really wanted to drive home is where we see the biggest shift in energy markets going on right now, and that is the natural gas.

Now, I don't want to preach or to convert you. You all know more about the silent revolution in natural gas in U.S. than I do, but there are actually two developments which need to be seen together in order to fully understand the potential global implications of that. First is unconventional gas and the production increases triggered by technological development in these countries. The second is the disappearance and the gradual erosion of gas price contracts tied to oil in much of the rest of the world.

Here, something which is actually from last year's statistic review. The amazing scale of that, which otherwise you would only find in textbooks, production and the number of recounts and you'll see the recount...production per *[inaudible]* rising exponentially because of horizontal drilling, hydrofracking. What is important to point out is less what you already know that gas prices fall and the trace parity with the coal that this triggered a big shift in the production of power in the U.S. from coal to natural gas.

Given flexibility, given existing system and amazing degree of flexibility, what is important to realize when we talk about energy policies or so that none of this was driven by sort of deliberate policy regulations. This was a market response to high gas prices.

And it is not an accident that it occurred to this country was a market response where you had a market. You had a large number of small, medium companies who could compete and you had a diesel in *[inaudible]* climate and that brought forward these technologies, which as a development which somebody said fell in our lap basically. And even last year when I showed...when we had this picture up, we and many others are not quite capable of seeing the forest for all the trees seeing the dimensions of what really happened.

But that's only one half of the story. To understand the other half of the story, you have to realize two things. First, what everybody knows, there is no global gas market at the moment. There is traditionally a gas market in North America, one in Europe, one in Asia, and their prices form was no connection. And secondly, many of the gas markets outside the U.S. are markets where you have the gas price not determined by demand and supply but by indexation to all prices. And this indexation to all prices, the long-term gas contracts indexing a total price is what is gradually evaporating in the rest of the world. That development was triggered by LNG. What should in many places all over the world …

[BREAK IN RECORDING]

Christof: The gas market be tied to oil prices? Very simple, because if you have one supplier or one consumer and the pipeline in the middle, you don't have a market; you need to find a price for it traditionally. Many people did this by linking it to oil and the same was true for LNG projects. And we have like a faction, a big cargo ship reclassification, the ship going from A to B to A to B and the whole plan and the whole

process over 2025, sometimes more years governed by long-term contracts, as far as the *[inaudible]* are concerned, and with prices traditionally tied to the price of oil.

That system started to come under pressure only five, six years ago when during the period of high growth, Asian consumers demanded more LNG and would start to contract cargos away from the original destination. We then would pay penalties for a higher price delivered at the gas elsewhere. The process was accelerated in 2007 when Japan needed more gas because they lost the biggest nuclear power station. And the process of...so gradually a segment in LNG markets develop a gas was fungible and which was...which became globally integrated.

Then the economic crisis...there was an excess supply of energy which is currently demand *[inaudible]* and that process was not stopped, was not reversed and accelerated. But this time *[inaudible]* produces driving it. Now imagine you sit in Trinidad and Tobago; you can't sell your LNG to the U.S. anymore. Of course, they don't need it and you happily discover the possibility of swapping a contract in Asia. And the share of these fungible prices kept increasing. Now, what this does, first of all is brought in other parts of the world spot prices down to whole *[inaudible]* over prices and below the long-term contract prices which are index to oil. Here's the example of Germany. This is the spot price, which for example exists in the UK, the core price. And the red line is the price which Germans have to pay for deliveries...pipeline deliveries from Russia, which are indexed to oil.

And that, for the first time, in a long...I think, for the first time ever, gave European countries a genuine alternative to these pipeline deliveries. And it hit Russian deliveries hard. Now, one last piece of technical information is pipeline deliveries are subject to take or pay contracts. So, European consumers have to take 85% of these deliveries and they did, and still you can see here how imports of pipelines went down into Europe and how storage in Russia went up, in productions and in Russia and Central Asia went down. That was the first time that price development somewhere else

in the world had such a massive impact on relationships, prices, and production, and places as far away as Russia and Central Asia and Europe.

Now, why does this matter? Because the erosion of these long-term contracts which have started in LNG markets are now creeping into the pipeline markets in Europe and, I would say, also in Asia. We have seen this when European utilities re-negotiated their contracts with Russian providers. We have seen this, a long list of things which have happened only over the last few months. The last piece of evidence of that was when gas from the Russian monopolist for gas exports suddenly agreed to halve the 15% of its gas deliveries, which are flexible priced at spot market prices. That's nothing a large Russian monopolist does without being forced to.

Now, bringing those two developments together and asked the question where else will these technologies which have been created here discover additional gas volumes, it will be in Asia, probably in Europe and bring that together with a flexibility or the contract system which we see emerging and you see that natural gas may indeed be a game changer. And let me just finish with just pointing out two of the major drivers which will accelerate likely that development. One is what we have discussed very often on: climate change.

On the left hand side, you'll see what everybody knows, CO2 emissions rising driven by...this is just from energy consumption, driven by the developing world. On the right hand side, you'll see a deeper problem namely the intensity of CO2 emissions per unit of energy, how much CO2 is emitted per unit of energy burned falling over long term long time as well as the fuel we use were gradually cleaner and rising since the late 90s again because of the increase share of coal in global energy consumption.

That together with the fact that, of course, natural gas only emits about a little more than 50% of the CO2 per unit of kilowatthour created may become a powerful driver for political support for investments in natural gas among the rich countries. And that energy security, the reasons why poorer countries use coal in the first place,

namely why are different from oil and gas because it is locally available, that may become a powerful driver for investments in that gas as far as the developing countries are concerned. I'm rushing through this to fulfill Adam's two-minute requirement.

Let me conclude with where all of this, in my opinion, sort of ends. This is an internal forecast until 2030 which we, this partisan in the public which we did admire the company I'm working for. If you would ask me what is the biggest uncertain...here is clear, OECD and non-OECD energy demand and here is the composition of fuel consumption between now and 2030. If you will ask me, what is the biggest uncertainty in that outlook? In 2030 we know, as we can be reasonably precise. The difference is between this and Exxon and the IEA and then it is not...is in for few percentage points only.

I wouldn't say the biggest uncertainties and the amount of renewal was. It will be somewhere between 5% and 10% of renewal that's globally. What more? I wouldn't say the biggest uncertainty is nuclear because if you will have a nuclear revolution as some people have. If you take renewable, it's hydroelectricity and nuclear together, you will have about 20% of carbon-free primary energy by 2030. And of course I wouldn't say the biggest uncertainty is whether we run out of oil.

To me the biggest uncertainty for this outlook is the borderline between coal and gas and more precisely the borderline between coal and gas in global power generation for those two reasons, climate change and energy security, in a situation where we have a unique combination of technologies which may make it possible to produce more gas in areas which used to import in China and where these contracts are coming down to really start generating a globalized market. And how finally will you realize when there is a globally integrated gas markets? You probably will realize it by the emergence of a gas cartel. Thank you.

Adam: All right. Thanks very much Christof. So, I know we're running late. Maybe some of you have got to take off but for those of you who want to stay, we'll do a

10 or 15 minutes' worth of questions. And the first questions is going to be for Matt Rogers and that is, Matt, could you give us just a little bit of detail on the infrastructure spending within the Recovery Act, specifically the Smart Grid and transmission lines.

Matt: So under the Recovery Act, we have $4.5 billion investment in Smart Grid, another $6.5 billion in the transmission infrastructure through the power marketing authorities in BPA, and the western area power administration. The fundamental factor we confront is that U.S. hasn't invested adequately in its transmissions systems since I was five. So, we have a system that's high cost, lower liability, highly vulnerable to storms and attacks and relatively inflexible to the introduction of new technologies into the grid. And what we need to do is make a relative...make major shift in that...in the robustness of that infrastructure.

The 4.5 billion is specifically a down payment. We funded 138 projects in 49 states, and a clear opportunity now is to make this transition from what the Federal government is funding now to a set of state initiatives to really build out that infrastructure more broadly. So, we made the down payment, which is quite clear is that these are higher return investments within the states can...and local utilities can take on in quite a good way going forward.

Adam: Great. Don, we had a question for you that had to do with the electric automobiles and how we would actually deliver power to those people.

Don: Well, yes, the question's asked as there are electric cars sufficient and some say that it does need electricity to generate transport electricity. And the answer is, of course, yes. You know, I guess kind of the way I look at electric vehicles is that there are cross-fuel technology. They will let you substitute for liquid fuels in a direct fashion. The fact of the matter is, you know, if you have a vehicle of a certain size and weight, similar tires and everything else, it takes a certain amount of energy to move it and that doesn't matter much by which you propel it with.

And so, the fact of the matter is that electric vehicles, because they tend to be smaller because the amount of energy they can carry with certain current battery technology is much, much less than the energy that you're carrying with gasoline. Even the most efficient, it would be the equivalent of pulling out of your garage with three gallons of gasoline in the tank. As one of my friends is doing. One of these cars as a demo says, you know, if you're with your ordinary vehicle, you'll be pulling out of the garage saying, where's the next gas station. But if the electric vehicle, you're full.

So, it's the fact that the vehicles are smaller, obviously, it's sufficient. So, I'm not sure electric vehicles is as much efficient in the abstract but they could be, if they're put into an energy system that can do other things with the system that can reallocate power that can store...potentially store power and all that. They become a demand storage...they become another element that could be optimized in the system. So, in that sense, they can be more version *[inaudible].* They'll be more efficient because they're...just the sheer size of the vehicles and they provide an alternative to using liquid fuels because there are many ways to make electricity. I guess that that's the way I would look at it. It's an intrinsic efficiency issue other than size.

Adam: Great. Steve pointed out the possibility that transportation growth in the developing world might change over time and this might be for both Steve and Christof. What do you think about growth in coal demand in China, and is it possible that coal growth in China...and I think, Christof, we saw that in some of your slides that that's the real key is finding some way to slow down growth in coal demand and, you know, maybe to a certain extent that, I guess oil, if we think about oil being transportation related, we might be able to fix the oil issue, but what about coal? Steve, why don't you take a shot?

Steve: No, I would sort of say that in less...one of the things we have to remember is that coal is very abundant and cheap in China. So, it's an almost irresistible fuel for the Chinese to use. And what we find is in countries that have a lot of

coal, it's an irresistible. That's true in the United States, that's true in Australia. And unless the Chinese join in some sort of international climate policy, I would expect them to continue to want to use coal to produce electricity and actually even move further in that direction as they grow.

Adam: Christof.

Christof: I mean there are two things about coal. One is what Steve said. It's plentiful available in China. And that was roughly, China accounts for 75% or so of global coal consumption growth every year. But China...and the second thing about coal is that there is a small but highly effective international market, which is not hampered by cartels or anything like that. Now, China is about to become a coal importer for the first time. That is one thing which will change the picture, perhaps.

And secondly, China has huge domestic environmental problems associated with coal. And that's more likely to trigger attempts to make this more efficient or even to engage in clean coal mechanisms than the global debate on climate change I suppose. But where these developments are going, we cannot tell. In principle, of course, they need coal for their development and they will not abstain from development just because it's based on coal.

Adam: All right. Matt, I mean, I think this is critically important. And did any of the Recovery Act's spending go towards coal capture...carbon capture and sequestration technology and eventually, maybe some of that might be made available to China and that could help solve this issue. I don't know. What do you think?

Matt: So, we're spending $3.4 billion on carbon capture and sequestration technology that encompasses five demonstration scale, carbon capture and sequestration plants of different technologies and then about a dozen industrial plants of...to demonstrate there and also occur at the industrial level. This is when the sector is very committed to doing in bringing the cost of carbon capture and sequestration down. The technology is known. It's clear how to do it. Key challenges, how do you do it

economically and how do you do it at the scale that we're talking about here. Because as you scale up these technologies, it proves a much more difficult than it is on the lab end.

And so by running the set of competing demonstration projects, I think we have the ability, really, to drive it down and we're in a set of international agreements both with China and with India in an effort to make sure that on a global basis, we begin to work different elements of this equation and the sum of the innovation parts actually, hopefully, turn out to be more than just the individual *[inaudible]* is doing.

Adam: Great. Here's a question. Maybe I'll take this one. What is the cost of finding and developing a barrel of oil globally or in the U.S. and then for conventional oil, I guess, what about shale?

And you know there are shale oils. The Bakken formation in Nebraska up into Saskatchewan, for example, were some of the technology being developed for gas shales, horizontal drilling, multistage fracturing, multiple laterals where you're going out, kind of like in a fan shape through the formation, might be applied to oil and could bring cost down. So, keep in mind we're, you know, Johns Hopkins SAIS and the Energy Information Administration, the sponsors of this conference...thank you very much for that by the way...the EIA does publish annually at the end of the year data on finding cost.

It's very difficult to separate oil and gas. And what they do is they do it on a barrel of oil equivalent basis, but let me just translate for you. The latest number comes up to close to $25 a barrel. That's a 2008 figure, might have come down a little bit in 2009. But if the long history in the oil and gas industry that the selling price for fuel has to be something like three times finding and developing cost, $25 times 3 is $75. For natural gas, if you just sort of do it on a BTU equivalent basis, the number probably is somewhere near $2. So, $2 times 3 is $6. So, maybe we really need $6 for oil and maybe we really need $75 or $80...$6 for gas, $75 or $80 for oil.

This varies tremendously across countries. It's a lot cheaper than the Middle East. It's, you know, more expensive in other places. Keep in mind that the causality in this tends to run from prices back to cost rather than from cost to prices. So, let me just quickly explain that. What that means is, when prices are rising for whatever reasons, it drags cost up with it. And if prices are falling, it tends to pull those costs down and we had prices going down and at the end of 2008, but now they're starting to rise again for oil.

They're going down for gas and I think that's one of the reasons why you're seeing a lot of these technological innovations in gas. It is being spurred in part by low gas prices. Interestingly, you know when you come back to this, what we might discover is from a long-term standpoint that we really do need oil prices somewhere near. The numbers that Steve was talking about in his presentation and maybe for gas it might...maybe $6 is going to end up being too high and it might be less than that. But we'll have to say we need more data.

Steve, a quick forecast. You said that you thought the EIA's forecast for oil was a bit too high. Do you feel the same way about natural gas? I think they've actually been talking about a relatively lower gas price forecast.

Steve: Yes, they have gas price. I mean, they show gas prices decoupled considerably from their oil prices. And I think their gas price is a lot closer to what I would sort of say is the mark, you know. I think $6 to $8 is probably a sustainable price for natural gas in North America given what we've seen in terms of shale formation. So, of course, if it turns out that there is going to be really strict regulation on the hydrofracturing in shale formations, then that I would have to take that away completely and say much higher prices will prevail. But it does look as though there really isn't any gas to oil competition left in the United States. Maybe a few places where that's occurring, which is basically diesel and…

[BREAK IN RECORDING]

…installations that are far from the gas lines that people are wanting to change. Well, I think, you know, we're in for much lower gas prices than oil price on a sustained basis, unless we become an LNG exporter in selling into an international market index to the price of oil.

Adam: It could be one of the reasons why that oil indexation might not last.

Steve: Yes, I can't say.

Adam: We'll do two more questions and then we'll try to get everybody out of here. Thank you for your patience, by the way. For Christof, Christof, what do you think? You had a graph of OPEC spare capacity. It looked like it was actually fairly flat, maybe even climbing a bit over the next year or two. How would you see that in 2015? I mean, I guess if demand is growing at a million and a half barrels a day and we have relatively flattened on OPEC supply, maybe we're going to erode that spare capacity away at some point.

Christof: It's just that's not the way to answer that question, saying it depends.

Adam: It depends.

Christof: It depends, yes. It depends on...it depends on whether economic growth and oil demand will be strong enough to *[inaudible]* that spec of passivity *[inaudible]* which we're seeing away while increased production from places, you know, like Iraq inside OPEC or even outside OPEC, it's held in bay. And the way things have been managed so far and the way things are going, I could imagine that we are not sort of drowned in spare capacity by 2015.

Adam: Great. Maybe we'll do three questions. This one's for Don. Don, you mentioned reengineering natural resources at scale. What examples for shale gas and so on...is there anything else out there that you think hasn't hit yet beside shale gas where we might see a breakthrough? What about the idea …

Don: Oh, you know …

Adam: Of the Bakken oils and type reservoirs.

Don: Well, the idea where you have, you know, basically unconventional reservoirs are actually where they really source rocks where they, you know, the oil and the gas is perfectly conventional. The issue of being able to essentialize, rubblize its scale in a controlled...because that's what you're doing, you're basically fracturing all of these material at and creating surface area hundreds of time or thousands of times, the natural fracture structure.

There are...I think once you people begin to understand how to do it, do enough of it, there's an opportunity to actually expand the amount of fracturing materially if you really want to. And so then, you know, and every time you increase the fracture density by a factor of 10, you've done a huge exposure on surface areas.

So, there is a lot of way to go. And these are enormous formations. These are formations that are a thousand meters thick. These aren't some little traditional producing reservoir or maybe a little hundred meters thick. These things are vastly larger. So, I think there is the opportunity to do that. I think the other thing that's out there was mentioned this morning. People are actually doing...they're at the early stage of whether...you know it exists. Can you make it a producing resource and that's methane hydrates. Hydrates and these are orders of magnitude more methane and hydrates that there are in all the other gas there's a role *[inaudible].*

If anything like that gets down the road, it isn't going to happen tomorrow. But in 20 years, if that's a developable resource for, that means the U.S. has basically a virtually unlimited gas then and as well as some other parts of the world. So, that's a long shot but to make that work, you're getting back to this thing where you're actually changing the structural mechanical behavior of the subsurface in order to do things. That we're at the...it's clear that that's an economic proposition today.

Adam: So, the interesting thing …

Don: And that's what the U.S. plays …

Adam: The interesting aspect about that is that if you go back...I had a discussion with one of the U.S. companies. It was very active in early in shale gases and I said, “When did you have your aha moment?” And the individual looked at me and he said, “What do you mean by that?” And I said, “Well, when did you realize having then an early player in the shale gasses in Texas and Louisiana that this was something that would influence the country and maybe the world rather than just being good for your company?” The answer to that was the end of 2008. I mean, that’s only a year and a half ago that the companies who were the most active in developing this play realized its full potential at scale. So, Don’s answer, I think to, you know, what might change is that something’s actually do come out as in big surprises.

Matt, let’s finish off with a question for you and maybe anybody else that wants to have a comment on this. Don mentioned the institutional factors in employing and developing and deploying the Smart Grid and how, in some cases, consumers didn’t seem to be quite willing, I guess to have their, you know, their electric meter showing up on their Facebook page maybe would be the way but...but are there ways that you can see that we might be able to deal with issues like that? Is there anything else from an institutional standpoint that might either help or slow us down in this effort to innovate a new technology in the energy area?

Matt: I think Don’s right to point at the institutional factors and whether behavioral factors is something that that is largely under study and under...understood. One of the things that we’ve done as part of the Recovery Act is with each of the major investment areas. We’re working with the Council of Economic Advisers in running a series of randomized economic experiments to figure out exactly how people behave. Don’s actually doing some of that in his work at USC and there’re out there, the other ones that are going on. So, we get some really empirical data on how consumers behave because whether it’s the Smart Grid activities or whether it’s how people use electric vehicles, this is something where I think the technology has clearly demonstrated. You

put something in the consumer's hand that has different feature functions capabilities than it's had before, we actually are not very good at predicting how they end up using that technology, and so we actually need some empirical base to figure that out, and I think the next couple of years we'll provide some rich data in that regard.

Adam: So, demonstrations. Right. Okay, so we'll see you all tomorrow morning. Please join me in thanking our panel: Matt Rogers, Steve Brown, Don Paul, and Christof Rühl. Thank you very much.

END OF RECORDING