Secretary Chu: Very pleased to be here. I'm very happy to be here to kick off the Energy Information Administration Conference. I think the work you do is incredibly valuable, it actually lets policy-makers have some real data, and that's always good.

We have a problem, we have many problems, but I think the energy problem is one of the problems that is arguably is something that science and technology must solve and there are many aspects to it. Our economic prosperity is intimately tied to having affordable energy. As conventional gas and oil become scarcer and as the standard of the world goes up, there's a potential for geo-political conflict in the escalating competition for energy resources, and finally, there's the risk of adverse climate change.

So this is the inflation-adjusted price of imported oil and, as you see, it is a drain on our economy. This goes out to (I'm trying to see where it is, the date's taken off), but it goes to into something like 2007, late 2007, where we're now spending hundred of billions of dollars a year importing foreign oil.

There's also a correlation between the price of oil and recessions. This was actually taken from an article written in 2005, which said there may be a seemingly correlation, but it's not really there. The gray bars are where there's a recession, there's a spike in oil prices; a recession ensues, of course there's a decrease in demand. As the recession continues, and it was, as I said, written in late 2005 and said, well, there might be a correlation, but where you don't have a recession now. So in any case, two years later we're hit with another one, a similar sort of thing, a very deep recession, now followed by an increase in oil prices.

Again, back to the dependency, these are two graphs you see, the net imports of United States oil in the upper graph increasing the domestic production in yellow declining, so they crossed over. We became an oil importer around 1950, a net oil importer around 1950. Before that we were a net oil exporter, but now we're importing roughly 60 percent of our oil, and on a different time scale. China has done the same, much more rapidly, it now imports roughly 50 percent of its oil. And this energy and the jockeying for position to have access to gas and oil has hit the news, it is becoming a more and more increasingly defining factor in geo-politics around the world.

So energy is a security issue, and then the newest 800 pound gorilla in the room is that we're beginning to see climate change. This is the temperature in the northern hemisphere over the last 1,000 years, and the red ones at the far right are direct temperature measurements and so the temperature of the world has been increasing somewhat dramatically over the last 100-150 years, and so the question is what economic impacts can this have on the world and what social impacts?

And so I just want to name one, these are localized computer modeling of what would happen in the state of California under two scenarios. The first scenario is a very optimistic scenario, I think, more optimistic than we can achieve, but I hope we can and that is that we can keep the level of carbon dioxide down below about 500 parts per million. We're right now about 420, at the beginning of the industrial revolution we were at 275. So, in this optimistic scenario, in the first part of this century before 2050, the optimistic scenario says that the snow packed in the Sierra Nevadas in California will decline, and so that there's only 74 percent remaining, a decline of 26 percent.

In the more pessimistic scenario, business as usual scenario, we will have lost 40 percent of the snow pack. Now for those of you who know California, you can recall that when there's about a 20-25 percent decline in snow pack two years in a row, California begins to ration water. And it's for only two years in a row where we begin to see this, so in the first half of the century, if we're say a 25 percent decline forever, on average, this is pretty serious business, but looking ahead, you see that in the later part of this century, there would be only 27 percent of the snow pack remaining in California, whereas in the pessimistic scenario, we've lost virtually all of it, there's only 10 percent remaining, roughly 10 percent.

So remember that the snow pack is the long-term water storage, it, there's a wet season in California, it rains and snows from roughly October to March and then after that the slow melt of the snow provides us with water during for example, the agriculture growing season. So this would have incredible economic impacts if either scenario turns out to be true, but devastating if the more pessimistic scenario turns out to be true.

There's also a common misunderstanding that the economic prosperity the standard of living of countries is directly proportional to its energy consumption. And so here what you see plotted is the human development index, which includes the gross GDP per person of a country but it also includes the educational level and includes health care. And if you look at the human development index verses the average use of electricity per country, what you find is a cluster of countries, Japan, France, Netherlands, Italy consuming a certain amount of energy, but the remarkable thing is that the standard of living does not increase as you go to countries that consume more energy - it just flattens out.

Now it is absolutely true that when you go to poorer countries, countries that are developing the use of energy is proportional to the standard of living. But the point here is that it plateaus and those clusters of countries that's shown, the United states is off to the right, but that cluster of countries, once it decreases energy use per person by a factor of 2 and I think the United States should follow. Here's another example, where the use of energy, electricity per person is not seen to be consistent with the increase in standard of living.

In the first of the oil shocks in the 1973-74, people in California took this very seriously and said we have to fundamentally change the way we use energy, it was both the Republicans and the Democrats said we have got to change our ways. They instituted stricter building codes, appliance standards, began to experiment with decoupling, that is to say that utility companies before were - they would make more money if they sold more energy and in order to align incentives right, California began to say, okay, we're going to decouple that incentive, what really matters, to a utility company is return on investment, if we can protect the return on investment and get them to be in favor of conserving energy the things would be aligned. Well, due to all those policies from the mid 1970's 'til today, the amount of electricity used in California has remained flat. The rest of the United States has gone up over 50 percent.

During this time the GDP in California doubled, it went up higher than the rest of the country. So here again it's another example that conserving, using energy more efficiently, conserving energy is somewhat decoupled from an increased standard of living or GDP.

So what President Obama has done, is he's realized is even in this time of crisis, we have to position ourselves in order to evolve towards the green economy and so he's created in the Economic Recovery and Reinvestment Act a plan to create new jobs, jobs that can't be outsourced and also, equally important, signals that say we're going to position the United States to be competitive in the economy of the 21st Century.

And by this I mean the following. This is a picture of some windmills; the wind turbines of today were not developed in the United States, they were developed in Europe, they were very stable fiscal policies in Europe that allowed companies like Vestas to develop these wind turbines. Many of the power electronics, the power transformers, things of that nature, are no longer manufactured primarily in the United States, they are manufactured in Europe or China.

And so I ask that we, you know that famous expression, "ET phone home," well, "ET" in this case is energy technology we want it to return home, and this is something else that we need some signals, policy signals that encourage industry in the United States to reinvest in themselves.

In terms of more efficiently using their energy, the biggest impact would be in the building sector. Commercial and residential buildings consume over 40 percent of the total energy in the United States. Here you see in the upper one, units are important but the highest use of energy that big arrow on top is our existing stock of commercial buildings. There, due to standards you can improve that by roughly 20 percent and that's the arrow that you see at 70.7. But you see on the left hand side a number of buildings that actually have reduced the amount of energy by two-thirds, down by 66 percent, and we believe that it's possible to reduce the energy consumed in commercial buildings by 60-80 percent with investments that will pay for themselves in 10 or 15 years.

But this requires a little bit of development of technology, especially computer design tools to help architects and structural engineers and others to actually lay out a plan for building and it would have to be a very smart building with electronics that could constantly tune the building in appropriate ways. We have a lot of these technologies in hand but they haven't been integrated and so building systems integration is now where I think the biggest impact would be. If you think by analogy, think of your modern car today. There are many microprocessors in your car, microprocessors to tell the engine how to mix the fuel/air mixture depending on temperature-air pressure, temperature of the engine, and so this modern processor actually is tuning up your engine on a minute by minute basis. You no longer have to take your car in to get it tuned up.

In a building, when you first build it, the tune up is called “commissioning of the building,” where you tweek the air conditioning/heating systems. But these buildings fall out of tune, in order to cut corners sometimes you, these buildings aren’t even commissioned, and just commissioning a building can save 10-20 percent of the energy, just to tune it. And then to re-tune it 10 or 20 years later it can save another 10 percent. So what we need is buildings that automatically tune themselves, put the heating and ventilation where people are, with very inexpensive sensors.

So how do we get where we want to go? An energy efficient economy requires, it requires Federal investment to promote efficiency, strong and sensible standards, but it also requires that many of the technologies that we need are not here today and so we need investments into research and development and finally it requires the collective will of the American people. While some of these things need to be developed over a 5-10-20 year period, I think the collective will of the American people is something we can get going today.

And I draw to your attention and remind you to those of you in the audience who are older than me, that during World War II conserving energy became a patriotic duty. These are the fuel that we were using in the United States was then - there was a huge effort to convince the American people not to used the precious fuel in the United States so that we can send it overseas to help in the war effort. And so these posters are exactly that. And so what we need today is beginning with the consciousness of all Americans, that it is simply our patriotic duty to go forward with these ideas. But there has to be things that the Federal government can also do and so Federal investments to promote efficiency have already started in the recovery act. There are 6 billion dollars in loan guarantees to help efficiency and new energy technologies. Over 8 billion dollars to weatherize homes, particularly low-income homes because the weatherization is the simplest thing you can do. The leaky walls, windows, and poorly insulated homes are where 20 dollar bills just simply float out the window and miraculously turn into carbon dioxide in our atmosphere.

So we're investing very heavily in the obvious things and also to set a tone so that American industry can reinvest in itself and that's why the R& D tax credit, there are plans in the out years to make that essentially permanent.

What do R and D tax credits do in fiscal policies? As I mentioned before, those fiscal policies in Europe allowed Denmark and other countries to develop a wind industry. On the right hand side you see that declining orange curve, maroon curve, that's the cost of wind generation. It declined by about a factor of 8 over a 20 year period. The cost of wind generation declined by a factor of 8. That's a wind turbine you see being installed offshore, these are huge impressive things. This is a pretty big wind turbine, it generates 6 megawatts the diameter of the rotors is 126 meters. And just to give you a feel for how big this wind turbine is - I put it in scale - the size of a 747 400 airplane, the wing span of a 747 is equal to one of those blades. And these things are now achieving 5/6 of the maximum theoretical efficiency that you can possibly get out of a wind turbine. This is a type of calculation that physicists love to do. They say here's a certain amount of kinetic energy going into the wind turbine. You have to conserve energy. You have to conserve momentum and the air has to end up on the other side. And aside from that, that's all the requirements there are, continuity of the air, conservation of energy momentum. It turns out the maximum efficiency of a wind turbine is that it can extract 59 percent of the energy of the moving air and the turbines extract 50 percent. Unbelievable considering these three skinny little blades.

Okay, strong and sensible standards are needed. Let me give an example, this is an example of refrigerator efficiency that brown curve is the size of the average home refrigerator, in the mid 1970's. It was 18 cubic feet, now it's 22 cubic feet, it's flattening out, not because of satiation of the American appetite, but it's really the size of the kitchen door, so they're making the refrigerators wider and the space you can put them in a little wider, so it's going to continue to increase.

The blue curve is the energy consumed by the refrigerators. So even though the refrigerators were increasing in size, the energy has declined by a factor of 4. It's now 2 percent: today's refrigerators are use 25 percent of the energy used in the mid 1970's. Those dots were standards first enacted in California but finally adopted Federally. And when the standards were discussed initially, the manufacturers said this is terrible, home buyers, the consumers will never be able to afford these highly efficient refrigerators - it would be a disaster. And so what has happened is the cost of refrigerators, the inflation-adjusted cost, the green curve, and it went down by a factor of 2. It's because efficient refrigerators have better insulation. They right-size the compressor - the compressor was the biggest cost of the refrigerator - besides the stainless steel outsides and so that has improved - greatly. How significant are refrigerator savings? If we had the refrigerators of 1975 operating today, versus what we now have, the amount of electricity savings is more than all the wind and solar renewable power we generate today. So it's a big deal. And it's also true of heaters and air conditioners.

But we do still need research and development to deploy new technologies. This is cost curves of certain areas in energy generation - photovoltaics, windmills and gas turbines. So on the axis, on the X axis is not plotted time, but it's actually the more significantly of plots, the deployed investment going out, the more you deploy, the more you drive down manufacturing costs. And I've manually put in where we are today in costs in photovoltaics and windmills in 2005, and gas turbines. They all follow Moore's law curves in the sense that steady incremental improvements drive down the costs, actually exponentially, but a very slow exponential. The windmills are becoming competitive with gas or within 20 percent because the price of gas has gone up an average, and so the issue, though is photovoltaics are still considerably higher, and that's why most of the renewables today are wind and photovoltaics. Now in the long run, if you consider the energy resources the world has, I think photovoltaics will play a major, if not <u>the</u> major role, say 100 years from now. Why? Because if you can get inexpensive photovoltaics to make economic sense, then you need only a few percent of the world's deserts to supply all the world's current electricity needs.

So the question is, how do you make it cost competitive? Now, we can follow this learning curve - this steady, incremental improvements in our existing technology - or you can go to something else, what I call a transformative technology. So what's an example of a transformative technology? Well, I'll, in terms of history I'll bring out one example - that AT&T was developing vacuum tubes, which was an essential component of transcontinental telephone system. Just in case you want to know what a vacuum tube looks like, for those of you younger, that's what they are. And so in the 20's and 30's, AT&T, Bell Laboratories become the primary research and development arm of vacuum tubes because it was seen as core to their business. But the trouble is, vacuum tubes generate a lost of heat, you have to heat a wire to red hot so that electrons come out and they eventually burn down. And so there was a lot of research to extend the life of the vacuum tubes from one year to two years to four years, they were getting six years. But during the time, while they were heavily investing in improving vacuum tubes, they also started a little skunkworks outfit in the late 1930's, and it was based on a new development in physics that occurred in the mid 1920's - the development of the quantum theory of so-called quantum mechanics. The invention or development or discovery of quantum mechanics and its application to how electrons move in metals and semi-conductors told the physicists at Bell Laboratories that maybe we can make a solid-state vacuum tube.

And so they tried it, that's the first one, that's the first transistor, it's a picture only a mother can love, but from that transistor developed the integrated circuits, developed the entire semi-conductor industry, the computer industry, the internet, all these things made possible by, in the 1920's a fundamental theory of the microscopic world that was then applied to communications. So that's an example of a transformative technology.

And so what we need in terms of solar cells is something where we have a continuous process where we can print out the solar cells on thin inexpensive polymer backing that the electronics for the solar cells are imbedded already in this printing thing and they can be it should be very, very inexpensive, the entire module. And if we get this price point right, then people without subsidy will think anything of putting it on their roofs and power companies can eventually use them.

And so are there, is there Bell Labs today in the energy sector? And the answer is, well, not really, and so, I think the Department of Energy is poised to become to be that industrial lab. The power utility companies don't invest the way IBM and Bell and Xerox invested in their technologies, and so, as a start, the Federal government can begin to invest and begin to do the research and development that will lead to this new generation of photovoltaics and other technologies

I want to remind you that the Department of Energy is the largest supporter of the physical sciences in the United States. It has 17 national laboratories, and it has actually funded the work of 88 Nobel Prize winners in the United States. This is more than any other science funding organization in the U.S., has come from the Department of Energy. So we have incredible horsepower, both in the national laboratories and in our universities, Department of Energy funds all these people, and the question is can we engage this intellectual horsepower? Maybe not these horses, but a different kind of horsepower. And so, President Obama's out year budget calls for doubling of the investment in science, both in the Department of Energy Office of Science, and NSF, in NIST. This is incredibly important. What will this new science give us? I'm going to give you two examples.

We have the promise or potential of biofuels. These are biofuels that are based on specific grasses. This is also the use of biowaste: wheat straw; corn stover; other things; rye straw. And so the idea is very simple: the plant grows, it uses sunlight energy, it captures carbon dioxide out of the atmosphere and combines it with water and other nutrients to create biomass and we convert that biomass into chemical energy.

There are many ways to improve the plants, to improve the way these plants grow - alter the plants so it's easier to breakdown and separate out the sugars and there are incredible possibilities of also improving the processes of converting this lignus cellulose into fuel, not only ethanol or butanol but fuels that are equivalent of jet plane fuels, diesel fuels and gasoline. So already the

Department of Energy has started three research institutes to look at advanced biofuels production, and within the first 6 months for the inception of these research institutes we have now gotten yeast and bacteria to be able to munch on simple sugars, and instead of creating ethanol, using a 5000 year old technology, they now create diesel fuel and gasoline-like fuel that separates from water. So that's a start. We have to get the commercial viability.

Let me give you an example of how science and technology has really transformed the way we think about things. This is a plot of world grain production and in 1960 the population of the world was roughly 3 billion people. This is not exactly accurate. There's a book called, "The Population Bomb," that went to press in 1968. In this book, written by a Stanford biologist, it said that despite any crash programs, the world cannot feed the people of the world and hundreds of millions of people will starve to death. And so what happened was something quite different, in fact in 1970, just two years after that book, "The Population Bomb," went to press, Norman Borlaug received the Nobel Prize, the Nobel Peace Prize. And what Norman Borlaug did, is he developed a hybrid strain of wheat that was, could tolerate more fertilizer, and this hybrid strain of wheat, which is also disease-resistant, was able to increase the productivity of wheat, not only in the United States, but in countries like India, Pakistan and Mexico 3 to 5 fold per acre.

And so what happened is, and the lines down at the bottom, the black and green curves, you see that the amount of land put under cereal production actually remained flat, even though the world population more than doubled from 1960 to 2005. In the meantime, the productivity of that land increased, so the blue and red curves show the amount of grains, rice, wheat, corn, the grains being produced. It's because of the new so-called green revolution. It completely transformed how we grow food.

There's another thing that happened at the turn of the century, two chemists, Fritz Haber was the first one, and he invented a process of synthesizing ammonia. We now synthesized ammonia from now primarily natural gas, the ammonia is then used to make nitrogen-based fertilizer. That invention was deemed so important that it was awarded a Nobel Prize in Chemistry, when Haber invented his process, because it allowed Europe to feed itself. Before, they were facing a crisis at the beginning of the 20th Century. Their soils were becoming depleted, the rotation of crops, the use of manure weren't sufficient to maintain the nutrient quality of the soils. And so Europe was debating two technological fixes: one is to, well, they colonized a lot of the rest of the world and say we'll get the rest of the world, we'll import the food, but others said we actually enjoy fresh vegetables and things like that, so why don't we just import their top soil and use that?

So that was the debate. And so, a German chemist invents a way to make nitrogen-based fertilizer. Carl Bosch, another German chemist, invented a way to make it much more commercially viable and because of that he got a second different Nobel Prize for fertilizer. Again, it was considered that important. And in 2007 there was a third Nobel Prize for the understanding of the Haber-Bosch process, again given in chemistry, the catalytic understanding of how it actually worked, so two and a half Nobel prizes for fertilizer.

So, let me give you another example of what we've been able to do. When man first began to think of flying, they looked toward nature, and this is taken from the sketch book of Leonardo Di Vinci, and he's sketching how birds flew, and then he devises this contraption shown on the right and the idea is you strap yourself into this and using your leg and arm power you jump off a cliff, flap your arms and legs and hope for the best.

Now the first flying machine, powered flight did not use muscle power, so it was a hybrid, this is the Wright brothers plane and the Wright Brothers wanted to control flight, so they used a lot of the technology of birds, so what you see in this front-on view is their plane, and the wings are warping the way a great soaring bird would warp his wings. So that part was taken from birds. But there's no muscle power, it was the gasoline engine, so it was a hybrid solution.

Now if you fast forward to what we have today, again, look at a 747. That 747 doesn't really look like a bird but it works very well for our purposes and really much better than birds. Now admittedly the 747 can't do certain things that birds can do. For example 747s don't mate, lay eggs little 747 eggs that grow up to be airplanes. As a physicist, I think it's because of that large vertical stabilizer prevents that from happening. You notice the Wright Brothers plane has only horizontal stuff, just like a bird? But they decided later that a vertical stabilizer was a good thing.

So the point here is that by using materials that are not accessible to nature, structures not accessible to nature, we can actually do better than nature. So, if you think of how nature takes sunlight energy, makes energy. This is biomass for example, or the way algae accepts sunlight, makes energy. And the primary ingredients of photosynthesis are now understood. Actually a Nobel Prize was given to someone at Berkley Lab for primary understanding of photosynthesis in DOE-supported research. You look at that, that upper picture and say can we do better than that using today's materials, today's nanotechnology. And the first step in that, artificial photosynthesis, is you use the sunlight energy, take water and split it into its components, oxygen, hydrogen. And then from that you assemble a hydrocarbon.

Now why would you want to do this? Because we already have plants. Well, plants don't use most of the water to make a fuel, the water gets transpired through the plant, and so we want to use every precious drop of water and convert it to fuel. And the other thing is taking our lessons from things like airplanes and other technologies that we have invented, that you can really - we think - do much better. So again, this is something the Department of energy would like to support. This won't happen in the first 5 or 10 years but perhaps in the next 10 or 20 we can hope that we can begin to develop this artificial photosynthetic systems.

So let me close by just reminding you of a very famous photograph taken by the first astronauts that went to the far side of the moon. This is the Apollo 8 mission, and on Christmas eve 1968, they took this famous picture called

“Earthrise.” And we should think deeply about this picture, because what you see is a very bleak lunar landscape. You also see a very warm, inviting Earth, and the other thing you should think about is there’s no where else to go. And so, we should really take care of what we have.

Thank you.

Mr. Nordhaus: The United States and other high-income countries face several long-term challenges relating to energy. The headline issue, which is engaging a small army of scientists and international negotiators, is the carbon question. The key economic policy requires placing a price on carbon fuels that reflects the social costs of their emissions. Over the longer run, nations will need to find an economical way to make the transition from today's technologies – so dependent upon fossil fuels – to that are essentially carbon-free.

Another set of questions involves oil. The oil question involve a highly complex and controversial set of issues. These include among other things the rising share of imports for the U.S., local and regional pollution, the interaction with national security, particularly visible in our Iraq strategy, the rising dollar burden of imports, recycling oil revenues, price volatility, unacceptably high profits of U.S. oil companies, tradeoffs between drilling and environmental values, and oil's contribution to global warming.

<u>The Integrated Oil Market</u>

My remarks today will encompass all of these, but in a roundabout way. My major point is that much thinking about oil is misguided because analysts often have misunderstood how the oil market works (no one in this room, to be sure, but many people outside this room)

I suggest that it is fruitful to think of the oil as a single integrated world market. That market will be the outcome of a multitude of individual supplies and demands, but the overall price and quantity are determined only by the *sum* of the demands and the *sum* of the supplies. The composition of the supplies and demands is irrelevant. If you look at the world through these spectacles, the world looks very different. That is the point of my talk today.[1]

In this integrated-market view, we can envision the oil market as a giant bathtub (as this Figure shows). The bathtub contains the world inventory of oil. There are spigots from Saudi Arabia, Russia, the U.S., and producers that introduce oil into the inventory; and there are drains as the U.S., Japan, Denmark, and consumers that draw oil from the inventory. But the price and quantity dynamics are determined by the sum of the demands and supplies and inventories, and are independent of whether the faucets and drains are labeled "U.S.," "Russia," or "Denmark."

You might naturally ask, How do we know it is an integrated world market? The best test for market integration is to examine prices, in this case, the price of oil in different markets. This figure shows a graph of weekly oil prices over the period 1997 to 2009 for 15 different crude oil markets. The picture shows in a striking fashion how oil prices move together. Taking 33 prices with long historical records, the median correlation coefficient of prices over this period was 0.994.

This figure shows one further measure, which is a scatter plot of the log price of Iranian and Libyan crude. These are particularly revealing because these two countries have been subject to sanctions and embargoes, but none of these shows up in the prices of their crude oil.

This correlation here is markedly higher than virtually any other traded good or service. We show in this figure, as a more typical example, the prices of standardized saw logs (#2 sawmill Douglas fir logs in the Pacific northwest of the U.S.). These show substantial variation of the prices, and the median correlation coefficient is 0.75. Similar empirical findings on the failure of the law of one price have been seen for virtually all products, even very homogeneous ones.

[1] Some technical details: In this discussion, I will consider the polar case of a 100 percent integrated world market and recognize that it is oversimplified and

only 99.8 percent accurate. But 99.8 is pretty close to 100, so the analysis of the pure case is very close to the more complete truth. I emphasize that this discussion applies to oil but not to most other energy sources such as natural gas or coal. Also, for this discussion, I will abstract from national security implications, such as the military costs of protecting oil supplies, or the cost of going to war to protect oil producing countries from predation or chaos. These are important questions but involve issues far beyond the scope of this talk. Finally, note that these are pre-tax prices from EIA and are FOB prices. They will differ from wellhead prices and definitely will differ from consumer prices of retail petroleum products.

Implications

Few of you will find the discussion up to this point surprising. I spend some time on it primarily to lay the empirical foundation for the substantive discussion. My plan now is to examine several common themes about oil policy and analyze them in the context of an integrated world oil market.

Let's begin with one of the most common fallacies in oil policy – the need for oil independence. A hardy perennial is the idea that we should limit our consumption to countries that are "secure sources." We might concentrate on the Western Hemisphere, or perhaps our neighbors Canada and Mexico, or perhaps rely only on the United States, or we might even exclude Alaska lest it decide to secede.

These policies make no sense in an integrated world oil market. They have zero value. Suppose that we were to concentrate our imports on completely reliable sources – ones that would never, never cut off supplies to the United States. But a "cutoff" from unreliable country A to the U.S. would lead country A to send its oil to other countries. In the integrated world market, this would simply lead to a reallocation of global production from other countries to the U.S. to make up the difference. Unless a country actually reduces its flow into the world bathtub, there would be no impact on the U.S. of sourcing imports from secure regions.

A corollary of this point concerns U.S. embargoes on foreign oil producers, such as Libya or Iran. To a first approximation, these have no effect on world prices or production; no impact upon the countries whose oil is embargoed; and no impact on the United States. They are purely symbolic measures.

We should not conclude from this discussion that we should relax our concerns about security of supply and price volatility. Rather, the point is that these are global problems that arise from the balance of global supply and demand. The world oil market is vulnerable if global supply is tightly constrained, say because there is no excess capacity. Even if the U.S. has limited its purchases to secure sources, a crisis anywhere is a crisis everywhere.

A related fallacy is the security concern about the "competition for resources." We might worry about who will control oil production in distant lands? As an example, national security specialists sometimes fret about whether Russia is gaining oil-production concessions in neighboring countries; or whether China will dominate drilling in the South China Sea; or whether India will have concessions in the Sudan. These concerns are more appropriate to the 19th century than to the 21st. In fact, the major U.S. interests are that the world's oil resources be fully and quickly developed, not who develops these rights. If India can find and develop Sudan's oil resources quickly and efficiently, that will add to the flow into the oil bathtub, will reduce world oil prices, will diversify world supply, and will benefit the U.S.

Turn next to the broader question, what is the value of “oil independence” in the context of an integrated world oil market? This requires considering the question of the “oil premium.” This concept refers to the “externality” generated by oil consumption. In other words, what is the difference between the social cost and the private cost of oil consumption?

Literature on the oil premium has identified three sources: first are the technological externalities (such as air pollution and congestion); second is the price effect – the fact that higher consumption drives up the world price and therefore raises total costs; third are macroeconomic externalities – the finding that an increase in oil price tends to produce or worsen recessions.

Energy independence would be valuable to the extent that it reduces these three external costs of oil consumption. The important point is that none of these costs involves oil independence or the share of imports; rather, each of them involves total consumption of oil along with the elasticities of supply and demand for oil in the world oil market.

Begin with the price externality. If the U.S. consumes an additional unit of oil, this adds to world demand. The impact on the oil price is determined solely by the *world* price elasticities of supply and demand and is independent of domestic demand and of the share of imports in domestic consumption. Take the simple example where the world elasticities of demand and supply are minus and plus one-half, respectively. Then the oil price externality is exactly equal to the initial oil price. The share of imports does not enter into this calculation.

This reasoning indicates why oil independence will also have no effect upon the macroeconomic externality. Most analyses of the recessionary impact of oil prices find that the impact goes through two mechanisms. The first is the “tax increase effect,” through which consumers find their real incomes decline as rising oil prices rise. A second effect is the monetary-policy effect. As oil prices rise, this increases the rate of inflation. To the extent that central banks target inflation and do not completely remove oil price shocks from their target inflation rate, oil price increases will lead to higher interest rates. The contractionary impact of the interest rate effect reinforces the tax increase effect.

However, note that both of these impacts are affected by the total domestic expenditures on oil, not by imports of oil. The fraction of oil consumption that is imported has to a first approximation no effect on either the tax increase effect or on the monetary-policy effect. Therefore, here again, the key focus of policy should be on the world market, the U.S. contribution to total consumption, and not on oil imports.

This discussion has ignored up to now the implications of our oil consumption on the balance of payments, foreign indebtedness, and the external accounts. For many people, this is a central concern. We are, it might be thought, impoverishing ourselves because of our addiction to oil. This figure shows the trend over the last four decades. The dollar value of oil imports peaked at about 28 percent of total imports in 1979-80, fell to around 5 percent in the late 1990s, and then rose to between 15 and 20 percent in the last few years. People might naturally be concerned that oil imports are a serious issue for our external accounts.

Two points are important here. The first relates to the microeconomic principle of comparative advantage. We import oil because the cost of domestic oil is higher than the cost of foreign oil. It is more economical to grow and export wheat and use the proceeds to import oil than to drill for high-cost oil or to grow oil from corn. Comparative advantage applies just as much to oil as to textiles, to bananas, and … dare we mention it … to automobiles. There is no reason to engage in uneconomic import substitution for oil for balance-of-payments reasons than to engage in import substitution for tennis shoes, paper boxes, or automobiles.

The second point is a deeper one. Macroeconomists have gradually changed their view of the reasons for countries' trade deficits and surpluses. We can best understand our trade deficit and China's trade surplus as the result of national and world savings and investment patterns, not as the result of the microeconomics of oil drilling, free trade, or cheap foreign labor. The large U.S. current account deficit is primarily a result of low U.S. saving and high foreign saving, not of our addiction to Saudi oil and Chinese toys.

Reducing the value of oil imports would take place through the same mechanism by which our overall trade deficit would be reduced. Higher governmental and private saving would lead to higher national saving. The full-employment equilibrium would come at lower domestic interest rates and a depreciated dollar. This would raise import prices, including dollar oil prices, and raise export prices. The net effect would be to reduce domestic consumption of oil as the world oil price in dollar terms rises. So here again, as in the other issues, the key variable to keep your eye on is total domestic oil consumption, not imports of oil.

Enough of fallacies. If we look at the world through the lens of an integrated world oil market, how should we think about oil policy? What are appropriate measures to deal with our oil problem? What exactly is our oil problem?

A full discussion will need another talk, but I will sketch a few points. Beginning with the basics, we have two major but closely related objectives. The first is that oil prices should be low, stable, and sustainable. Second, however – and this is a big however! – low oil prices must be in the context of the proper pricing of carbon. Low oil prices are beneficial to the economy as long as they do not drive us into dangerous climatic waters. Hence, it is critical for sensible oil policy to get climate-change policy right. Until countries put an appropriate price on carbon emissions, energy policy will be incoherent, and energy and environmental policies will be working at cross-purposes.

Once we have corrected the price of carbon, the major objective is to take policies that will ensure low, stable, and sustainable oil prices. Within this framework, we need to consider oil policy in terms of world demand and world supply, rather than domestic demand and supply. In terms of supply, we should encourage development and production by all producers, independent of whether or not they will benefit American consumers or producers. The world oil price will be lowered equally by increased production by Chinese, Indian, or American companies in any part of the globe. This also implies that we should not subsidize domestic production. There are around $2 billion of U.S. tax expenditures for oil and gas production today. Many of these are rationalized as encouraging domestic production to reduce dependence on imported oil and are wasteful in the context of an integrated world oil market.

The second point is to encourage policies that lower the demand for oil everywhere, not just in the United States. There are many examples, but a particularly important one is to work to reduce subsidies to oil consumption wherever they occur. According to the International Energy Agency, there are around $100 billion of subsidies on oil, with the biggest subsidies in Iran, Indonesia, Saudi Arabia, Egypt, and China. These are not only inefficient policies and costly to these countries, but they have spillover effects and drive up oil prices in the world market.

The lesson here is that we need to broaden our horizons when thinking about oil policy. We are all in this tub together.

Mr. Rowe: Thank you, Howard. You are very kind in that introduction. And it is a great pleasure to be on this panel. If Secretary Chu is Isaiah Berlin's fox seeing many things, and if Professor Nordhaus is the hedgehog seeing only one thing, a utility executive by definition is a myopic animal who sees very little clearly, but still must pull things effectively.

Now in a world where many of the things described by Secretary Chu may happen and in a world in which the volatilities described by Bill Nordhaus happen every day, we in the utility industry have to determine how to cope with the challenges Secretary Chu described and to do it effectively and economically.

It is a very good time for this conference that Howard has put together because it is clear that today is the time to deal with some of these challenges decisively. In particular this is the time for decisive climate legislation. President Obama has said so. The Congressional leadership has said so. And the introduction of the Waxman-Markey bill accelerates the debate.

It has been a long time coming. I first testified before Congress on the need for prudential action with respect to carbon as long ago as 1992. And in 2004, The National Commission on Energy Policy, which I co-chair, recommended a cap and trade system. We at Exelon have not been waiting in our efforts to cope with this problem. Last July we announced Exelon 2020, our low-carbon road map for reducing, offsetting, or displacing our entire carbon emissions, more that 15 million tons, by 2020. You can find Exelon 2020 on our website. I didn't bring a lot of copies, because after all, that is more CO_2.

Our plan has three components: to further green our own operations; to help our customers and communities reduce their greenhouse gas emissions through energy efficiency; and to provide more low-carbon electricity in the marketplace. The single bit of news I bring to you today is that we have completed some major steps toward achieving those goals. As of the end of 2008, we have exceeded our greenhouse gas reduction goals that we made as part of the U.S. EPA Climate Leaders program. In 2005 we committed ourselves to reduce our CO_2 equivalent emissions by 8 percent from 2001 levels. We have actually achieved 35 percent. That is the equivalent of taking 1 million passenger vehicles off the road. The largest part of this was retiring our oldest, least efficient, and most carbon-intensive fossil plants. We have also substantially reduced the leakage of highly potent sulpherhexaflouride, SF_6, the insulating gases used in our circuit breakers. And we are especially proud, particularly because Secretary Chu talked about energy efficiency so much, that our new Chicago headquarters offices, a rehab of a 1970's office building, 10 floors in it, became the largest office space in the world certified as lead platinum, and in doing so we reduced our energy consumption in those offices by 50 percent. We have a goal across our system of reducing our energy consumption by 25 percent and we share the Secretary's view that energy efficiency is again and again the first place to look.

More than that, it is our experience that the curves of technological improvement, which the Secretary discussed, are far more dramatic at the end use of efficiency than they are on the supply side. But now let us come back to Professor Nordhaus' point. We simply have to get the price of carbon in the marketplace.

Every one of us comes to the energy issue or the climate issue with a lot of different motives. Jobs, our affection for different technologies - it may not shock you to know that I have never seen a power plant or a transmission line I didn't like - energy security, and so forth. But while we have many motives, we have to come together on real policies that endure and real prices that stick in the market.

What fundamentally differentiates the utility role in all of this from the Energy Secretary's role or the economics professor is that we are the ones that have to collect the cost from customers every day. And while our passion for getting these prices into the marketplace is as high, our concern that we get it right the first time, may be even higher. And the reason for that is, when we screw up, we pay for the problem for a very long time. For this reason, as part of Exelon 2020, we developed a supply curve for carbon dioxide equivalent reductions.

What that means is, we calculated amounts of CO_2 that could be reduced by different activities, and then attempted to calculate the cost, and to put them on a curve, starting on the left, with the lowest cost items and proceeding to the right to higher cost items. Now this curve changes every time the economic news changes. It changes especially every time the price of gas changes, a subject that I will come back to. But the shape of the curve is very important. As many of you have heard, energy efficiency is often very cheap. Sometimes, even free. We simply have no way to know how much of it is cheap or how much of it is free. Or to take the California chart the Secretary put up, we don't know how much of that is really reduced consumption and how much of that is consumption that has been moved from California to neighboring states.

What we do know is that efficiency is the first place to look and the best place to look and the fastest place to look for energy efficiency. Those are the yellow bars. The pale blue bars are up rates in our existing nuclear plants. Often getting more capacity out of what we have turns out to be the best thing to do. Then there is one little bar that is my favorite. It is landfill gas. It doesn't add up to a lot of megawatts, but it always works. It is really cool.

But then we get to the harder choices. Things like the big purple bar, about $45 pre-subsidies. New nuclear plants. $45/ton, give or take, in our estimate of last summer. And then wind. $50-$60-$70 a ton of CO_2. And then solar photovoltaics. At that time, out around $700 a ton. Now the point is, it makes a huge difference. Every $10 a ton is about a penny a kilowatt hour for electricity. I have heard estimates from the California Air Resource Board that their renewable portfolio standard will cost $150 per ton. Well, that will certainly bring about efficiency, because it will take the average electricity rate in California from something like 18 cents to north of 30 cents. We have to be very careful with numbers this large. Now of course anyone here might rightly question whether we at Exelon got it right. They might also question whether the numbers we see in Illinois and Pennsylvania or in Texas apply somewhere else. Or whether this curve we developed for ourselves applies more generally. McKinsey has tried to do a more general curve. But there is even a more dramatic reason for question. If you look at my next chart, we have attempted to update our estimates based on changing natural gas prices and the more depressed state of the economy.

If you look at each of these four boxes, one dealing with energy efficiency, one dealing with wind, one with nuclear up rates, and with new nuclear, you see a little bit of the effect of change cost numbers. You see a lot of the effect of changes in natural gas prices. When we did Exelon 2020, our long term forecast for gas was around $9.00. Today, it is around $8.00. That is the center set of boxes. But in one of our scenarios, we look at what happens if it is no higher than $6.00. And that one factor can drive much energy efficiency from economic to relatively uneconomic. Drives wind from $60 or $70 to $80.

Drives new nuclear from $40 to $80.

Now my point isn't to criticize any of those technologies. My point is to show that we are trying to develop robust and durable policy in a very volatile set of markets. We must have policy that is clear. We must have policy that puts the cost of carbon into the markets. And we must have a lot of room for markets and their feedback loops to test and retest what is really working economically as we go.

I see four critical components. The first is, as Secretary Chu said and Professor Nordhaus said, and as I said earlier, is to put the price on carbon and carbon dioxide into the market. The Waxman-Markey bill meets that test. But I hope people will pay as much attention to the climate part of that bill as to the stimulus part and the renewable portfolio standards.

Stimulus money is fun to take. We are working with the city of Chicago on a solar project, which we hope to use a piece of it for. We'd love to have some of it for our smarter grid efforts. It is fun. It probably is even fun to give for a while. But we all know we will have to pay it back someday. Renewable portfolio standards are fun because you focus on particular technologies that you like. Again, what is the cost?

Opponents of cap and trade legislation have been scoring points recently by saying it is a hidden tax. Yes, it is a tax. They are right. A carbon tax is a tax, probably the most efficient one. Cap and trade system is an implicit tax. But renewable portfolio standards are taxes, too. And if not used with great subtlety, they impose higher costs on the economy than the other taxes. Exelon has in the past supported Senator Bingaman's proposed renewable portfolio standards. We will continue to support renewable portfolio standards, but we shall argue they should be kept closer to the Bingaman bill than the current

Waxman-Markey proposal because they, too, are taxes. And we want to end up with the most efficient tax that we can.

The second thing we have to deal with in carbon legislation or climate legislation is some sort of cost control system. What you really want to have happen is to make this cost somewhat predictable over a long time so that it gets internalized into decision making. But you would like to do it without the equivalent of another oil price shock on the economy. Most proposals that we have now have a mix of a fixed floor and some sort of cap or lending mechanism to allow cost control. It is very important to have cost control before we put too much stress and undermine the very working of the bill that we need.

The third tenant of good climate legislation is that we have to have a sensible method of allocating allowances. President Obama's initial proposal was that they all be auctioned. The U.S. cap proposals, which underlie much of the Waxman-Markey bill, suggest the granting for limited of periods substantial portions of the allowances. The utilities industry has managed with great anguish to come up with an agreement as to how it would allocate allowances if it gets them for free for a time.

This is basically a position that is backed not only by our industry but by the U.S. cap group and the National Association of Regulatory and Utility Commissioners, and also two labor unions. The point is to phase in the effects while getting the price signals clear. And it is terribly important in this that the allowances that are free go to regulated delivery companies in large part so that you avoid the windfalls that were experienced in Europe.

Now I think the final component that we need to make climate legislation work is to continue our national commitment to competitive markets at wholesale in electricity. The real point I am making, myopic that I am, is that we cannot know which of these technologies will do what when. There isn't a person in this room smart enough to know what will pay off at what time. We simply have to get this cost into the marketplace and we have to let the marketplace grind out the efficiencies in its sometimes inexorable way.

We are dealing here, not with millions of dollars. We are dealing here, not with billions of dollars. We are dealing over the decade with hundreds of billions and trillions of dollars. And the difference between designing a policy that gets on with it and allows the market to help get it right and in designing policies that are based largely on our own beliefs at the moment is huge.

We have to encourage more efficiency. I would advocate everything on the Secretary's list. We need to encourage more investment in renewables. I submit we also need to encourage the first round of new nuclear plants. But on the whole we have to avoid saying, I have seen the future and it works. People who say that are nearly always wrong. We need to help design a future. We need to plan as best we can. But we deeply need the power of the marketplace to sort it all out. It is time to get on with it. This conference is a wonderful place to celebrate what the Congress and the Administration are trying to do. Let us proceed.   (Applause)

Mr. Gruenspecht: It is a little late, but with such distinguished panelists, I do think we have to have questions and answers. So using the authority invested in me as the Interim Administrator of the Energy Information Administration, I proposed that we take questions until 11:05. Let the break run from 11:05 until 11:20. So you get 15 minutes of break. I know you will be disappointed, but we didn't have cookies in our budget, so 15 minutes should be enough. But there will be coffee. But let's take the next 12 or so minutes and get your questions in front of this group of distinguished panelists. First question, I guess for both panelists, supposing that the U.S. eventually adopts the carbon price, how should it respond to countries like China that are unlikely to adopt a carbon price for many years? Anybody can jump or hide.

Professor Nordhaus: I will just say that I was not assigned to talk about carbon, but I think actually quite a bit about carbon. I think some of the points that were just made about the relative advantage of carbon tax and cap and trade are extremely important. I have advocated with increasing intensity the carbon tax over the last decade or so. One place where I think people haven't appreciated the importance of carbon tax is in the international arena. A carbon tax is actually a very friendly regime for countries to join. If we look at it not from the point of view of how are we going to get it through the Congress, but how are we going to get it through, say, 20 legislatures of important countries? The point becomes clear.

If you are a country thinking of joining a Kyoto-Protocol type plan, ask yourself which of the following sounds friendlier? You are a country like Mexico or Argentina or Brazil or maybe China or India. In one case, you are going to sit down and you are going to be assigned an emissions reduction. You don't know how big it is because it is not written into the agreement. All you know is the bigger your emission reduction is, the more the other people on the other side of the table have to lessen their emission reduction. You also know there are some pretty heavy people on the other side of the table. So it sounds like if I were a Mexico or an Argentina, I would probably not want to join that club.

On the other hand, if you think of a carbon tax, it is actually much simpler. All you have to do is say; the domestic price of carbon emissions has to be up to some internationally agreed upon standard, 10-20-30 dollars per ton of CO_2, whatever it is. And then you can join the club. So I think one of the things that is insufficiently appreciated is how very unfriendly the current regime is for countries that are not in the plan. And that is one of the reasons I think we should add a tax provision or a tax component to a new Kyoto protocol so the countries can join by simply agreeing to have their domestic prices up to some minimal level.

Mr. Gruenspecht: I have another question. I guess I will direct this to Mr. John Rowe. Why do you think a cap in trade policy will yield a superior outcome to carbon pricing than a carbon tax?

Mr. Rowe: I don't. I agree with Professor Nordhaus. A carbon tax is better and more efficient. The reason most of us talk about cap and trade systems is a sense that the tax still does not have sufficient political support. But I agree with Bill entirely.

Mr. Gruenspecht: Okay. I guess - these questions were pretty interesting. Are you concerned that Congress is not the proper venue to construct something as intricate as a carbon market. For example, last minute amendments, less focus on whether the system actually works. It said this is directed at you, Mr. Rowe.

Mr. Rowe: Well, on that question, you have to go back to Winston Churchill's great line that democracy is a very poor system of government, just better than all the others. Congress is hard-pressed to develop something as subtle as a carbon market and the best it can hope to do is frame it and put the CO_2 price into it. But Congress is the law-making body that we have. But again, this goes back to Bill Nordhaus's point. Congress is better at levying taxes than it is at designing intricate markets.

Mr. Gruenspecht: Bill, would you like to have a word?

Professor Nordhaus: Once a generation, we have to behave like grownups. And this might be the time where we would say that this is an important problem. We need to devise a system that is workable, that we know how it will work, that it will work not only domestically but internationally. If I had to say, I would say this is the issue where I think people should just swallow, say we have to be grownups, whatever system we have is going to be a price-raising scheme, whether we call it a tax or a cap and trade, whether it is auctioned or not auctioned. I think the main thing about a tax system is that it is a system we know. The international cap and trade program has never been tried. There is no example of a system for an environmental problem or other problem where we have a functioning international cap in trade system. And if that doesn't make someone who is concerned about climate change nervous, it should.

Mr. Gruenspecht: Well, here is a question back on oil markets. How do you think education and understanding of oil markets and oil itself can be improved? I guess that would be Bill.

Professor Nordhaus: Well, there is no substitution for education. An educated electorate, an educated group of people in the Executive Branch and the Legislative Branch, so all I can say is let's go to college. Let's take physics. Let's take economics. Let's study regulation. And then we will have people like our distinguished Acting Administrator who will understand all these things extremely well.

Mr. Gruenspecht: I have had the bus backed over me so many times. (Laughter) But it was fun to go to college. I would love to go back. The next question is for Mr. Rowe. In your view, what are the benefits and risks to electricity decoupling?

Mr. Rowe: In my view, electricity decoupling is a useful tool, but no more than that in trying to get the incentives right for delivery companies to do the most efficient things for their customers. A more powerful tool, one that also exists in California and used to exist at least in New England, is to give them a profit incentive on their energy efficiency measures. But just for the rest of the audience, let me be clear what decoupling is. Normally a utility is given a rate for its delivery services based on an estimate of how much it will sell and a revenue requirement so that it can earn a fair return on capital. It is much more complicated than that, but that is part of it. What that means is if you can sell more kilowatt hours, you can make a little more money. Decoupling is a device to keep you revenue neutral. It separates your income from your sales. The risk in it is that it puts more and more of your charges on demand, which is not all a bad thing. But it can annoy the hell out of your customers.

Mr. Gruenspecht: Okay. One more for Mr. Rowe, or this could be for either, really. Do you envision a role for distributed energy in the future? Distributed energy.

Mr. Rowe: Well, of course. But right now, 98 percent of distributed energy is simply burning natural gas in a less efficient machine. It is not environmentally efficient. Now if solar becomes more economic and that is the place on the supply side where the productivity curve is steepest, then you may have a distributed energy source that is both low carbon and effective. That is where I think solar plays the biggest role, but I yield to the Secretary's physics.

Mr. Gruenspecht: Okay. Well, we are getting there in time. I think that this...I won't ask my questions. I think that in this session in Washington, I guess the game is to set low expectations and then exceed them. In this case I had very high expectations for this session, and they were exceeded. I thought that our speakers did a fabulous job. I think they also set the groundwork for the rest of the agenda for this conference. John Rowe talked about natural gas, for instance, and how it affects his planning. I think there is a panel that should have begun 3 minutes ago, 11:20 I think, on the future of natural gas. There is a lot of talk about the greenhouse gas emissions policy and what is next. That is another thing that is on the agenda tomorrow.

So I think our speakers have given us plenty of food for thought. Please join me in thanking our two remaining speakers. (Applause) And thank you all for your great questions. Secretary Chu will get the rest of his, and I look forward to the rest of today and tomorrow morning. Thank you very much and we will reconvene at 11:20 for the breakout sessions. Thank you. (Jazz music).

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