SECRETARY STEVEN CHU: So this is in part about – there's two parts. One is in part about the president's first 100 days and the Department of Energy and a little bit of a glimpse of what I think would be coming down the pipe in science. So in the first 100 days of the Obama Administration, as Governor Ritter said that President Obama has said, in order to prepare the United States for the future economy, not one year from tomorrow or five years from tomorrow but ten, twenty, thirty years from tomorrow where gas and oil prices will be higher, where it will become increasingly apparent to those who actually look outside their window that the world is changing and that we have to do something about it, that because of those things you want to get ahead of the curve and as the great hockey player (I'm drawing a blank now), as Wayne Gretzky said, what you do is – when asked why was he so good he said, "Well I skated to where the puck was going to be," and so this is the president's vision of knowing what's going to happen ten, twenty, thirty years from now and we want to go to where that is rather than finding a rear guard action hoping the world can go back to what it was 50 years ago. And so, in the first 100 days of his administration, he's heavily in the economic recovery but a lot of that has to do with energy and so these investments will immediately create jobs but they are going to be laying a foundation for a clean energy future and that clean energy future will make us competitive in this century. So in that, he wants incentives to double the alternative renewable energy production over the next several years and the Department of Energy has been entrusted with an enormous amount of money beyond the usual budget of about $25 billion a year. There's an addition $38.7 billion that is under the care of the Department of Energy. So this gives you an example of what's happening. On the left is the standard budget, the FY09 budget, and on the right is the amount of money we need to obligate, get out the door, and being spent help rebuild America's infrastructure. In addition to that, and that we are working to get out in two years, and in addition to that there's another $136 billion in loan guarantees to help industry. So how are we managing this loan guarantee? Well we want to launch projects quickly and wisely that will provide enduring value with unprecedented transparency and again, I'll repeat again and again, it's to set America on a course towards a secure and sustainable energy future. So, the question is how have we done so far? The program was put into place I believe mid-late February and so far within the first 100 days we have designed programs, worked them through the OMB process (which is no mean feat), gotten it apportioned, and the programs have now been announced. So roughly $26 billion has been announced. That's 80% of the Recovery Act funds. We hope to obligate by Labor Day over 70% of the total. How do you get it to go so fast? Well, that is an issue and when I first came to – well I'll tell you the story a little bit later, but what we're doing in order to make things go faster than usual is we're actually having daily Recovery Act meetings. It turns out that if you have a daily meeting and say, "Okay, what happened yesterday," and all the people around the room have to get up and say what happened yesterday, that actually stimulates activity. In a way that is genuine. I should say that the vice president has been interested. The President of the United States has told Vice President Joe Biden. He's doing the same thing for the Cabinet members. So once a week we have to do the same. What have you done? So it keeps us on our toes. We are looking at program risk management. When you're getting money out that quickly there is potential for waste, abuse, things of that nature, and so something very unusual is happening. There is actually a cooperation with the centralized IG of the administration and the IG office of the Department of Energy. Usually when you say the letters IG people freeze up and they clam up and get very nervous. But this is more of an IG where we're going to be working with the programs to say, "Look, let's think of ways which things can fall through the cracks where waste can occur and try to prevent it." So hopefully in this new spirit IG becomes an ally rather than a gotcha. So we're doing a lot of things. In giving out the money we're phasing it in. For example in the weatherization we're saying here's 10% of the money, stand up an organization, as soon as you stand up we're going to look at it. After that we'll give you 40%. We'll see how that goes. When you're down to the last 40%, if it's going well, we'll give you the next 50%; again, to make sure that things are going well because it's not just getting the money out of the Department of Energy, for example, into the states. The president has made very clear he holds all the agencies accountable to make sure the states spend it wisely as well. So in the first 100 days we've got out our first loan guarantee. It's conditional in the sense that the Department of Energy has approved the loan and they just have to secure their financing and talking with them, they're going on a road show but it looks very promising. They will get their loan in a week or so. It remains to be seen. Solyndra, those of you who know, are developing, have developed a CIGS technology that actually is largely developed here at NREL and has been transferred into a company. When I first came to the Department of Energy, I looked at the loan guarantee program. It had been started in a 2005 energy bill, was appropriated in early 2006, and the first week I got to the Department I asked where the status of the approval of these loans and they said, “We think we can get the first loan out in perhaps middle 2010.” So roughly four years and I said, “This is to help a very sick economy. If it’s going to take us four years to get a new set of loans out, either the patient will have recovered by herself or it would have died.” So it’s got to be done much quicker. I said come back with another plan and they came up with another plan saying, “Maybe we can cut it down by a factor of two,” and so I said, “Okay this is not good enough.” So Matt Rogers, who’s really the head of this, and some extent I rolled up our sleeves and said, “Okay tell us exactly what you’re requiring for the loans step by step and step by step figuring out how you can accelerate it.” And so that time was taken down from roughly 15 months to less than two months and I think it’s actually more rigorous. Minor things, for the new loans instead of requiring a 1,000-page application, 50 pages we’ve decided is about right. Actually in my mind 50 pages is still too long. If you can’t get an idea out in less than 20 pages there's something wrong with the idea. If there are 1,000 pages there are very few people who have read it. So there are many, many things that we have done every step of the way. We hope that this will continue but this gives you a plan for some of the money that's going out. I don't want you to dwell on this list. Another thing that's been happening and I'm new in government so I don't really know what has happened before, but there is a very, very healthy sprit of interagency cooperation. For example we know that if we are going to develop renewable energy, wind, solar energy where the resources are in large part where people aren't and you've got to port it over and we still have yet to develop large scale energy storage, that you need to develop these things and a transmission line is imperative and so there've been now weekly meetings, or say every ten days, let's not exaggerate, between FERC, CEQ, Interior, and Agriculture to try to figure out how to put together an international – a national system that's going to make sense. Right now the distribution system we have is really locally centered. They are vertically integrated power companies. There are RTOs. There are ISOs. But there was no one looking out for the whole of the United States and just as we now have a national highway system, we have to have some interplay between all the stakeholders to get it so we can port our greatly renewable energy around the United States. Other interactions with HUD for low-income energy efficiency financing and Education and Labor and automobile industry and things like that; so, lots of cooperation. The secretaries don’t hesitate in picking up the phone. We have one-on-one meetings. We have group meetings. I’ve been told this is very unusual in Washington, where we are trying to get beyond the usual territorial stuff. But so far it’s been wonderful to be working in this Cabinet. We have begun to start some reformation of the Department of Energy. The president has said we need greater transparency and for example in the Recovery Act investments there’s a website, Energy.gov/recovery. We’re going to be moving more and more to high quality evaluations of all the science and technology proposals with peer review by some of the most distinguished scientists. That’s another thing that the mood of the country has dramatically changed in the last few years. Many people are saying what can I do to help the country and its economic, energy, and climate change challenges and so many people are saying, “Sign me up, what do I need to do.” We’re going to be looking at all procedures that have come out of the Department of Energy in order to reduce waste, unnecessary paperwork, and burdensome orders. I want very much to return to the government owned contractor operator mode of operation. I think that was a very good mode and in so doing I want to reset the Department of Energy. So it’s really trying to maximize our mission goals. Right now there are very well-meaning people in environmental health and safety in the CIOs office and you just go down the whole list, procurement, finance, that whose job it is to protect the Department of Energy. But they forgot the Department of Energy has a job and it’s not to protect the Department of Energy. It’s to get something done. So now all these things are very important. If we have a terrible accident, that would be terrible. If we have some financial waste, that will also be terrible. But it has to be balanced against the mission of the Department and so this is something that I feel very strongly about. It's not going to happen overnight in the first 100 days but maybe in the first 1,000. So for that we need your help. We need your suggestions on how to improve the Department and save the taxpayers' money and again, go to our website, Energy.gov/reform. Now, so what does all this have to do with NREL? Well I'm very happy to announce that more than $100 million of the Recovery Act money will be going to NREL.

(Applause)

You're clapping in the wrong places. You should be clapping at that too. We're going to be supporting a research support facility for $68 million, renewable energy and site infrastructure for $19 million, and the Integrated Biorefinery Research Facility for $13.5 million. We're also investing $93 million investments in wind energy through the Recovery Act and wind is an incredible resource in the United States. Estimates, I think some of them from NREL, are saying that we can go to at least

20% wind. Colorado has excellent wind resources and the first 1,000 megawatts of wind in Colorado have already resulted in 1,700 or more construction jobs, over 300 operating jobs, $2.5 million a year in land-lease payments and it’s saving billions of gallons of water every year. So this is an incredible opportunity, a path forward to future economic prosperity. We will be investing $10 million of Recovery Act money to upgrade the existing dynamometer at your National Wind Technology Center to I’ve been told it’s 5 megawatts so that you can test even larger turbines. We will also be investing in wind turbine drive chains, R&D and testing $45 million, wind universities, R&D consortia, $24 million, wind energy technology partnerships $14 million. Alright so that’s what we did in the first 100 days. It’s a start. What’s going to happen in the next 100 days and in the next 1,000 days? So here’s a preview. President Obama addressed the National Academy of Sciences at their annual meeting last Monday and it’s a marvelous speech. I encourage you all to read it but I’m going to read some excerpts from it. He said in that speech, “I believe it is in our character, the American character, to lead and it is a time for us to lead once again. So I'm here today to set this goal. We will devote more than 3% of our GDP to research and development. We will exceed the level of achievement at the height of the space race through polices that invest in basic and applied research, create new incentives for private innovation, promote breakthroughs in energy and medicine, and improve education in math and science. This represents the largest commitment to scientific research and innovation in American history." He says, "The pursuit of discovery a half century ago," (he's talking about Sputnik and the space race), "Fueled our prosperity and our success as a nation in the half century that followed. The commitment I am making today will fuel our success for another 50 years. This is how we will ensure that our children and their children will look back upon this generation's work as that which defined the progress and delivered the prosperity of the 21st century. In no area will innovation be more important than in the development of new technologies to produce, use, and save energy, which is why my administration has made an unprecedented commitment to developing a 21st century clean energy economy and why we put a scientist in charge of the Department of Energy."

(Applause)

The entire speech was breathtaking to hear so I encourage you to read it. Let me remind you what the Department of Energy has done over its time. It is the largest funder of the physical sciences. It runs 17 national laboratories and it supports researchers at 300 universities. Also it has funded 88 Nobel Prize winners, more than any other funding agency in the world, and the part I'm most proud of is the fact that it has trained scores of young scientists that later went on to receive Nobel Prizes. We're trying to get a number but I know from my days at Berkeley Lab I personally went back and looked at all the biographies that you write when you get the Nobel Prize and it turns out that about 30 young scientists, graduate students, post-docs, and young career people, started their career at Lawrence Berkeley Lab and then went on to get Nobel Prizes. So if one laboratory could have grown 30 Nobel laureates, I say figure at least ten more for the rest.

(Laughter)

So I said scores and we’re trying to get a good count of this. I was a graduate student and post-doc at the University of California-Berkeley and during that whole time I was also a lab employee. What we need going into the future are not only the deployment of what we have today but we need really transformative solutions in both energy demand and supply that are necessary to achieve the president’s goal and the goal of what the climate scientists tell us is to reduce carbon dioxide emissions by 2050 by 80% or more. In a world where economies still want to grow, including the United States economy, this is not trivial. The first 10-20% we can achieve largely by efficiency but in order to get down to 80% and still have a rising GDP to the world we need new technologies. So what’s an example of a transformative technology? So I brought one out of the history of AT&T and AT&T developed the first transcontinental phone system in the world and an essential component of that phone system was an electronic amplification system. An essential part of that was the vacuum tube. For those young people in the audience this is what they look like. For those older people in the audience I remember when we had this vacuum tube TV that every year I'd gather up the tubes, go to the hardware store and see which ones were weak and replace them. It's because the hot little wire, the filament, would glow red hot. It would eventually burn out and get weak and this is not good for a reliable phone system. So AT&T spent enormous amounts of money over two decades making vacuum tubes last first more than a week to a year to two year to four years. They actually got them starting to last six years which is astounding based on my experience of those TV tubes. So they burned out. So while they were investing heavily in vacuum tube technology they began a little skunk work research to develop a solid state replacement for the vacuum tube and the reason they did that is because in 1925 we have a new view of the microscopic world, quantum mechanics. By 1930 that theory which was developed to describe the spectral properties of atoms, how atoms give off light, was actually applied to how electrons move in metals and then how electrons move in semiconductors in the early ‘30s. So the physicists at Bell Labs said maybe we could use this theory to figure out how to make a solid state vacuum tube and in the late 1940s they announced that solid state vacuum tube. That’s a picture of the first transistor. Admittedly it’s something only a mother could love, pretty big and ugly, but they knew what it was all about because the actual gained part of it was a little point of contact, a teeny, teeny point of contact and this was the beginning of a lot of things. It was the beginning of the semiconductor industry. It allowed computers to be ultimately practical. It allowed the Internet. It created great wealth for the United States. So this is a transformative technology. It went well beyond what was just required for the phone system. So let me give you examples of what I think some potential transformative technologies. Building, building efficiency but particularly building systems; 40% of the energy in the United States is used in buildings and roughly half and half residential and commercial buildings. This chart gives you a breakdown of how much of the energy is used in lights and heating and air conditioning and so on. It's an incredible amount of energy. A consortium of international companies, listed here by their logos, have come together and they have begun to examine how one can build more efficient buildings and they said if you want to go to a slightly more than a ten-year payback the incremental investment may be as much as $800 billion. That sounds like a lot of money but if it's a ten-year payback what that means is over the life of (this was commercial buildings) over the life, the 60-year life of commercial buildings, the rest of it's better than free. It's making you money. That means the payback time is let's say ten or fifteen years and if you're willing to go to a 15-year payback time you can reduce the carbon dioxide emissions by 80%. 80%, so if I can multiply .8 by .4, that's the amount of energy the world, actually that's not only in the United States. It turns out it's roughly the fraction in the world, that should reduce carbon emissions by 32% all in buildings, just buildings. It's not going to cost money. It will make money, okay? So now the question is do people believe that? Well, let me say why they may not. LEED buildings and I understand that the first LEED platinum building of a Federal building was built here. It's somewhere across – okay, it's great and the first zero energy building is going to be built at NREL. But LEED rates are based on design performance. They're not based on actual performance. They're based on what you think you will get and so this is a chart of LEED certified silver, gold, and platinum, the various symbols, and on the x-axis. Let's see if this really works. No it doesn't really work. Okay, anyway on the x-axis is the actual energy end use intensity, how much energy you're really using, and if you go towards zero on the x-axis you're trying to use less and less energy and on the y-axis is a ratio of what the building actually used in energy divided by what its design criteria was. So if that ratio is one, you've met design goals. Anything less than one is good. You've actually done better than your design goal. So what this chart tells you is if you're not that concerned with energy conservation, you're shooting for LEED certified, you do pretty good. You actually do better than your design goal. As you push harder and harder that you want to reduce the energy by let's say 65%, then you begin to fail. Sometimes you can fail as much as a factor of 2:3. Okay, so in fact if you look at the scatter between LEED platinum, gold, and sliver, there's a huge overlap. LEED certified might be here and LEED platinum might be here. So the point here is that sometimes the design goal doesn't get you where you really want to go, what is actually happening in real life. So the way we normally design buildings is there's a conceptual design, you get a detailed design, you talk to the future occupants of the building, let's say if it's a national lab, and the scientists and engineers tell you what they want. You go and design it. You go back and forth. Of course you realize that you're running low on money. There are cost overruns so you value engineer things. One of the critical value engineering is very rarely do buildings get commissioned before they're brought on. Commissioned means you tweak the building, the HVAC system in particular, so that you're balancing the loads and then you operate the building. So 95 of the new buildings are not commissioned to save a little bit money but it's well documented that if you commission a building that will pay for itself in the first year in maintenance; not maintenance but in energy costs. Alright what's the desired state? The desired state is to build buildings the way we build airplanes. From the 777 onward these buildings were essentially designed in software. There was a massive software program that actually kept track of everything. If you made any design change it would immediately say how it would affect the performance of the airplane, its fuel economy, its payload, everything. So when you're doing all these things you're trying to optimize something. In the case of a building you're optimizing what the people want but you're also trying to optimize its cost of operation. So we need some building software that has embedded in it design tools that will help architects and structural engineers do this and any modification will automatically be –

there might be a little bah, bah, buzzer sound that says no, this is going to cost you a lot of energy. Once you finally make the building we want it to be computer controlled so that there’s a very smart set of sensors and computers that actually tune up the building in a continuous mode in exactly the same way that your computer now operates how much fuel it’s going to inject into your engine and you get 23% more horsepower per unit of fuel per size of engine. It’s because it’s constantly tuning up on a minute by minute basis what are the needs of that engine and much better things can be done in buildings than in engines because quite frankly most buildings have a Goldilocks problem. There are some rooms that are too warm, some that are too cold, very few that are just right and then you make an air conditioning in a building and you have an administrative person in the desk with a space heater underneath.

(Laughter)

You’re chuckling but you know it happens all the time. This is incredibly wasteful because the air conditioning and everything. So you can make the air conditioner as efficient as you want and great strides have been done in that. But it’s the system that really counts. So what I propose is you think hard about building integrating all the things, the windows, the lighting, the building materials, the passive shading, the thermal storage and inertias. You limit what kind of equipment can go into a building because that’s in your energy budget and if you do that then you don’t have to overdesign the chillers in the building. You can right size them. But most important you need building design tools embedded in that energy analysis. Again, using the analogy of the 777 jet plane and beyond, or using analogy of what now we use design computer chips. I used to be on the board of directors of Invidia before I took the vow of poverty to come here and Invidia, these are high end graphic chips. Some of these chips have 700-800 transistors. The total design time, from writing the specs to when you go tape out and send it to a FAT plant, is 90 days. That actually tells me why you can do things quickly rather than nine years. But the thing is that computer systems actually lay down the wires and tell you where the transistors are going to go. So the design is at a very high level and the computer does all the nitty-gritty. So we need computers to be laying down the size of the duct work, where it should go, that right-angle car turns are really bad, that gentle turns are really good, and just automatically does that. So these are building design tools and then building operating platforms, these platforms should be open Linux based open source type of thing where then all companies can add value to it. So it forms a basis and when you have design tools and building operating platforms like this then you can actually get very efficient buildings. Solar energy, you guys know a lot about solar energy. You also know about learning curves. This on the x-axis is the amount of stuff deployed out there and it’s well-known that the more you deploy the more you can drive down cost, the more you drive down manufacturing costs and it’s incremental stuff but it continues to increment decade after decade and photovoltaics have gone down by a factor of five, almost ten. Wind turbines have gone down by more than a factor of ten. Gas turbines have been marching down the same thing until they are beginning to plateau. It’s a mature technology. But still photovoltaics are a bit off from fossil fuel generation. I don’t want to debate whether it’s a factor of five or a factor of ten but it’s still, without subsidy, it’s still higher. There are two ways to go. NREL is one of the leaders in developing extremely efficient solar cells, for example based on multiple band gap materials, as shown here. You and Spectra Lab (in fact you’re collaborators) Spectra Lab have now set the world’s record of roughly 41%. Another tactic and you’re also pursing that and others are to develop really inexpensive methods that achieve say 15%, maybe even 20% efficiency but a continuous process ideally that can be put on a polymer backing instead of glass that you can embed the electronics and inverters on that material and make them all parallel so that if one inverter fails it’s okay. In that same area you’ve got 1,000 others so it’s not devastating and make it very, very inexpensive. Another tactic, we have to pursue both of them. During the time when we look at how do we harness solar energy we also always should remember that nature has figured out how to do things. It’s had a longer engineering time to develop these techniques, a couple billion years, although it does it in a somewhat haphazard way. So this is from a sketchbook o Leonardo da Vinci. Leonardo dreamt of flying so he looked at birds, noticed how birds flew, designed this contraption over here, and the idea I think is you strap yourself to this, you walk to a cliff, you flap you arms and legs furiously, and hope for the best. For the sake of our art and scientific heritage, Leonardo da Vinci was a theorist in this respect.

(Laughter)

The first powered flight was not exactly like a bird. It was a hybrid solution. This is a picture of the Wright Brothers plane. What you see looking at John is the wings and the wings are warping like great soaring birds and so the Wright Brothers actually took that lesson from birds. But instead of muscle power they use a gasoline engine. Now look at today’s airplanes. I flew here on a 777. The blades of those jet engines are single crystals. The turbine blades are single crystals of metal. It’s incredible because once you are lifted from the constraints of nature you can use materials and processes that nature really can’t use in a warm, wet world and so now the planes work better than birds, at least for our purposes. Now to be sure, birds have a lot more of life than planes. They mate, they make little birds. 777s don’t make and lay little 777s and I have a theory for this. See the Wright Brothers plane there’s no vertical stabilizer because birds don’t have a vertical stabilizer either. Neither did Leonardo’s design. So that big vertical stabilizer on virtually every plane interferes with mating.

(Laughter)

That’s my theory. Stick with physics, you say.

(Laughter)

Okay, so if you look at what nature does in photosynthesis, it’s a remarkable thing. It actually captures carbon dioxide out of the atmosphere. It captures sunlight energy and it converts and it takes water as a first step and splits it into oxygen and hydrogen and it begins to assemble a carbohydrate and it’s a form of stored energy. So can we make an artificial plant? Again, we don’t care about the reproduction, any of those other things. We’re liberated from staying in a warm, wet world, so can we use nanotechnology to capture sunlight in a membrane technology because you have to split the reducing and oxidating steps to create hydrogen and oxygen. Now this has actually already been done but it is at a very low level, very inefficient. Nature does it much, much, much better. But why would you want to do this is because in the end you want to convert every precious drop of water directly into a fuel, again capturing carbon dioxide out of the atmosphere. Let me give you another thing where we can take some inspiration from nature. We all know that carbon capture and sequestration worldwide is a very important goal. It’s because of many developing countries have great coal reserves (notably China and India) they will not turn their back on coal. So it’s up to the developed countries like the United States, Europe, and even China is aggressively going towards this, to develop economically viable means of capturing and storing the carbon from coal. There's a lot of coal in the world. We don't actually know what technology is going to be the best. We have to pilot and test all of them. But one thing's for sure. Before we actually get something viable on the market, we're going to go through a period of roughly another decade where conventional coal plants will be built. Before the recession, China was building a coal plant once a week. The world is still building at roughly that and so there's incredible growth of coal in the world and so we will have many hundreds of coal plants going upward of a gigawatt a piece, investments of a billion plus a piece, $1 billion a piece, and so once you invest $1 billion in a coal plant you are not going to turn that asset off. So it's very important that we have to develop a technology that captures the carbon from a conventional coal plant with some modification in the footprint of the coal plant. So this means we have to develop what is called after stack capture, as one example. So, how do you do this today? We pass what comes out of the flue up over a material like amine or cold ammonia. The amine gets absorbed onto the surface and then afterwards you heat it up and you drive the CO_2 out and you now have captured the carbon dioxide. But it takes a lot of surface area in order to absorb it and more importantly it takes a lot of energy to release the carbon dioxide. But the human body actually has an existing proof that you don't have to do it that way. In our own cells we metabolize and we oxidize things and we have as a waste product CO_2. So consider what happens in your cells. It wants to get rid of the CO_2 and so it actually gets embedded in your blood. The primary reaction is the carbon dioxide with water with an enzyme called anhydrogenase. It actually puts it into a carbonate at "high pressure" and that's the partial pressure next to your cell. It gets transported by your blood into your lungs. You exhale it. The reaction is 10^6 times faster than if you didn't have the enzyme. There's no energy penalty. It's all done in body chemistry and so you can actually adjust rates by very slight changes in temperature. You can make this thing go like blazes. Now, that's the existence proof that this enzyme makes this reaction go very, very well. Now the enzyme itself can break down and so that's a problem. So I toss it out to the biologists and biophysicists. Nature has figured out how to do it just as nature figured out how to fly and nature figured out how to capture energy and turn it into – sunlight energy and turn it into chemical energy. So we can take a clue from nature. Energy storage; let me just close by saying there's two kinds of storage. There's large storage. If we go to a wind and solar energy of the future and imagine a future where 50% of our energy comes from renewable sources, also imagine what happens when the clouds roll over, when the wind stops blowing. We have a problem. So as you go to higher and higher fractions of energy you need large scale storage. The best energy storage we have today is you pump water up a hill into a hydroelectric dam or you compress gas and the compressed gas is not actually commercially viable. So we need to develop large scale storage and it's very, very important. Otherwise the standby power will be – because wind can vary by a considerable amount in a matter of just an hour. If you don't have standby storage what you'll need is you'll need a fossil fuel plant like a gas plant that actually has the boiler hot, not just you're going to fire it up because it will take three or four hours to fire it up. You actually need it hot and so the carbon benefits of a hot gas reactor when you're 50% renewable are not going to be appreciated. So energy storage is huge. The ability to transmit over larger distances decreases the amount of storage you need but you will still need storage. Let me also say that batteries in automobiles are another big deal. So in case you can't read, what I'm implying here is the energy per volume and the energy per weight and so going very high, lots of energy per unit volume, lots of energy means a lighter battery, a more compact battery. Chemical fuel is fantastic. This is diesel fuel, gasoline fuel, and body fat. They're really up there whereas a battery is down there, near zero. So this is a lithium ion battery and just in case you can't read the numbers, for example a kerosene jet fuel has 43 million joules per kilogram. A lithium ion battery has .54 megajoules per kilogram, almost a factor of a hundred by a factor of 80 or less and similar in volume. However, if you made a battery at that mark right there, you will have transformed the world. It means electric vehicles, not only plug in hybrids. You can get electric vehicles that can go let's say 215 miles because the engine is much lighter and so we need a rechargeable battery that can last for fifteen years of deep discharges and has roughly five times the energy density. So that's a goal. Let me point two things that I'm very optimistic that this could happen. There was a plan in the '90s to try to make a very light battery instead of going to an anode, the positive end of the battery which is lithium and it typically is carbon or carbon nanostructures, to make it solid lithium because once you get to the solid lithium it's as light as it ever can be and you have an electrolyte, this is polyethylene oxide, in a cathode material. But as you recharge more and more, these little defects grown on the anode and finally they short out. So what a scientist has done using a very simple idea, they take this very flexible polymer, polyethylene oxide, and join to another polymer, polystyrene, which is a principle component of football helmets. Now why did this person do this is because the poly4sterene is very tough stuff and it has such a high surface tension that if there’s a little defect it gets to form as the lithium plates back onto the anode, the surface tension is so high that it just flattens it. It doesn’t allow it to grow. When you just mix these polymers together in wet solution they actually self-form into these stria and the ions, the lithium ions, we go around in dark spaces and conduct but the mechanical, the strong mechanical properties of the tough polymer were actually made this thing very good. So what happened in the end is that again, my vow of poverty I had to resign off that, the battery was tested in deep discharges, 80% discharge, over 1,000 charges and discharges, no sign of wear, none, so which means maybe 10,000, certainly 5,000. Now so this has a 50% shot of becoming viable; maybe higher, maybe lower. I’ve been incommunicado now for the last half year. But this is an idea that is – another idea is the typical battery is an anode, electrolyte, a cathode and if you can form nanostructures in three dimension and can suck the electrons and holes out in a three-dimensional nanostructure, again you have something very different. So there are many ideas out there that can really transform the way we think of batteries and I encourage you to think very deeply about that. So let me close by saying this is a picture taken from Apollo 8. That was the first mission that went around the far side of the moon and in doing so the astronauts when they came around the far side of the moon, they went around a couple of times, they finally turned the space craft and looked towards Earth and they said, “Oh my God, look.” This famous picture called Earthrise shows a very bleak lunar landscape, a very warm, inviting, and beautiful Earth. The other take home message is there’s nothing else around. President Obama actually mentioned this as well and he quoted Bill Anders, the astronaut who took that picture, and he said, “We came all this way to explore the moon and the most important thing we discovered was the Earth.”

So we have an Earth, it’s our home, there’s nowhere else to go, we’ve got to take care of it, and so with that I applaud all the work that’s being done here at NREL and across the country. Thank you.

(Applause)