Steven Chu

Nobel Conference 50

Thank you. It's a pleasure to be here to address this audience. And so without further ado, let me just begin. I want to look back 50 years. The year was 1964 and what happened 50 years ago when this series of conferences started?

Well, Martin Luther King was awarded the Nobel Peace Prize in that year. Arnold Penzias and Robert Wilson discovered a three-degree background hiss radiation that was now interpreted as the radiation from the 'Big Bang' creation of the universe.

Townes, Basov and Prochorov were awarded the Nobel Prize for developing the maser and laser principle and in 1961 the first laser was demonstrated.

And the United States Surgeon General issues the first warning about cigarettes. And for those of you who don't remember, it was a mild caution, cigarette smoking may be hazardous to your health. The following Surgeon General said, 'Cigarette smoking is hazardous to your health,' and was promptly fired.

So let's look at that and I'll, and it's gonna get to climate change in a moment. This is tobacco use 1900 to 2005 and in the turn of the last century, 1900, Americans did not smoke cigarettes. But by the middle of the 1960s, the average consumption of cigarettes per adult male, including the non-smokers, was 220 packs a year, including non-smokers.

So the deaths due to lung cancer are in black. These are the male adults. And the deaths, sorry, that's the number of cigarettes smoked. The blue line is the deaths of that population cohort. And you might suspect that blue line rising like it did was rising above the noise. And so medical research began to suspect in the 1950s and beyond that perhaps cigarette smoking is hazardous to your health. But that's what we call an epidemiological study. It's a correlation between two events. One is the rise in cigarette smoking. The other is the rise in lung cancer deaths.

But as we all know, correlation does not mean causation. And there were tobacco companies, all of them, saying that we have no proof that cigarette smoking causes cancer. We have no microbiology understanding of its mechanisms. Oh, by the way, it’s not complete even today. We can’t predict who will get cancer, who will not. Therefore this might be just simply a coincidence.

All right. So what happened? The Surgeon General’s report comes out in 1964 and a bit while later, lung cancer deaths peak and also decline. We know today if you smoke a half a pack or more of cigarettes each day, your chance of getting lung cancer is increased 25 times. Not 25 percent. 25 times. Coronary heart disease, 2 to 4 times higher chance. Stroke 2 to 4 times higher.

The other thing I want you to notice is there is a delay between the onset of smoking, statistically, and when you get lung cancer, which, by the way, is still a fatal disease. It’s about 25 years. And remarkably, big public health campaign discouraged young people from smoking, picking up the habit. I hope you people in high school are not [laughs] smoking. Or if you are, it’s not too late, you can stop. But this decline, the market share declined by more than 50 percent. And the female lung cancer deaths are delayed because it took longer for women to start smoking.

All right. So I’m gonna take an epidemiological view of climate change and mostly stick to observations. And so here’s an observation. The temperate record from 1800 to 2011. This is the average land temperature around the world. And you could see if you look at all this data that clearly the temperature seems to be rising. There are fits and starts over the last 12 to 15 years. It’s roughly plateaued.

I should also point out between 1930, or let’s say 1940 and 1970, it declined a little bit. But overall in the 200 years, one could say it’s increased. Now in Washington, there is a fixation in the last 12, 15 years and said, ‘No, the temperature’s not increasing. See? Can’t you tell the data?’ Uh, so they’ve fixed on that.

But the point here is that most of the temperature has increased from 1980 to 2013. Now if you look at this and you look at storms, this is just counting storms, tropical storms, local storms, thunderstorms, things of that nature, what you find is that these climate or weather, I should say, changes, changes that trigger insurance losses. And this is data assembled by Munich Re. Munich Re is what’s called a re-insurance company. For those of you who don't know, a re-insurance company insures insurance companies.

If there is a big natural disaster, an earthquake, a hurricane, a major flood, insurance companies take out insurance because they may not have the liquid assets to pay all the claims. So they actually have insurance. And what you see from 1980 to 2013 is a roughly linear increase in the number of events that trigger insurance claims around the world.

So that's just a fact. It's a green ice age accumulation of this because the insurance companies and the re-insurance companies need to know how much to charge for premiums.

Another thing, this is both land and satellite measurements of the ice mass loss over Greenland and Antarctica from 1992 to 2010. Again, very noisy data. There's bumps and wiggles and starts and fits but as you see over this longer period of time, there appears to be a loss of ice mass on Greenland and in particular West Antarctica.

There are satellite measurements now of mass changes all over the world. I'm happy to say that a proposal has bee approved by the first, my first graduate student, now a professor at Stanford, for a satellite measurement of the change in masses using a cold atom technique that will improve the sensitivity perhaps 50 fold.

And so where you see in red, you see that there's a loss of mass of ice, in Alaska, Greenland, West Antarctica. These satellite measurements and other direct techniques also measure the change in water around the world. And this is the O'ga'lla-la Aquifer that spans from South Dakota, a little bit of North Dakota, all the way to Northern Texas. And this is what was seen, I forget the time of year but it was, oh, 1997, and blue means there's more water, light shades of green means there's less water.

And then you go to, I forget the time, but anyway, I apologize for that but now you see, and a couple decades later, what you see is a depletion of this reservoir where you see dark brown or various shades of orange. Dark brown means it's more than 90 percent depleted. So this is an underground aquifer that was established during prehistoric times and takes at least 100 years to replenish. And the southern part of it is now mostly gone.

This is the only calculation I'm going to show. And depending on various scenarios of how you control carbon dioxide, you have, in this particular model, what it says is at the year 2300, you'll abruptly stop all human greenhouse gas emissions. But in these lower pictures over here in green and blue, for example, you very aggressively, you being the world, try to control this.

And in the lower set of graphs, you see what the rise in temperature is. So the temperature around the Earth rises. For example, in the green and blue, it's rising somewhere in the neighborhood of 2 to 3 or 4 degrees centigrade. Remember the data I showed you was point eight degrees centigrade. So if the weather is changing due to point eight degrees, then a few degrees, two, four degrees, you'll see bigger changes.

The point here is even if you stop all emissions, how long does it take to cycle back to preindustrial revolution times? And the point is, it takes over 1,000 years. So let me go back to this smoking analogy.

So we're, we're doing something. The signal is rising above the noise. There are concerns and there are risks. And the damage to the environment of the greenhouse gasses we've already emitted is actually not know. And may not be known for a century.

Let me also say, what is the time delay? Well, it's, it could be 50 years, it could be 100 years. That's not known. The computer calculations of what might happen have very large uncertainties. In my mind, perhaps even larger than the models. But nevertheless, there are risks. And so, and as I said before, if we stop emitting greenhouse gasses, the time of recovery is about 1,000 years.

So we're in a very unusual situation that science has made us aware of, or at least aware of the risks. And that is, before science said, if you smoke, you may get lung cancer. Now we say, if you continue to emit carbon dioxin and other greenhouse gasses and it continues to increase, you may not see the consequences but your children, your grandchildren, your great-grandchildren, and many grandchildren beyond that will see the consequences.

So many people say, 'What's the problem? I like smoking. If my grandkid gets lung cancer, I don't care.' Strangely, the way society's behaving today, that is the attitude. And they say, 'Well, we're not really sure this is happening, so why don't we wait a couple of years, 10 years, 50 years, to be sure that these changes are climate and not weather.'

And I would say, do you really want to wait longer to be 100 percent sure or is there enough risk involved that you might want to change things?

All right. Now some people will say, 'Not a problem, we're gonna run out of especially oil and natural gas.' But let me quote some authors I deeply respect. And they wrote, 'Our ability to find and extract fossil fuels continues to improve, and economically recoverable reservoirs around the world are likely to keep pace with rising demand for decades.' Well, I said that. [laughs] And why did we write this?

This is a history of U.S. oil production 1945 to 2012. This graph goes up to 2010. And you see that oil production peaked in the United States in 1970 and started to decline. The brown-orange is the production of the, from the great Alaskan oil finds. But then there's this little triangle over on the far right that says Tight. Tight means tight oil, a release by hydraulic fracturing and horizontal drilling. Well, what happened in 2013 is production rose to seven and a half million barrels a day. By the end of 2014, production is expected to rise to eight and a half million barrels a day.

Let me put that in perspective. If the rise in production due to hydraulic fracturing were a standalone country, it would rank number four in the world, only behind Russia, Saudi Arabia, and the United States. The increase in production is more oil than produced in Canada, China, Iraq, Iran, UAE, and everybody else.

So this increase in production is not only true in the United States but it's roughly estimated that maybe 10 times as much oil and gas reserves are there around the rest of the world. Same thing with natural gas production. The actual data, this was a prediction made in 2008 was that gas was plateauing, natural gas production was plateauing and would decline. But in actual fact, it went up by 19-, '13 to here.

So it's turning out that the ability to find and economically extract natural gas and oil are racing forward. So let me quote Shaik Yamani. He said, 'The Stone Age came to an end but not for a lack of stones, and the oil age will come to an end but not for lack of oil.'

Now he's, was the former Saudi Oil Minister, not for saying this. [laughs] What he was really thinking of is that there could be a transition to better solutions, as, for example, we transitioned from the Stone Age to a series of metal ages and all those unused assets, all the stones you see around the world, were not used for tools. And so he was thinking perhaps we will transition to better solutions.

And better solutions means two things. It means environmentally better solutions but it also means economically as good or better solutions. And so I think science and technology will play a crucial role in to helping us and I'm going to very briefly mention a few things.

I'm going to start with energy efficiency. Energy efficiency is nominally a good thing but people usually think if you buy a more efficient appliance, for example, it might cost more money. And if you have regulations that say the appliances have to be more efficient, it actually might increase the price.

So now as a physicist, I decided while I was Secretary of Energy, let's have a really, you know, look at the data, both in the United States and Europe. And this is data taken from the United States. In the blue, it, and the open blue symbols, you have the cost of both the refrigerator, the purchase price, and the cost of energy folded in. So it's the cost of owning the appliance. And it's plotted every time you double the shipments of refrigerators; the price and the operating expenses go down by a certain fraction.

And the solid symbols is where the beginning of regulations, starting in California, three energy standards in California, followed by three federal standards. And so the cost of ownership started to plunge. If these standards were not put in place, you could make a guess that perhaps the cost of owning and operating a refrigerator would be up here around $4,000 but instead it's maybe 1500.

But here's the shocking news. The purchase price, inflation-adjusted purchase prices of refrigerators, did not go up when you started to see these standards. They just remained on the slow, same decline and perhaps by the beginning of the federal standards, it actually began to have a sharper decline.

So we looked at room air conditioners. This is a paper that will come out in environmental research letters. My co-authors are former physicists as well. Well, I'm a, I'm not a former physicist, I'm a physicist. [laughs] Room air conditioners, the cost of ownership declined as expected. The arrows are when standards in California and federal standards were enacted.

But strangely, the cost of the appliance actually began to go down. We looked at room air conditioners. We looked at central air conditioners. We looked at clothes washers. Completely unexpected. How can an efficiency standard make the purchase price go down? And what economists would say was this may work in practice, but it doesn't work in theory. [laughs] That was essentially the first reviews we got back. And you can wave your hands and become a theorist and, well, you know, if you design a more efficient condenser or more e-, you know, then it actually becomes a less expensive one.

But whatever the reason, this is just data. Very, very exciting because it really means that appliance standards really save you money, all the way around, including the purchase price.

Let me now move to clean energy sources. Wind turbines are getting bigger, they're getting more reliable, they're getting more efficient. This is a typical standard height, is moving towards 100 meters on land and even higher on water. This is a humongous wind turbine being installed in Northern Europe seas where the diameter is 93 meters, which is longer than the Wright Brothers first entire flight. [laughs] And about one and a half times the wingspan of the largest airplane, the Airbus 380.

The levelized costs of energy, that's the investment costs, the hookup, the transmission costs, the establishment of the lines in moderately good sites in the United States, in the Midwest and better, is about 7 cents a kilowatt hour and there's an expectation it will go to 6 cents. This is the cost of wind without a subsidy.

We have what's called power purchase, we have what's called a production tax credit that recently expired but with these production tax credits, you build a wind farm. You sign a contract with a utility company and you agree to sell electricity at a certain price. And the agreed-upon price in the last couple of years is between 3 and 4 cents a kilowatt hour.

If you build a new natural gas plant today in the United States and amortize it over the life of that gas plant and the cost of natural gas, if it stays at 4 or 5 dollars a million BTU, which is enormously low, it's due to the abundance of natural gas, but let's just assume it stays there, wind will become cheaper than natural gas.

Well, first let me say that costs of that new natural gas plant is about five, five and a half cents a kilowatt hour. If you take out the tax credit subsidy, production tax credit, wind is slightly more expensive but it will pass natural gas. Whether it passes it 5 or 10 years from today, I don't know. But certainly by 15 years, including transmission, it becomes the lowest cost option.

Solar has made great gains. This is crystalline solar. Again, the same learning curve, every time you increase shipments by, in this a factor of 10, there’s a certain fraction decline in price. These are bumps and wiggles to a very generous German subsidy, an overabundance of investment that made the market plunge. And right now the price of solar modules is here. It’s stabilized. They’re beginning to sell the modules they produced and it’s expected to go down to here within 5 years. Selling at a profit where that little green symbol is.

If we get to that little green symbol, the price of solar modules will have declined over this period of time, about 40 years, 50 times. That’s pretty good. That’s like saying you have a $25,000 car and now you can buy it for $500. But not quite because there are other things involved with it. It’s not just the module. It has to do with the electronics, which is also rapidly becoming cheaper, installation, land use. But still, solar is catching up very rapidly as well.

So in the United States, there were virtually no solar installations, beginning to trickle forward in the late 1980s, being completely flat until something began to happen and by 2009, ’10, ’11, ’12, something dramatic happened and there was a correlation in this [laughs] [‘My time at U.S. Secretary of Energy’ on screen] that, correlation doesn’t mean causation. [laughs] But before we get too excited, I have to remind you that solar electricity generation today is only point two percent of total generation.

The capacity is huge. In the United States, especially in the southwest, it is fantastic. Where you see deep red you have a tremendous solar capacity. In private homes now, companies are installing solar in rooftops where they own the solar equipment, they pay for the installation, no out-of-pocket expenses and then they sell a contract to the homeowner. You buy electricity from us for 15 years, it costs 9 cents a kilowatt hour, 5 cents less than when you buy it from the electrical company.

Again, there's an investment tax credit but within a few years, even without the investment tax credit, maybe 5 years or 10 years, you don't need it anymore. So it, too, is becoming a low-cost option, especially wehre there's a lot of sun.

Now when you see these blue and orangey things, it's not so good. Here's Alaska. It has about the same, southern Alaska has about the same solar resources as Germany, which, by the way, has the largest solar installations in the world. But it will be surpassed by China in very short order. China in the last 2 years is the biggest installer of renewable energy in the world.

The Germans have gotten very good in installing German. If you, the full-in costs for installing solar in Germany costs $2.50 a watt, even though the solar module price is a universal commodity price, it's double that in the United States. And you ask what's the reason why? And the answer is not because German labor's cheaper. [laughs] You know, you don't have to be Secretary of Energy to figure that out.

But we did, we were, we began to study this in the department of energy and began to notice all the licensing and inspection fees that were due to towns and municipalities in the United States were not present in Germany. They don't make you stand in a line for 3 hours to get a permit to install solar in Germany. You can do it online. And the laborers spend one-third of the time on the roof that Americans do.

So I think this is a technology we can learn. So the good news is, if you look at natural gas, that is still the lowest, without subsidey, that's still the lowest in the country. But onshore wind, with the subsidy and without the subsidy, will catch up in due course, again, 5, 10 years, for sure in 10 years, and utility solar will also catch up.

Now the question is, all right, but as you go to 10 and 20 and 30 and 50 percent renewable energy, then these natural gas resources, glualcohol[sounds like] plants, other nuclear reactors, they have to be there anyway, so that really is part of the cost of renewable energy, because sometimes the wind stops blowing, the sun stops shining. And you're absolutely right. And the question is, how much renewable enrgey can you, the system tolerate and not have blackouts or brownouts?

Well, we don't know but we are [inaudible] some experimental data. Today, or 2013, Spain produces 25 percent of its electricity from renewable resources. It’s relevant because Spain does not have a major tie to an electrical grid in Europe. The lines would have to go over the Pirineos. So it’s an isolated region in Europe. Ireland is about 20 percent renewable energy generation. Again, since it’s an island, it’s isolated.

So within the technologies of today, you can certainly get 20, 25 percent renewables without the brownouts, with buffering witih traditional resources and both of those countries want to go over 50 percent. This is 50 percent integrated over the whole season which means during some days it’s 100 percent. And so they’re already at 25 percent and we think they and the United States can easily go to 50 percent without straining the grid if planned correctly.

That would require better transmission distribution and that would require also some energy stores once you’re at the 50 percent level. And so as mentioned, ARPA-E, which stands for Advanced Research Project Agency for Energy, we were trying to start very bold research in radically new approaches to both converting electricity to very high voltage DC, which can be transmitted over thousands of miles very efficiently, and the electronics.

And we think that you can make power transistors that can turn a 70,000 pound transformer into something that weighs perhaps one or two hundred pounds. And already a prototype of that is emerging. And we also wanted energy stores to be very inexpensive, as inexpensive as hydroelectric storage.

In another DOE program, we said we wanted to drive the cost of batteries for automobiles down. In 2008, it cost $1,000 a kilowatt hour, in 2012, $500 a kilowatt hour. The Tesla S, which is a$100,000 car, the long-range 270-mile Tesla S, the batteries cost $30,000. It’s one-third, roughly one-third of the cost of the entire vehicle. Our target for automobiles was to drop that by one-third so the cost of the batteries become comparable or maybe a little bit more in the cost of the engine, but not too much more.

And when you have a cost of $160, a $25,000 car going 300 miles, 350 miles, but costing one quarter to operate compare to gasoline costs today would be very enticing. So that was our goal. How are we doing? Well, this is Bloomberg New Energy Finance. This is a projection of the costs of batteries that they made several years ago. The X's are the actual manufacturing costs. They're below what was then considered to be an optimistic projection.

And the Department of Energy was saying we want to do things and support research that would get the costs down here. But already the Tesla Giga Factory, if it is going to be built, is planned to be finished construction in 2017, or start production in 2017. The cost of the batteries will be down here.

So this is all very good news. We do need something else. And this I turn to the chemists and I believe Harry Gray and perhaps others will talk about this, is we need summer-winter storage. And the thing we need most is ability to turn sunlight or electricity, electricity from sunlight in the form of solar or wind, into a liquid hydrocarbon storage that you can put on a slow tanker and ship all over the world, as we do oil.

If we can in an economical means of doing that, we have transportation fuel off the list and we have energy storage because today the developed world countries have 90 days storage of oil, gasoline, diesel products in their own shores so that they have energy security. So what we still need, and what we still need science for is the low-cost production of liquid hydrocarbon fuels that can be transported at room temperatue. That would be a very big deal.

So while I was in the Department of Energy, I started a few programs like ARPA-E, SunShot for the solar, revised solar program, and EV stands for electric vehicles everywhere. And I told the people that were wrokign there and the people we recruited that the greatest danger for most of us lies not in setting our aim too high and falling hsort, but in setting our aim too low, and achieving our mark. And that was said by Michelangelo. And that is what I tell all my students. Set your aim high. Don't be afraid to fail. Fail fast and move on.

Now if I look back on my four and a third years in the governemtn, there are many things that I'm very happy about, very proud about, most of them invisible to the public, because it was being done at the lower levels. How do you design new funding programs? How do you recruit and retain the very best scientists and engineers to work in government and I personally recuirted a couple of dozen of them.

We had a very, very good bunch of people, six people in the Natioanl Academy of Sciencies or Engineering. Some of them elected in their 40s, but guess what? They were still in their 40s and they came and worked for the government. And there'll be at least a half a dozen more who will be elected to the National Academy of Sciences or Engineering who were in their late 30s or 40s.

And we need more of that. We need ultra-talented scientists and engineers to come and work in the government for 2 or 4 years because they ultimately are the people making decisions on what to fund and what not to fund. How do you design the programs to be the most effective to take the research tax dollars of tax payers as far as they can go.

And so that was the good stuff. The wrost part of it was probably dealing with the press. They always want to play gotcha and catch you on a slip or something. And so I had told the president 2 weeks after his election that I'd love serving with him but I needed to stop down and go back to California. My wife and I wanted to return to the Bay Area and so on February of 2013, I was allowed to make the announcement that I was stepping down. And then 6 days later, The Onion ran this story, 'Hungover Energy Secretary Wakes Up Next To Solar Panel.'

Now I'm gonna read you a short excerpt of this. Press is very venal. 'Sources have reported that following a long night of carousing a series of D.C. watering holes, Energy Secretary Steven Chu awoke Thursday morning to find himself sleeping next to a giant solar panel he had met the previous evening and didn't even remember the manufacturer's name. According to sources, Chu's encounter with the crystalline-silicon solar receptor was his most regrettable dalliance since 2009 when an extended fling with a 90-foot wind turbine nearly ended his marriage.'

So I walked into work Friday morning and my press affairs person said, 'We can't, we have to answer this.' So I smiled and said, oh, yes. [laughs] And so we issued a release. Here's an excerpt:

'I just want everyone to know that my decision not to serve a second term as Energy Secretary has absolutely nothing to do with the allegations made in this week's edition of the Onion. While I'm not going to confirm or deny the charges specifically, I will say that clean, renewable solar power is a growing source of U.S. jobs and is becoming more and more affordable. So it's no surprise that lots of Americans are falling in low with solar.'

That was fun. Anyway, let me go back to the picture I started this talk with, it's nearly 50 years ago. Christmas Eve 1968 and the astronauts of Apollo 8, this is the mission that preceded the first lunar landing of Apollo 11. They skipped numbers. And in the last orbit, the fourth orbit, they turned the capsule earthward and one of the astronauts took this picture, which is now known as Earth rise. And he, the astronaut, Bill Anders, said, 'We came all this way to explore the moon and the most important thing is we've discovered the Earth.'

Now if you look at this, you see that there's a bleak lunar landscape. Earth looks pretty good from that view. And the other thing I wanna stress is look around. There's nowhere else to go. So since 1968, there's been increasing evidence that the climate is changing. There are compelling reasons to believe that humans are at least a partial, if not a major cause of it and the weather has been changing. And so we run risks. Although I will be the first to say we don't know the magnitude of those risks. The risks are there. They're very real. And they could be very serious. So it's prudent risk management.

But the good news is, it may become the low-cost option as well. In fact, it will become the low-cost option. The point is, we've got to make it the low-cost option in 10 or 20 years, not in 50 years.

All right. So another further point of view. When Voyager 1 was leaving the orbit of Pluto, Carl Sagan convinced the NASA engineers to turn the capsule towards Earth to take one fleeting picture of Earth. And he is going to narrate what he saw and what the NASA engineers saw.

'From this distant vantage point, the Earth might not seem of any particular interest. But for us, it's different. Consider again that dot. That's here. That's home. That's us. On it, everyone you love, everyone you know, everyone you ever heard of, every human being who ever was lived out their lives. The aggregate of our joy and suffering, thousands of confident religions, ideologies and economic doctrines. Every hunter and forager. Every hero and coward. Every creator and destroyer of civilitation. Every king and peasant. Every young couple in love. Every mother and father, hopeful child, inventor and explorer, every teacher of morals, every corrupt politician, every superstar, every supreme leader, every saint and sinner in the history of our species lived there on a mote of dust suspended in a sunbeam. The Earth is a very small stage in a vast cosmic arena. Think of the rivers of blood spilled by all those generals and emporers so that in glory and triumph they could become the momentary masters of a fraction of a dot. Think of the endless cruelties visited by the inhabitants of one corner of this pixel on a scarcely distinguishable inhabitants of some other corner, how frequent their misunderstandings, how eager they are to kill one another, how fervent their hatred. Our posturings, our imagined self-important. The delusion that we have some privileged position in the universe are challenged by this point of pale light. Our planet is a lonely speck in the great enveloping cosmic dark. In our obscurity, in all this vastness, there is no hint that help will come from elsewhere to save us from ourselves. The Earth is the only world known so far to harbor life. There is nowhere else, at least in the near future, to which our species could migrate. Visit? Yes. Settle? Not yet. Like it or not, for the moment, the Earth is where we make our stand. It has been said that astronomy is a humbling and character-building experience. There is perhaps no better demonstration of the folly of human [inaudible] than this distant image of our tiny world. To me, it underscores our responsibility to deal more kindly with one another and to preserve and cherish the pale blue dot, the only home we've ever known.'

So let me just close by saying there's an ancient Native American saying, 'We do not inherit the land from our ancestors, we borrow it from our children.' Thank you.