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P R O C E E D I N G S

MR. LIEBERTHAL: Good morning. I'm Kenneth Lieberthal, senior fellow emeritus in Foreign Policy at Brookings and at the China Center here. It's a pleasure to have the opportunity to introduce our speakers and then to moderate the discussion after the formal presentations.

This is a meeting to introduce, really, a rollout of a report that's been done by the Steyer-Taylor Center at Stanford University. The two authors who are here, two of four coauthors of this report, are: Dan Reicher, who is executive director of the Steyer Center. He has an extensive background, both in government and in the private sector. All of it revolved around clean energy and climate change, in one dimension or another.

In the private sector, he was the founder of a private equity group that invests in clean energy technologies and clean energy business. And in the government, had worked in the Department of Energy under the Clinton administration, worked in the Obama administration and also served in as staff of a committee set up in the Carter administration. And I believe he's been at the Stanford Center since 2011. I think so, yep.

And then secondly, Jeff Ball, who has been the major person responsible for this report itself. And Jeff was a member of The Wall Street Journal, both writing and editorial staff. He focused on environmental coverage and clean energy issues. So, environment, energy, and climate change and was an award-winning reporter on those issues for the Journal. And he is now a visiting scholar at the Steyer-Taylor Center.

I want to note, also, that Dan, in addition to his background in government and at Stanford, is also a nonresident senior fellow at the Brookings Institution. So, it's really a pleasure to have both of them come here today.

We're going to have to start off with Dan, kind of framing the report and where it fits in the broader work at the Steyer Center. Jeff will then go through an extensive take on the report, with a very rich slide set.

We'll then have a little time to come up here and talk among ourselves. I want to ask some questions and tease out some issues on the substance of the presentations, and then we'll open it up to all of you for Q&A.

And I believe all of this will be available on the Brookings website. I'm not sure how quickly, but -- pardon me? Tomorrow. And so, if there's anything you miss and have to review, it will be available to review.

With that, let me ask Dan to come up. Welcome.

MR. REICHER: Well, good morning all. And thanks so much, Ken. It's wonderful to be here. I've really enjoyed my time as a senior fellow at Brookings.

I come from the Steyer-Taylor Center for Energy Policy and Finance, as you heard from Ken. We are a joint center of the Stanford Business School and the Law School. And we focus on this intersection between policy and finance, as it exists to drive clean energy technology into the market, both in the U.S. and globally, including major countries like China and also India.

I want to thank a couple of people. I want to thank Mark Muro, who I've worked with extensively here and really enjoyed my time and collaboration with Mark.

I want to thank the Brookings staff. There's several who have helped us put this together today and done a great, great job.

And most of all, I want to thank my colleague, Jeff Ball, who really has been the sparkplug for this.

But as you'll see on the cover of the report, and all of you should have picked up this executive summary, we have two colleagues on the report: Xiaojing Sun and Cait Pollock. They were the research team that we worked with and have really helped us make this happen today.

I want to make sure you see handles and links. Lots and lots of information today regarding this report. I was -- sorry about that. I was clicking it forward, mysteriously.

So, there's a Stanford press release that's out at https://News.Stanford.edu. You can reach the report at the Steyer-Taylor website, which is https://law.stanford.edu/steyer-taylor-center-for-energy-policy-and-finance/.

Just a few minutes ago, the New York Times put up an op-ed that Jeff and I wrote, and that's at https://newyorktimes.com. Twitter handles @Jeff_Ball and @Dan_Reicher. And so, there's lots of information out there, and we're very pleased today to be able to talk to you about it.

I want to thank the U.S. Department of Energy, which gave us a grant to do this work a

few years ago. But in giving us that grant, it was arranged in a way that we had complete independence in terms of the work we did and the findings we reached. So, very much a shout out to DoE for the help we got.

Jeff is going to take the lion's share of the presentation. We decided to focus it on him. Today, he's going to give us the findings. I'm going to come back up for a few minutes to talk about the recommendations that the report reached. We're going to talk with Ken for a few minutes, and then we will take your questions and answers.

I'll simply say, that this is a report that really looks at the Chinese solar industry in a pretty deep way. We came up with the idea to do it when we realized how important an industry this was, how fast it was growing, and most importantly, the implications for what we're doing here in the U.S. The Department of Energy, as most of you know, as a very large solar R&D budget. We went to DoE and said, we think it's important that as much as possible we understand in depth what's happening in the Chinese solar industry, what's going on in R&D, what's going on in manufacturing, what's going on in deployment and its implications for how both government and the private sector move ahead on solar in the U.S. So, that was kind of the genesis of this.

With that, I'm going to ask Jeff to come up, and we will dive into the findings of the report. Thank you.

MR. BALL: Good morning. It's really a pleasure to be here. It's a terrifically large crowd when there's I'd a say little bit of news happening in Washington and elsewhere. So, thank you all for making time. I'm just going to pour myself a glass of water.

I just want to reiterate what Dan said, which is a shout out to Xiaojing Sun and Cait Pollack, our co-authors on this report, who are not here today but were an intrinsic part of the work. They were the co-managers of research on this. And you'll find out more about, specifically, what they focused on, if you look in the report and in the About the Authors page, in the packet that you have.

And, again, I just want to reiterate thanks to Ken for taking the time to do this. Thanks to Chung Lee, Ryan McElveen, and Vincent Wong at the Thornton Center here at Brookings. And thanks also to Mark Muro at Brookings, without whom we would not be here today. So, Mark, thank you very much.

One little introductory note and then I'll jump in. And I'll maybe talk for 25 minutes or so, and then we'll have plenty of time for the three of us to chat a bit and then open up to questions for all of you.

So, I just want to say one thing about where we started with this idea. A couple of years ago, at Stanford, we got about 20 C-level executives from the global solar industry together at Stanford for about a day and a half. And we did a scenario-planning workshop, that was pretty rigorously structured. And the question we asked, was not how big solar is going to get, because no one knows, but rather, under different scenarios of how big solar might get, who would do what. Which countries would do what? Which kinds of companies would do what? And how would those variable affect lots of different things.

And so, we literally came up with kind of a quadrant. We came up with a report called Avoiding Sunstroke. You can Google that or find that on the Steyer-Taylor website. A very, sort of a thin report, 17-pages long. Not data filled but very qualitative and analytical, kind of looking forward. And it was interesting to us how much interest that generated among people in the solar industry and in the clean-air and energy industry broadly.

They told us that they hadn't seen anyone kind of parse this question of global strategy around this industry quite this way before. And it left us thinking that there was a lot more deep work to do fleshing this out. And so, that was where we got started with this.

So, enough of a windup, let me jump in here. So, here's what we're going to do today, we're going to talk a little bit about kind of first principles of this report. We're going to talk about five myths busted but myths that we think this report busts, that hopefully help frame this in your mind. We're going to go through findings in four key areas: The financial status of the Chinese solar industry. Research and development in the Chinese solar industry. Manufacturing and deployment, essentially, installation of solar modules. And then we're going to talk about recommendations. And then we'll chat about all of that and please feel free to ask us whatever you'd like to ask us.

Okay, so let me just -- this is a picture taken in a city in China called Jiaxing. Jiaxing is in Zhejiang province. And Zhejiang is west of Shanghai, maybe an hour by a fast train, west of Shanghai.

And these are solar panels on the roof of a company called Flat Glass. We're going to

talk much more about China's solar manufacturing center in a few minutes. But Flat Glass is a company that cuts its teeth making construction glass. And consonant with the rise of solar manufacturing in China, Flat Glass decided that solar was a place that it could make money. And now Flat Glass has become one of the largest makers of solar glass in the world.

It just struck me as an interesting photo because you see the juxtaposition of solar panels in the front and something other than solar panels in the background.

So, just to set us straight, let me just walk through a couple of statistics about where China is in terms of energy, because we shouldn't get too carried away about solar here, against the context of what else provides energy in China.

So, here is the mix, according to the International Energy Agency today for China. In terms of electricity generation: Coal provides 73 percent. Hydro 18 percent. Nuclear, excuse me, wind 3 percent. Nuclear and gas 2 percent each. And solar 1 percent.

In 2040, the IEA says coal production will slash nearly by half from 73 to 43 percent. Hydro will drop a little bit. Nuclear will increase from 2 to 12 percent. Wind will increase from 3 to 12 percent. And solar from 1 to 6 percent.

So, I'm not going to go through all the numbers for the United States and the world, but suffice it to say, solar is a tiny slice of the pie. Solar is expected, according to the IEA, to remain a small slice of the pie, although six times larger than it is now.

And let me say one other thing, if we were to project two pie charts up here of say the United States and China, those pie charts would be -- the slices would be slightly different, but even more importantly, the size of the pie would be different.

So, when China goes from one to six percent in solar, it's a massive increase because one percent of a massive pie is still a pretty big slice. So, I just want you to keep that in mind as we go ahead.

All right. So, here's the goal of the study: The goal of the study is to clarify an economically efficient growth path for the solar industry, which is maturing and dominated by China.

This is very important. The goal is not to define how the United States beats China or the other way around. The goal is to elucidate comparative advantage in an industry that's changing

incredibly quickly.

Okay. All right. So, here are three questions that the study asks: Number one, how's the China-based solar industry changing? And that's what I'm going to spend the bulk of my time up here for the next 20 minutes or so talking about.

Number two, what do those changes say about China's comparative advantages?

Number three, what are the implications of that analysis for U.S. policy and investment. That is U.S. policy and also private investment in the United States. That would facilitate two things:

Number one, the growth of solar power so that it becomes significant enough that it can make a dent in global carbon emissions. Because let's be clear, it really hasn't so far.

And number two, a U.S. solar industry that's viable for the long term. And viable for the long term is very important. This is not about gigging a U.S. solar industry that may show some real rapid growth for a couple of years and then tail off. That's not what we would regard as economically efficient. This is about the United States finding an economically efficient place in a growing global solar industry for the long term, fundamentally about comparative advantage.

Now, we find ourselves at an interesting time in the world. You'll notice the two gentlemen on the screen, President Trump on the left and President Xi Jinping on the right. Rex Tillerson, the U.S. secretary of state and Xi Jinping met Sunday in China. And President Trump and President Xi will meet next month in Florida.

Suffice it to say, I don't think for this crowd I have to go into the details of what each country has pledged, but in the last couple of years, each country has made fairly significant pledges to reduce its carbon emissions. I think it's fair to say and important to say although many people regard those as significant against the backdrop of what was said before, very few people think that either of those pledges are enough to put the world on a path to reduce global carbon emissions enough to prevent global temperatures from exceeding two degrees above preindustrial levels. So, again, important context.

Now, Xi Jinping has a couple of -- as I don't need to tell, I think this audience -- I'm sure almost everyone here has been to China a lot, many of you have lived there, there's imperative to clean up the air in China. There is an imperative to diversify the energy supply. There is real interest in

developing technological leadership.

And one last thing I think is often overlooked but really, really important to my mind, in the research that we did in China, which is that there is real pride in much of China in the extent to which the solar industry in China has become a brand identity in China. Think of what other Chinese brands, I don't know how many of you are solar geeks enough to know solar brands, but I think there are very few industries where people who buy a product see as the biggest name in that product space, a Chinese company. That's certainly the case in solar, whether you like that or whether you don't like. And I think that's quite significant to people in China.

Now, we can come back and talk about President Trump, and what his policies and the extent to which his policies differ from President Obama's -- have an impact on this.

Okay, I'm going to go through this really quickly. Methodology. Again, Dan said we had a research grant from the U.S. Department of Energy. Really importantly, that grant gave us freedom to frame the inquiry and conduct the research and write the report.

We made a number of visits to China to a lot of on-the-ground research. During those visits, we interviewed lots and lots and lots of people. And we used a lot of data, various data sources. I'm not going to get into the weeds on that but happy to talk more about if that's interesting.

And we had a couple of workshops. Again, thanks to Mark, we held a workshop here at Brookings, where we gathered a lot of people in the U.S. solar industry. And we held a couple of workshops in Beijing at a center that Stanford has, the Stanford Center at Peking University, where we talked to people in the Chinese solar industry, Chinese research, and government.

Okay. All right, so, myths. Here are five prevailing myths that we hope this study busts:

One, China's solar industry is a financial bubble about to burst. Two, China doesn't innovate. The global solar industry is centralizing in China. Tariffs imposed by the West are hobbling the Chinese industry. And China's solar market is largely closed to foreign investment. What are those not accurate?

As I'm going to say in a moment, I think what we discovered is that it's really important that Chinese solar companies are reforming their capital structure in attempt to become more economically efficient. Now, let's not misunderstand, these companies are still in tough shape, many of

them. But if you look at early indications of where this industry is going, the notion that the Chinese industry is a bubble that's about to burst and go away, I think is not born out by the facts.

China doesn't innovate. This is a really prevailing notion we've encountered a lot in the United States, and I think it's really important to understand that we're seeing pretty strong early indications that that's not the case.

China, in fact, is improving significantly in solar. And again, not just in manufacturing process, not just in the efficiency of cranking out stuff, which is often I think what people in the West think about China, but, in fact, in underlying R&D. And we'll talk about that.

The global solar industry is centralizing in China. I'm going to go through some statistics that are pretty striking in terms of the extent to which China dominates the industry of making goods in the solar industry.

But this what this research discovers is that we're at the start of a real geographic decentralization of the solar industry. And to a large extent, Chinese companies are in the driver's seat of that decentralization. But that decentralization, even by Chinese solar industries, has important implications for lots of countries around the world, including the United States.

Tariffs. I suspect many in this audience are familiar with the fact that the United States has imposed tariffs on imported Chinese solar goods, and that China, after the imposition of those tariffs by the United States, imposed tariffs on imported United States polysilicant.

So, we'll talk about this more. Unfortunately, it's right on a seam there. But indeed, what we found is that the tariffs have pushed the Chinese industry actually to get more efficient, and that their effect on U.S. manufacturing is mixed. There are many indications, in fact, that the tariffs have had a deleterious effect on U.S. manufacturing in important areas. And we'll talk about that.

And last, really, really important, maybe a little wonky, but I think one of the really most important findings in this study. There's generally a notion in much of the United States and at least in Europe, that the Chinese solar market is closed to foreign investment. And one of the really striking things to my mind that we found in the research was that increasingly, leaders in China, both at senior levels of the government and in industry, are hungry for sophisticated, economically efficient investment structures from the West.

So, to be clear, there's not a real shortage of capital in China, but there's an increasing realization in China that a lot of the capital has been spent inefficiently. And that if China is going to reach solar deployment goals that are as aggressive as the ones that it has enunciated, it needs to get much more efficient in the way that it deploys its money and the way that it spends its money. And that it's very interested in importing into China, some of the structures that have been used in the United States. Clearly, there are marked impediments to doing that. But broadly, again, as kind of a trendspotting point, I think potentially is really important.

Okay. Now, let's dig in. So, I'm going to whip through this stuff really, really quickly. I apologize. We can come back to whatever you want to come back to.

First, financial status. So, there is a general sense I think in much of the West that the Chinese solar industry is kind of, as I said, a bubble fueled by cheap debt, a bubble that's about to burst.

And there's a lot of analysis in the report about the financial status of the Chinese solar industry, and I'd encourage you if you're interested in this, to take the time to read it.

But there are various indications that although the industry still has really thin margins, that those margins are improving in a way that suggests a strength ahead, long-term strength. And I want to be very clear, that these are precarious times in the solar industry, broadly, particularly, in China. And I'm not suggesting that there won't be significant dips here. But we're kind of talking the long term here.

I just want to say one thing about debt before we move on, out of finance. And that is that despite the conventional wisdom that cheap debt fueled the Chinese's industries growth, it's clear that there was plentiful debt that fueled the Chinese's industries growth. But it does not appear to have been cheap money.

So, I think the thing that's important to take away is that what happened in China, is that the Chinese industry came to prominence just before the global financial crisis. And the markets seized up in the rest of the world, obviously, and it was very, very difficult for solar companies, like companies in other industries, to get liquidity in the United States and in Europe and in much of the West. It was not difficult for companies in China to get liquidity. And therefore, the debt fueled a very, very strong expansion of the Chinese solar industry right in those years.

But it's important to note, that that does not appear to have been cheap money. The

interest rates that Chinese companies paid were market rate, and in many cases, above market rate, defined by western standards.

One last thing on debt. It's important that we talk about the kind of debt.

So, there's a distinction between long-term debt and short-term debt. And for various reasons of the preference of, and I should say, that the providers of debt in China are overwhelmingly banks and many of them state-affiliated banks. And I mentioned before, that there's an increasing interest in China in bringing more efficient sources of capital. That involves capital other than bank. Institutional capital. Pension funds. Insurance companies. Because the notion is that they can provide cheaper capital.

But the banks' lending is what came in short-term debt. And that became a problem for Chinese companies. And it's important to understand that in terms of sort of what happened, the fever in China.

These are short-term loans that were extended, and then in many cases, they couldn't be repaid. And so, the short-term loans were effectively renewed multiple times.

And those short-term loans were taken out initially, largely, to fund factory expansion, manufacturing expansion.

Now, a factory is not a short-term proposition, right? A factory is a multi-decade investment decisions.

And so, in retrospect, and Chinese solar executives are quite frank about this, it was not the best decision to take out lots of short-term money to fund factories. But that was what was available.

And so, the extension of those things created kind of intermittent crises for these companies.

Why do I mention this? Because now, the prevailing spend in China is shifting significantly, from manufacturing to deployment. We can talk about more about the reasons for that, if that's interesting to you.

But short-term debt is much more properly suited for deployment spending than it is for manufacturing spending. So, what we'd argue in the report, is that there actually is less structural reason for concern about the use of short-term debt in China, given the current structure, than there was when it

was being used for manufacturing.

Okay, let's go into R&D. So, I said at the outset, that China indeed is innovation, bucking a myth in the West that that doesn't happen.

So, let me just give a couple quick data points. This is from the National Renewable Energy Laboratory, which is affiliated with the Federal government. And this is kind of a widely-watched barometer of world record solar cell efficiency. So, you can go online and find this. And people in the solar industry watch this with baited breath and consider it a mark of honor to have a spot on this chart.

So, what I will show is that for the first time, Trina Solar, a Chinese company, has a spot on this chart. And Trina scored a world record in multi-crystalline solar cells, which are the prevailing type of solar cell in the world today.

So, we can talk more about the kind of R&D that China's focusing on, but the fact that a Chinese company is on this chart, is clearly a point of pride for China and relevant to the way that this industry develops in the world.

Okay. I don't want to spend too much time, but in the report, we do a lot of dissecting of comparing research progress in specific subindustries of solar.

So, these are two -- I mentioned that multi-crystalline solar cells are the prevailing technology by far. I won't go into the weeds of what HIT and SIGs are, but they are technologies that are on the market today but not nearly as significant in terms of market shares as multi-crystalline.

And what I just want to point out is, the red dots are China records, the blue dots are non-Chinese records. And what do you see? You see the gap narrowing.

Now, I want to really, really clear about caveats here. And I'm going to come back to this, because I don't want to leave a false impression here that we're certain that this is iron clad indication of an irreversible trend.

One really important indication of this is that the world -- so this came from a pretty extensive literature search that our team did. The non-Chinese records had been verified by third parties, many of them are in peer-reviewed journals. The Chinese records, many of them are not in peer-reviewed journals. And there's an extensive literature search. Much of this is in Chinese journals. And people have differing opinions about the legitimacy of those.

But I'm not aware that anyone else has done this kind of comparison before. And at the very least, it's an indication of increased effort on the part of China. And there's much more to say in the report about how this differs among specific sub-technologies.

Okay. Let me spend two minutes on this. This is another chart that despite its complexity, we're pretty proud of in the report.

We spent a lot of time trying to understand and map out the R&D ecosystem in China. Again, to our knowledge, this has not been done before. And, again, I'm not going to spend a lot of time on this, but I just want to make a couple of points here. Many of you are aware of the five-year plans in China. This is the universe of actors who are involved in coming up with the targets in the five-year plans and in implementing those targets.

So, let me just talk, I mean it's a very hierarchical system. And the five-year plans in China are directors of investment, private investment, as well as public investment, to a much greater extent I think it's fair to say, than any kind of public document in the United States is.

And let me just quickly walk you across the yellow boxes. So, we're going here from most basic to most applied R&D. So, on the left, is the National Natural Science Foundation in China, which is akin to the NSF in the United States, broadly. Really basic stuff.

The National Energy Administration is involved in research as well as, it's also the agency that's most involved in deployment, setting the -- there's a feed-in tariff in China, setting those targets. By the way, that's being reformed as we speak.

The NDRC, many of you will have heard of, essentially, the overarching economic planning agency in China. And it's the NDRC and most, the Ministry of Science and Technology, which together come up with the solar targets and the five-year plans.

Lastly, the Ministry of Industry and Information Technology, MOIIT, is essentially, sort of the trade arm of China. It's the government bureaucracy that's in charge of furthering the interests of Chinese industry. And so, it's been quite involved in the whole tariff fight.

Okay, just one second. So, just one other thing before we move off this slide. We are, all of us, in the middle of a moment when China is embarking on a pretty massive restructuring of its R&D enterprise.

China has said at very high levels, publicly, that it does not think that it's been spending its R&D money very efficiently. And it has embarked on a restructuring of the way that it does that. To be clear, not just solar, technologies beyond solar. But solar is a part of it.

And one little example is that the two key R&D programs that the Ministry of Science and Technology has been using for years to fund solar, are going away, and they're going to be replaced by a new bureaucracy, which I will not go into here. But the point is that there's an increased effort on basic research in this restructuring.

So, this is an important takeaway in terms of the notion that China is intent on upping its innovation game. And I would just suggest to you that the people who are overseeing this shift are quite sophisticated and have a very clear idea of what they want to do. Now, we can debate the point about whether China will meet its targets. But there are very, very detailed notions of what China needs to do, not just what numbers China wants to hit in terms of solar broadly, but where China wants to go in specific sub-technologies in solar.

Okay. Let me go faster here. So, we're going to get into a little spending numbers. And I'm going to really quick, with apologies to Ken, here, who was explaining to me, that these are -- and he's right, these are complicated. But I basically want to show you here, the big red blob at the bottom. This chart, it's more important for its caveat than for its numbers.

One of the most time-consuming efforts in this whole study was try to figure out what China is spending in various aspects of solar, including in spending in R&D. And the bottom line is we got I think farther than other people have gotten. We did not get far enough to give you an overall picture.

So, you'll see there's no total line here, because we don't want to suggest to you that this is falsely comprehensive. Indeed, the only number that we're sure is comprehensive is the Natural Science Foundation number, which over 14 years comes to $26 million, hardly a lot of money.

And in fact, if you look at the bottom, you'll see that the amount of money that is spent by solar companies in China, this is private spending, is obviously massively more than that, $1.4 billion.

So, again, we'll come back to it. We'll come back to the -- well, let me make one other point. There's an entity that's really important in China's R&D infrastructure, which is called the State Key Lab.

If you go to a couple of the large Chinese solar companies, you will see literally next to the factory floor, very large new buildings that are laboratories.

And that represents a very, very different model of cooperation between government and industry in China than prevails in the United States. We can have a discussion about to what extent that's relevant for the future of the United States, but it's a very, very different model.

And when you into those buildings, what you see is that there is a pretty sophisticated effort to take iterations that happen in those labs and try them out on the factory floor, essentially, to chuck the technology just over a few hundred yards.

That's a very, very interesting model. It's a pretty interesting way to scale up iterative improvements in technology. And one of our recommendations is understanding very, very important differences between the United States and China. It's an interesting thing for the United States to be aware of.

Okay. U.S. solar R&D spending. Again, this is pretty easy. These numbers are pretty clear. We do have a total here. These numbers were -- there is some lack of certainty here owing to how one defines what a solar dollar is in the Federal budget. But these numbers come -- and thank you to people at the Department of Energy and the National Energy Laboratory, who have done these calculations.

Okay. Manufacturing. I'm going to go quickly here. So, what do you need to know here? If I showed you, and if you look in the report, you will see graphs that show country-by-country manufacturing for various parts of the solar value chain. We just chose modules here because people typically are aware of solar panels. And what do you see? You see China vastly dominates the industry.

So, these are numbers are according to IHS market. In 2016, according to IHS, China produced 77 zero percent of solar modules in the United States, I'm sorry, in the world. The United States produced one percent.

Again, we can have a conversation about what's happening in terms of manufacturing and solar in the United States right now. There have been some interesting announcements lately. But most analysts think that despite those announcements, that's going to fundamentally change the picture. You can see the U.S. is the blue line, which is running right along, kissing the bottom line of the chart.

And you can see the projections out at least to next year.

Okay. So, this is the inside of one of the factories that we visited. This is in Suzhou in Jiangsu province west of Shanghai. And this is Canadian Solar, one of the large solar companies, which has its headquarters in Canada but the massive majority of its operation in China.

This is the Yangtze River Delta. The Yangtze River Delta is essentially solar central of the world. And I will show you in just a moment, the numbers that bolster that.

But let's just familiarize ourselves with the geography. So, you see Shanghai on the right. You see Suzhou, where Canadian Solar is, where that picture was taken. You see Zhejiang. You see, let's see, Jiaxing, which is where the Flat Glass roof was, just blowed that seam. Anyway, and you see all the names of solar companies that you're aware of it you're watching the solar industry.

So, why is this place significant? This is why this place is significant. So, look in the yellow line. This is the Yangtze River Delta as a percentage of total global -- let's just take a couple of these things. Silicane cell production, 45 percent. Silicane module production, 60 percent. So, this is two provinces in China responsible for 60 percent of solar module production in the world.

Okay. Now, again, solar subsidies. This is a hot topic of discussion in Washington, particularly. And I want to reiterate the caveat, that I talked about before, which is that we are not suggesting that this is at all a comprehensive list. There's a significantly longer list in the report than these, and you're welcome to take a look.

So, suffice it to say, that there are all sorts of subsidies that have been extended to companies in China. We can have a discussion about how significantly or not significantly the nature of those subsidies differs from the nature of subsidies given in the Unites States or in Germany or in other countries. But clearly, there have been lots of subsidies given, and it is very, very difficult to quantify them in any comprehensive way.

So, we did a lot, a lot of work pointing up these things. But, again, I want you to understand that we're not suggesting that we found even the majority of this.

Now, one would think that that's a little strange because there's been a whole tariff case -- let me go back to the next slide, a whole tariff case raging in Washington as its center between the United States and China. And one would think that that's a -- I mean I'm an old reporter and I love

documents. These documents are not terribly helpful. So, this is the public version of the documents.

And so, the point -- not to put too fine a point on it, is that these are fairly heavily redacted documents. The contention of the redactors, a fancy name, is that these are effectively company specific information that shouldn't be released to the public.

But, so what one is left with is largely a real tit for tat between allegations by people who have alleged serious violations of international law on the part of the Chinese government and Chinese solar companies and retorts in China that those don't constitute violations of law. And let me be clear, the purpose of this report is not to come down on either side of that legal questions, I'm not a lawyer. The purpose is to elucidate facts behind this. And we've done it as much as we can. But because of this, it's sort of difficult to get a complete picture.

Let me go back here really briefly. So, we talked about the Yangtze River Delta, and the extent to which the Yangtze River Delta is kind of China manufacturing central. Let me just offer a caveat to that, and that is that we are at this moment witnessing a pretty profound -- the start of a pretty profound change in China. And that is a diversification geographically of where Chinese companies make their stuff, where Chinese solar companies make their stuff.

And I just want to point out that, look at Malaysia. Malaysia, if you look at -- this chart basically shows where beyond China, the largest Chinese solar companies are manufacturing solar goods. And what you see is obviously Malaysia is the biggest one. And there are reasons for that. Malaysia offers quite generous incentives. And Malaysia is outside the zone of tariffs imposed by the United States. So, if you are a Chinese company and you manufacture in Malaysia, your goods are not subject to tariffs if you structure your operations properly.

But the point is that we are witnessing the start, pretty clearly, of a significant diversification of this industry. And so, if you thought that the global solar industry, which clearly is dominated by Chinese-domiciled companies, is going to continue to be an industry that is undertaken almost exclusively on the Chinese mainland, I would suggest to you that you're wrong. And there's a lot of discussion in this report about the way that this globalization is playing out and the implications of the globalization for countries including the United States.

Okay. All right. So, we talked about the modules, again. And I wanted to show you one

other thing on the tariff point.

So, polysilicant. I mentioned before that after the United States imposed tariffs on China, China imposed tariffs on the United States. And those tariffs focused on polysilicant, which is essentially the building block of modern solar cells in solar panels.

Polysilicant is the one part of the solar industry that the United States had a real toe-hold in. Largely, because of cheap energy in the northwestern United States. Polysilicant production is extraordinarily energy intensive.

What happened? Well, you see the blue line of the United States, and you see what happened starting in about 2012 and then more pronounced in 2014. And what happened is Chinese tariffs kicked in. And those tariffs had an effect of making polysilicant produced in the United States, significantly less competitive on the global market.

And you see at the same time what happened to the red line, the Chinese line, that grew. Now that's not simply a function of the fact that manufacturing in the United States of polysilicant failed, it's also a result of the fact that there was significant expansion of manufacturing of polysilicant in China. And in fact, the biggest polysilicant makers among them now are Chinese firms.

Okay. Last bit, deployment. Deployment, again, this is -- we've talked about iterating the stuff, we've talked about making the things, and now we're going to talk about putting the things out on the ground.

So, this is the world. And let me just point this -- so, the teal at the top is China. And what you see, just focus on that teal for a moment, you see essentially in the last 10 years, China went from zero to a very big slice.

Now, let's look at the red. The red is Germany. We can talk a little more about why that red is so thick. But suffice it to say, Germany is not the most sunny country in the world. Germany has a very significant regiment of incentives.

But I wanted you to know is that we had to stop the research on this report at a point when it was not possible to get global numbers for 2016. But if you look at 2016 numbers for China, and we can talk more about them in detail, there's a vast increase in deployment in China.

So, China's deployment now is about twice the United States' deployment. And China

installed roughly twice as much in the last year as the United States did. And the United States, in 2016, had its by far best year yet.

If you look at predictions in China for where deployment is going to go. Deployment of solar in China is going to dwarf anything that's come before in China. So, all suggestions are that that teal wedge gets thicker.

Okay. Just very quickly, this is deployment by -- we talked about manufacturing by Chinese companies in China versus abroad. Similarly, Chinese manufacturers are diversifying geographically in where they are deploying. If you fly out to San Francisco where Dan and I are going to fly back to in a couple of days, you will notice that most of the Chinese companies, the large Chinese companies, have offices. And they have offices largely because they're building solar projects in the United States.

This is the whole world. And more important than the fluctuations from year to year, are the fact that the blue lines are growing. Again, this is a diversification trend in the Chinese industry.

All right. Let me turn it over now to Dan. Thanks. (Applause)

MR. REICHER: All right. So, we dug fairly deep into this whole area of R&D, manufacturing, and deployment and also included this look at the finance aspect of this whole situation.

And so, what I want to do quickly, and we do want to have time to have a discussion with Ken and then take your questions, is talk about what we would recommend. Particularly recommendations to folks in government and industry and NGOs and beyond here in the United States.

So, if I had to pick three words about our recommendations, those are cut solar's cost.

Solar has come down a lot in terms of cost, but we still have a long way to go. Some of you know the DoE Sun Shot Initiative. It's 2020 goal is to get to six cents a kilowatt hour for utility scale solar. But the new Sun Shot Initiative for 2030 is down to three cents a kilowatt hour. And let me emphasize, these are unsubsidized costs. So, take away all the subsidies. DoE is talking about cutting 50 percent. So, that's a big chunk.

So, that's got to be a focus. It's got to be a focus in R&D. What can you do? More efficient cells. Balance of systems. A whole host of things.

Storage. We haven't talked much about the fact that solar is an intermittent source of

energy. We've got to deal with that intermittency. Today, we deal with it by firing up gas-fired, fast-ramping natural gas power plants. Storage is one of the answers. We've got to build more transmission. So, there's a lot we've got to do to really bring down the cost and increase the deployment.

Secondly, leverage. Don't seek to bury China. We've got to figure out a way for our two countries and the companies in each of our countries to work together more. Less of a battle, more collaboration.

We understand there are security issues. We understand there are intellectual property issues. But to the maximum extent, if we're going to have the benefits, the economic benefits, the security benefits, the environmental benefits of rapidly expanding the deployment of solar, we've got to figure out a way to work with China, both government and industry.

Third, solar manufacturing. There is a role for solar manufacturing in the U.S. But as we say, we've got to be surgical about it. We can't do everything. There are those things that are probably just too expensive for us to do here. But there are others that do make sense.

So, let me quickly move through this. Terms of R&D: Increase U.S. spending on R&D, government, and industry.

The trend right now, with the recent release of President Trump's budget, may well be to go the opposite direction. We think that's a mistake. We've really got to continue to spend. As Jeff pointed out, the Chinese are radically changing their approach to solar R&D. They're greatly expanding the investment they're making in solar R&D.

R&D has been an area where the U.S. has led for decades. We invented solar in the 1950s. We put it into space in the 1960s. We need to keep a very strong role in solar R&D, that does take government money. And we ought to be ramping up, not down, that spending.

Include China in internal solar R&D efforts: As I said, we've got to figure out ways to collaborate. There are issues. But there's all sorts of ways being mindful of some of those issues, security issues, intellectual property issues, that we can collaborate.

There is also a requirement, that if you're a U.S. company or a company more broadly, that receives R&D funding, you've got to essentially commit to producing the resulting goods substantially in the U.S.

We have concluded that that's, for the most part, a counterproductive requirement. It has pushed some really talented R&D, potential R&D players, out of interest in applying for these funds. And we think that that ought to be rethought.

This is not just the view of us. This is not just the view of industry folks. But there are indeed folks in government who feel like the time is to change this substantial manufacturing requirement.

Manufacturing recommendations. Again, we're not going to manufacturer everything here in the United States. But we point out three categories of solar products where we feel like there is a role to put people to work making solar stuff in the United States.

One, is just things that are expensive to ship. They're big. If we're not just talking millions, but we're literally talking billions of solar panels that are going to have to be deployed, that's a lot of equipment to put on a ship and ship across the ocean. That's definitely been the experience of the wind industry in the United States, where increasingly, their making more and more parts of wind turbines here. The solar industry has some of the same aspects to it.

Jeff mentioned polysilicant. We should be producing more of that. We could be producing more of it. It's energy intensive. We have a lot of cheap hydro. We have a lot of cheap natural gas. And increasingly, we have a lot of cheap renewables-produced electricity. That ought to be something we should be doing.

And then the so-called first factories. When you develop a new technology, you go to go out and build, literally, the first factory. Things that we invent here. This is a good place to be building that first factory even if ultimately, down the road, again, for economic reasons, you might go offshore. One example of that is the new technology that literally produces no waste. Kerfless. Kerf means waste. Kerfless solar wafers. That's an example of one of those technologies.

Deployment recommendations. A lot of this will not be new to folks sitting in D.C. But we do think; however, you get to it, and there are so many different ways, we do have to put a significant price on carbon emissions. There are now interesting proposals, bipartisan proposals that have been made to do that. But that's really quite important.

The solar tax credit, the investment tax credit, as many of you know, extended in December of 2015. Let's not tamper with that. Let it run its course. It was put in place in a bipartisan

fashion. We should keep that on the books.

The clean power plan. We think it ought to continue. We'll see what happens in the D.C. circuit. But we don't think this is something that ought to be withdrawn from EPA regulation.

Many of you know there are net-metering fights, state by state across the U.S. Net metering being how much you get paid when you generate, particularly, smaller systems on the roof, how much you get paid by the local utility. That ought to be resolved. It's a very complex area. It's decided state by state, utility by utility. But this is an important area.

State-renewable portfolios have really driven a lot of solar deployment, along with the investment tax credits. Let's not pull back on those renewable portfolio standards. There are better and less good renewable portfolio standards. There are indeed ways to tune them up from an economic standpoint. Let's do that, but let's not pull back. California has a recent 50 percent. New York has a recent 50 percent one. This will help drive the deployment of solar.

And then the loan guarantee program. $41 billion left in the loan guarantee program. A chunk of that for renewables. We believe strongly that that program ought to move forward. We've learned a lot about how and how not the Department of Energy ought to make loan guarantees. It's a program right now that has seen $6 billion in repayment of loans. Another $2 billion roughly in interest payments. It's a net positive for tax payers. It's a pretty good portfolio overall. And we ought to move that forward.

And finally, help U.S. investors engage in the Chinese solar market.

The Chinese between now and 2030, are going to spend $6 trillion, six trillion with a T, between now and 2030, in deploying clean energy. solar is a big, big chunk of that. This is something that U.S. investment firms ought to have a piece of.

The Chinese are, in fact, interested in getting help, getting expertise, getting investment from the U.S. side. U.S. investment firms here have helped with Chinese IPOs, initial public offerings. They want to move on. And it's not just investment banks. As Jeff mentioned, how do we move pension fund money, insurance company money. A whole host of large entities with a lot of capital, that could be deployed, low-cost capital, because it's not just the amount but the cost of that capital that's so critical.

Bilateral discussions have happened on this front, that is how the U.S. can collaborate

with China on more creative, lower-cost investments. We think that ought to move forward.

And with that, I think we are ready for Ken to come up. We'll have a discussion and then take your questions. So, thank you. (Applause)

MR. LIEBERTHAL: I'm going to try not to fall between the crack in the stage. I thought Jeff recovered well from that fall, so. And we have that on video. I think that's going to be something we show regularly at our parties. The always elegant Jeff fall. Yes, slow-mo. You're going to see this on YouTube. It's already on YouTube if it's (inaudible). It's going to be all over the internet.

MR. BALL: Yeah awesome.

MR. LIEBERTHAL: Jeff, thank you. In part, I've been up on this stage many times, and I never noticed that there was a gap there.

MR. BALL: Now, you know.

MR. LIEBERTHAL: I'll be very sensitive to it.

MR. BALL: There is an OSHA investigation that's been undertaken, so.

MR. LIEBERTHAL: We are going to get in to regulations and how effectively (inaudible) around here.

Seriously, thank you very much. This is a very, very rich report. It's a 250-page document. I guess downloadable as of today, from the Steyer-Taylor website. And where can you get hardcopies, just is my curiosity?

MR. REICHER: There are hardcopies of the executive summary, stacks of them out there, if you didn't grab one. We have a limited number of hardcopies of the real one. And in the interest of not counteracting the carbon effects, we would encourage you to download them. But if you're adamant that you need a hardcopy, see us afterward.

MR. LIEBERTHAL: This is a fascinating report. And the report adopts an approach that is sophisticated, I think addresses in a very realistic fashion, what the U.S. role in global development of solar ought to be. How to think about global development of solar and how to promote cost-effective deployment of solar energy without exaggerating what this can accomplish in the overall battle against climate change and so forth.

So, I thought it was, you know, it was elegant. It's serious. It's logical. My one concern

about it is that this report would have had a tremendous impact, must read, in a Hillary Clinton administration. But that isn't the administration we've got.

And so, my question is, how do you preserve the core of the argument? Because your argument is a powerful and important argument. But perhaps frame it in terms that it stands some chance of resonating in the Trump administration. Because this report as it is, argues in terms, you know, comparative advantage on a global basis, cooperating with China, technology taking the lead, and then manufacturing jobs following development of technology. A whole series of things that have been, shall we say, not a priority of the incoming administration. In fact, many of which have been in principle, explicitly repudiated by the relevant people in the incoming administration.

So, can you give us a sense of kind of without sacrificing the core of the argument, how would you reframe it or is this really a kind of just a kind of argument that's going to sit out there until you have -- the politics get more favorable to addressing these issues?

Let me note by the way, I haven't read it. I'm not sure whether it's up yet or will up this afternoon. It's up now. There is an opinion piece in The New York Times today in the digital edition that addresses some of these issues, including, I guess, some recasting or addressing this within the context of our current administrations' priorities. But let me ask you to elaborate here.

MR. REICHER: So, let me just quickly say, and then I think Jeff definitely has some thoughts on this, that yes, this would have been a fairly straightforward set of dots to connect in the Hillary Clinton administration, had she been elected president.

But I think there are elements to this report that are compelling for the Trump administration. And I'll highlight a couple of things:

One, this is a very quick growing industry that does put people to work. And we focused a lot on jobs in manufacturing. And I think there will continue to be jobs in manufacturing. There's a solar cluster that's developing in upstate New York. New solar equipment manufacturing plants near Buffalo. There are increasing R&D capabilities around Albany. You could imagine, not that the size of the Yangtze River cluster, but you could imagine this sort of jobs being created. Many more jobs have been created simply in deploying solar in this country. Hundreds of thousands of jobs that have been created.

So, if I were to sit down with President Trump, I'd say you're looking to create good

paying U.S. jobs in the U.S., this is an industry that is already doing that, and the more we can help in realistic ways with the growth of this industry, the more that this is going to happen.

I'll make one other point and turn things over to Jeff. The International Energy Agency has talked about global energy infrastructure investment, amounting to about $48 trillion between now and about 2035. One of the biggest business opportunities of this century. Forty-eight trillion. That's trillions per year that's going to get spent.

Whatever one's view on climate change, simply, that kind of economic opportunity ought to be convincing to an administration that is so focused on job.

And the Chinese, as you saw today, are getting very well organized to take a big chunk of that industry. Increasingly rethinking how they're doing R&D, manufacturing, and deployment. We ought to be tuning up our system, not just in solar, but in a whole host of clean-energy technologies to do the same.

MR. BALL: I'm an old reporter, and I spent a lot of time at The Wall Street Journal where I spent a lot of years before coming to Stanford, writing about, essentially, a global race around energy, around fossil fuels, and then around renewable energy. And I think this is an extension of that.

There is a real global race going on to scale up all of these technologies. And we are not suggesting here that the president of the United States or the president of China or anyone else ought to sublimate national interest for the good of the environment. What we're suggesting here is that everyone ought to play to his or her interests, and the best way to do that is by thinking seriously about what one does well and what one does not do well.

So, in that sense, at the end of the day, I think this is an argument that absolutely ought to appeal to a president who is about increasing economic activity in the United States.

Number two, a lot of this report talks about inefficiency of government support for this industry over the years. Inefficiency in the way the United States has supported the solar industry, inefficiency in the way China has supported the solar industry. And there's lots of inefficiency to go around in other countries too.

So, this report is not at all apologizing for government spending that could have been done better, in fact, it suggests ways to spend that money better. And I think that that's a message that

ought to appeal widely.

Last thing, the solar industry in 2017 is not the solar industry of 5 or 10 years ago. This is a legitimate industry in a way this industry was not 5 or 10 years ago. And that has political implications as well, which is to say that there's bipartisan support for this industry in this country and much broader support for this industry as well in other countries.

So, it's not, I think, as clear that the political calculus about what one does on this industry even if one is talking in purely political terms, falls as neatly along left right lines as it might have 10 years ago.

MR. LIEBERTHAL: I have to confess, I'm a little more pessimistic --

MR. REICHER: I thought you were going to say that.

MR. LIEBERTHAL: Yeah. Just when I look at what some of the key players in the administration, including the president, have been saying, both about the U.S. economy and how you make it great again and about the issue of climate change, of carbon emissions as a potential problem, and of the role of the EPA.

You know, but let me ask you to take as a given that at the national level, this argument is going to have a hard time getting traction in the executive branch. And assuming that is the case, there is a lot of activity that's taken place up till now and prospectively in the future, at the U.S. state level and regional level within the U.S. And you mentioned some of that regarding New York and California for example.

What does your report -- what recommendations from your report should state-level leaders be focused on or are there dimensions of this that you would really direct to state-level leaders?

MR. BALL: Dan, do you want to start?

MR. REICHER: Yeah, so we don't go deeply into the role of the states. I will say that there's going to be quite a bit of follow-up work we're going to do with regard to this report, both focused domestically and internationally.

But what I would say, you know, everybody points out New York and California, obviously, Democrat-led states. But you look at states like Arizona, North Carolina, there's a variety of them across the country, where solar is really taking off. Where Republican governors, Republican

legislatures at the state level go out every day and see people building solar facilities, either big utility scale facility or putting solar panels on peoples' roofs. You do see, in the southeast for example, some new solar manufacturing capacity being built.

So, my point is, it's happening. We shouldn't resist it. And, again, can I say, there is this very intense debate about climate change. But solar isn't only about climate change, it's a way to make electricity. It's a way to create jobs. And as many in this room know, 70 percent of all new electricity generating capacity over the last couple of years in the U.S. has come from renewables.

So, it isn't a small alternative energy system anymore. This is real stuff with real jobs. We don't measure things in millions anymore. We measure them in billions and tens of billions. And as we said, we're increasingly measuring them in trillions.

So, set aside climate, let's talk about economic development, jobs, and even energy security, let's not forget that whole area.

MR. BALL: One point on states. We didn't get to this in the presentation. But I think one of the more important pieces of analysis in this report is in its recommendation, that to the extent that the United States wants to increase solar manufacturing, which is something that many people in Washington want badly to do, the smarter strategy is not to push the lever on manufacturing directly. The smarter strategy is to use the push of R&D and the pull of deployment.

Now, why do I mention that in the context of states? Because if you look at what states have done, they are some of the most important players in both that push and that pull. So, let's take the pull first. The pull of deployment that is notion that to the extent that any geography installs more solar panels, there is a more of a market that justifies the creation of a factory. So, states are extraordinarily important in terms of policy about solar deployment.

Now, let's go back to R&D really quickly. So, we talked, Dan mentioned in the report talks in some detail about the notion of clustering. The notion of clustering as I mentioned in the Yangtze River Delta, sort of the ultimate solar cluster of the world in terms of a manufacturing sense. But what's happening in New York is a really interesting example. The closest thing the United States has to an attempt at a real solar manufacturing cluster. And that's the result of, certainly, some federal work. But also, really importantly, state policy.

And so, if indeed this push/pull model is going to be employed, and again, in the report, we talk about that as being a much more efficient way to go then just chucking direct manufacturing subsidies at an industry, the states are going to be the ones, I think, to a large extent, to employ that.

MR. LIEBERTHAL: So, bottom line is at a national level because most of this report is really focused on national governmental policy, the most viable approach in terms of argument at this point may be more on this is a serious industry that is one that can produce a lot more growth, increase energy security, grow good jobs --

MR. BALL: Well, stop. That's the case --

MR. LIEBERTHAL: Okay, fine.

MR. BALL: -- that's the case I would make if I got a minute or two with the president.

MR. LIEBERTHAL: Is there any implication of this report for the American private sector and how would you spell that out?

MR. REICHER: Go ahead.

MR. BALL: Yeah, I mean I'll give you one example. I mean we talked a little bit about it. I talked a little bit about it up there. But to the extent that the Chinese market is hungry for innovation in finance, that is an opportunity for the United States. And to be clear, this is not just about the deployment of capital in China, this is about the deployment of know-how, about how to deploy capital.

And I think that one of the really, really striking things to my mind of the real result of this research is that one can sit in Washington and have a very jaundice view of the relationship between China and the United States, which is to say that it's this all the time. And when you start to spend time with people who are actually deploying money, what you see is that there is an increasingly tight relationship; very, very self-interested on either side, but that's the way it works.

And there are people who see, certainly, people in the United States, who see the infusion of Chinese capital in investing and technology and solar like in other areas that's going to then be scaled up in China as a real opportunity for American technologists. And similarly, to the extent that China is interested in importing know-how about how one deploys capital, a potentially significant opportunity for the financial industry in the United States.

MR. REICHER: I would just quickly add, we have significant U.S. solar companies that

are in the business of manufacturing solar equipment of various sorts. Kathy Weiss is here, a friend from First Solar. And that's a significant company. They do some manufacturing here. They do a lot of manufacturing in other countries.

To Jeff's point, this is already a highly-integrated industry when you get to the level of private sector players. When you get to the level of investors, you know, if you're at a major investment bank, you've been doing deals with China for decades. You've already been doing solar deals. You know how to do this.

So, the private sector, both on the solar technology side and the investment side, is way ahead of government. And we're just looking at that trend and saying, folks running the U.S. government today, this is the way it is, and you ought to think about getting on that train.

MR. BALL: And to be clear, I mean these companies that we're calling Chinese companies or Chinese solar companies, are obviously based in China. They're also publicly traded companies, almost all of them, that have investor bases that are definitionally global, including many, many investors in the United States. So, there's an inherent ambiguity that kind of the nationality of all these companies given that they're large companies.

MR. LIEBERTHAL: Good. We have 20 minutes left. Let me open it up to the audience. We have, I'm sure, a lot of folks who raise a variety of questions here.

We have a roving mic. When you watch this on the Brookings' website, you won't hear anything unless you wait for the mic and speak when it comes to you.

MR. BALL: And if you could please --

MR. LIEBERTHAL: Please start off just telling who you are and then direct a question to an individual or to both speakers as you wish. Please, right here.

SPEAKER: Thank you very much for your excellent report and presentation. Very insightful. I have two suggestions to your report and one questions.

My first suggestion is I think probably you should do a comparison between the solar industry and the China's fossil energy industry as well. You see, you already found a lot of incentives to incentivize the solar industry. But in China, you will find also, a lot of policies disincentives the fossil energy, that would be also useful for U.S. government, especially for this current administration. How to

regulate the coal industry in U.S.

My second suggestion is beyond as a solar manufacturer, you probably should go further to see the service industry for the solar as well. You know, for the equipment to install. This is an important industry. You will find one of the reasons why China's development is so fast is because of skillful, cheap, hardworking laborers. You know, that is really lowering down the price of the solar equipment to be widely used national wide. That also has some implications for U.S. As well, at least, you know, U.S. really need legal immigrants rather than illegal one, of course. That's lowering down the labor costs.

My question is you have already described the investment and R&D blah, blah and this. What are the secret behind this one? That's my question to you. thank you very much.

MR. BALL: Just so I understand your question. What are the secrets behind the rise, China's rise in the solar industry? is that broadly what you're asking?

SPEAKER: Yeah.

MR. BALL: Yeah, okay. Let me -- I don't know that they're secrets, but let me sort of sketch the history really, really quickly here.

You know, 15 years ago, China didn't have a solar industry. Frankly, 15 years ago, the world didn't have much of a solar industry. And what happened is that a couple of countries, and I'm going to really vastly oversimplify here for illustrious purposes. But what happened is the United States largely invented solar panels and put them on space ships in the 1960s. And they were for many years, the stuff of space ships and mountain tops, places where there was no other way to get electricity and people were willing to pay what it took.

And then, fast forward to the 1990s and 2000s, when European countries decided that largely for environmental reasons, they wanted to rollout fairly generous subsidies to start making solar panels a consumer industry. And that worked pretty well on the back of subsidies. Now, there's some consternation now about the cost of all of that.

But in any event, this is where we get in to China. There were some very, very smart Chinese entrepreneurs who had pretty significant scientific training, often in the West. Who looked at the incentives that were being dangled, in Europe largely, and knew that China can manufacture things

inexpensively; t-shirts, televisions, and it turns out, solar panels. And so, what these entrepreneurs did is build businesses. They built those businesses with a lot of help from the central government in China, with a lot of help, really importantly, from the provincial governments in China. And they built in the Yangtze River Delta, they built these businesses into a politically important industry in the country.

And importantly, two more things and then I will be quiet here. The United States' solar industry began, basically, as R&D first and manufacturing second. The Chinese solar industry began as manufacturing first and R&D second. And right now, all of us are in the middle of that transition, which to my mind is why this is so interesting. Well, let me just stop there.

MR. REICHER: Just one fun fact. One of the reasons this industry located in the Yangtze River Delta is because of the Three Gorges Damn, the largest power plant of any sort in the world, 24,000 megawatts. There was a lot of cheap electricity. Solar is an energy intensive business.

So, you can debate the merits of the Three Gorges Damn, proponents and opponents of it, but that was a major reason that things moved forward.

MR. BALL: And just a quick point. The Three Gorges Damn, the statistics is in the report. The Three Gorges Damn, a single facility, produces vastly more electricity than all of the solar panels in China combined. So, again, context here is important.

MR. LIEBERTHAL: Yes, sir.

MR. HAMID: Thank you. Javed Hamid, I'm retired from the IFC. And I have two quick questions. One is that where do you see more growth potential? Is it in the desegregated production; which is more on solar panels, roofs, and this and that or in utility size? And what are the, sort of trends in technology, which will drive one or the other? And the second thing is about storage. And what is happening in the area of storage and how that is likely to impact the future development of this industry? Thank you.

MR. BALL: Do you want to start again or do you want me to start?

MR. REICHER: Go ahead.

MR. BALL: Really quick. So, on the question of decentralized solar versus utility scale. So, for the people who are not the wonks in the room, decentralized is the solar panels you put on your rooftop, basically, and centralized is big, big solar farms, largely on the ground.

So, what has happened in China thus far has been almost exclusively big, big solar panels on the ground. Owing to lots of realities about the Chinese market. China has articulated a very, very clear ambition to shift that. Not to change it entirely, but to increase the percentage of decentralized solar. There are lots of interesting battles going on in China over market realities that have been an impediment to that shift. But pretty clearly, that's a priority, number one.

Now, on storage. Obviously, storage is really important for the world. Let's just review, the sun doesn't shine strongly in all places, all the time. Solar energy, like wind, is variable. And at least at this point, there's an expectation that there's going to be a need for a significant amount of storage globally.

All I would say about China is that China is in this game just like other countries are in this game, buying technology from abroad and also developing technology domestically.

There are many, many people in China who argue that the energy storage race globally, and China's role in that race, is very, very similar to the solar race globally and China's role in that race. Although perhaps, the energy storage race is several years behind the solar one.

So, storage is broadly more expensive than the market is willing to bear, but that price is coming down, and China is very much in that game.

MR. REICHER: Just on storage. Let me say, storage, whether it's in the U.S. or it's in China, definitely includes batteries but means more than batteries. Batteries, we measure, generally, at the kilowatt hour scale. We measure it in storage over hours, part of a day. That's where its focus is.

But if we're going to get to the sort of levels of large-scale solar deployment, not just 1 percent, but if we're going to get 15 percent or more, we've got to be measuring storage over days and weeks and months. That's things like pump storage, compressed air, hydrogen, thermal systems. A whole host of things that get you to megawatt hours and gigawatt hours. So, we're going to need them all.

To Jeff's point, and this may be the most important one, sitting here in the U.S., is that we've got a lot of expertise in storage. We've got a lot of venture-backed companies that are roaring ahead with storage. That's a great opportunity from a purely economic standpoint. To go to China and say these are the technologies of the companies, these are the things you need as you build

out your solar system, as we built out ours at the same time.

MR. LIEBERTHAL: We're going to take two questions and, you know, group them and then turn it to you just to save some time. In the back of the room and then --

MR. FAULKNER: Doug Faulkner, Leatherstocking LLC. For decades, the bedrock model for U.S. R&D policy has been public-private partnerships. You know, taxpayer dollars paired with money from the private sector. Mr. Ball, you touched on this a couple times, but I wondered if you could compare and contrast the Chinese model that you talked about, especially with an eye toward what can each learn from the other and maybe whether there's a new model emerging?

MR. LIEBERTHAL: Thank you. And this lady.

MR. STEIN: James Stein. Could you say a few words about the state and provincial key laboratory system and was there already analogies in Europe?

MR. BALL: Yeah, so you want me to -- Ken, do you want me to do both at once?

MR. LIEBERTHAL: Yeah, please.

MR. BALL: Okay. Okay, so I'll answer quickly and then, Dan, feel free to jump in.

On public-private partnerships. Again, look, let's be clear. The landscapes in China and in the United States are very, very different. And that is the predicate for the difference in the nature of public-private partnerships in the two countries. I don't think in this crowd, we need to go into a lot of details about that.

But nevertheless, the way that China has structured, very deliberately, public-private partnerships, defines the progress that China has made thus far in ramping up an R&D effort. And R&D effort, that to be clear, is still in need of improvement by the admission of Chinese officials but is undergoing improvement as we speak.

I think it's fair to say that one does not find in the United States, and now I'll just kind of segue way into the state key labs and provincial key labs, one does not find the physical proximity of effectively, a government facility or a largely government-funded facility and a single private company in the United States, that one finds in China. That's a physical manifestation of a very different situation.

Just very briefly on state key labs and provincial key labs. China, to be clear, has a whole range of, state means national in this context, China has a whole range of state key labs for all

sorts of technologies, of which solar and subsectors of solar are just one aspect. Similarly, on the provincial level.

But it's a very definite way that the Chinese government focuses its decisions about what its priorities are. And in fact, if you look at, and the report talks a good deal about this, if you look at where within subsectors of solar China appears to be making the most R&D progress, it's probably not a surprise that those are the areas that Chinas has spent the most money on. Decided for strategic reasons, and I'm not being pejorative at all in the use of strategic here, decided for strategic reasons that it wants to pursue those. That's kind of the intent and one can trace that.

MR. LIEBERTHAL: Yes, back here this -- yes, this woman in white and you.

MS. YU: Hi, my name is Fei Yu from the Asian Development Bank. So, at Asian Development Bank, we invest close to $1 billion a year on renewables, including solar. But this compared to what you just said about China's plan for investing in solar, is a tiny drop. So, we have been also trying to explore possibilities of leveraging institutional investors in North America and Europe, including pension funds, etc. And through PPPs to leverage funds into this industry, not only in China but also in Asia as well.

I just want to hear more from you about what are the feasible ways to do this. And do you see a role for multilateral development banks in facilitating this.

And my second question is just a very quick one. There is always this argument about public investment crowding out private sector investment in innovations. And whether you're seeing this taking place in China, whether this is actually a wasteful resource, is one story, but whether it's actually slowing down private investment in innovation in solar. Thank you.

MR. LIEBERTHAL: Yes, back there. Yes.

MS. MA: Hi, I am Xinyue Ma, student from SAIS across the street. My question is a follow up to your remark on the 2016 pike of deployment of solar in China. I'm wondering why that is? Is it because of a decrease of the cost over this year or maybe the incentives of stopping the coal plants? Or is it a measurement in terms of capacity or generation. Because we have been seeing a lot of taking down the wind and other renewables because of disconnection to the grid. So, I'm wondering whether that poses a question or a challenge to the future of the solar industry in China?

MR. REICHER: So, great question about the role of multilateral development banks. Yes, a billion dollars in the context of the sort of trillions we're talking about today, is small. But it's really pivotal money. You can really use that kind of money to help stimulate private sector investment. And there's lots of good examples of that around the world. And we need those kinds of funds.

Our own export-import bank is serving a very useful role. But there are MDBs, multilateral development banks, all over the world that have gotten involved. They can help sometimes pioneer new investment vehicles, point out opportunities. But, ultimately, it is going to be big, big, big private sector dollars coming from the big players where all that money is. Again, pension funds, sovereign wealth funds, insurance companies, endowments, and on and on. That's where we've really got to find the money. But very important that that gets driven by, helped to be driven by, the multilateral development banks.

One other thing. We did a report on what's going on in solar in India. It's called Reach for the Sun. We put it out in Paris at the climate negotiations. It talks about these kinds of public-private partnerships and how important it is, with India's goal of 100,000 megawatts of solar deployed by 2022. So, I encourage you to take a quick look at that. Jeff.

MR. BALL: Really quickly. The infusion of money from multilateral development banks is a really interesting slice of a broader question, which is a question that we intended, at the Steyer-Taylor Center at Stanford, to focus pretty seriously on in a kind of next tranche work, which has to do with the financing of this.

Pretty clearly, we're at a pivotal point in the world but also in terms of the relationship between China and the United States, in terms of the internationalization of finance deployed to cleaner energy sources, an area that I think needs a lot more thought and analysis, that we're interested in doing.

Two other quick things. So, with regard to the question of public money crowding out private money. One does hear that concern in China. And I mentioned a priority at fairly high levels in China of broadening the suite of financiers in this area, to include not just the traditional large banks, many of them state-affiliated banks in China, whose money has been comparatively expensive money, but new players. And those new players are, I think it's fair to say, private players, multinational private players.

Lastly, on the question of the spike in deployment, why. We don't have time to go into this in great detail. Let me just say, two things:

Number one, you're correct that a lot of solar power that is produced, never gets used. That's the same case with wind power in China. It's called curtailment. And in some provinces in China, it's on the level of 30 percent. Not a very efficient use of capital to have subsidized the creation of all those solar farms and then essentially turn them off at periods because there's not a lot of transmission. Again, this is not news to people in China. It's a very serious issue, understood at very high levels. And China just like other countries around the world, is racing to figure it out.

Lastly, why a spike in deployment? Because China needs lots of energy. And also, frankly, because China, having built a manufacturing industry in solar and having seen the incentives from the West that spurred that manufacturing industry dissipate, has decided that's it's going to use its own domestic deployment incentives to keep that industry in good health. And those domestic deployment incentives are largely responsible for the increase in deployment.

Lastly, really, it's really important to watch a reform that's going on in China in terms of the nature of those subsidies. At least an articulated desire to get a lot more efficient in the way that China is spending its money. And we shall see how that plays out.

MR. LIEBERTHAL: Thank you. Yes, here.

MR. HALPERN: Josh Halpern, Howard University. I'd like to raise an issue that goes beyond -- goes to this issue of curtailment. It seems to me, just as is the aluminum industry in the U.S. moved out towards the dams in the West and also polysilicant, there's an opportunity for people who are looking for cheap energy for industrial processes. If they can reform their processes to basically get some cheap energy. If they can become flexible enough in manufacturing.

MR. REICHER: Great, great question. A couple things on that. One, Texas faced this real serious problem of dumping electricity, having to curtail electricity in the emerging wind industry there. There were years not too long ago when there was close to 20 percent of the wind-generated electricity that was dumped. When he was governor, now, Energy Secretary Perry, the state put in a very aggressive program to develop over 3500 miles of transmission lines. It got built quickly. And they're down to one or two percent curtailment in Texas. So, that's number one. We know how to do it from that

prospective. Not easy to site transmission.

In California, we're increasingly seeing solar curtailment. We're generating solar a lot in the middle of the day when we, in many cases, least need it. Think about a March day when it's not all that warm, no one's running their air conditioners. Wind and solar are blowing hard. Solar doesn't blow. But whatever. So, we do face that issue.

And to your point, one of the ways to address it is in fact, through what's called demand-response instead of, you know, instead of running some piece of equipment at the end of the day when you come home, maybe you can program it to operate in the middle of the day and take advantage of that otherwise curtailed electricity and pay a lot less for it.

So, there are ways beyond storage, beyond transmission, this whole world of demand-response is very important.

MR. LIEBERTHAL: Thank you. I'm afraid our time is up. This report really, both opens up a lot of issues and clarifies a lot of issues on developments to date, but also, raises some fascinating things to follow in the future. So, please join me in thanking both Dan and Jeff for coming here today. (Applause)

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