Department of Energy – Quadrennial Technology Review
Clean Electricity Workshop
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University of Colorado, Boulder
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XXX: Good morning everybody. Good morning, thank you all for coming here to – thank you all very much for coming to join us here on a beautiful day in Boulder. Uh, we uh very much appreciate you taking the time to come here and help us, uh, as we work through this Quadrennial Technology Review for the Department of Energy. Uh, my name is XXX, I work for Undersecretary Koonin as a AAAS science and technology policy fellow um, and I am just going to go through some of the boring logistical stuff before I hand it over to XXX to do the more exciting parts. So, pardon me while I read this to you. Uh, the point of having you here is to solicit your individual opinions. Uh, participants attending this workshop are not members of a federal advisory committee, nor do we intend to use this group as a federal advisory committee. We are not seeking group decisions, or consensus views with respect to the issues before you, or as to any action the federal government should take, and we welcome your individual recommendations and advice, and are looking forward to a productive workshop. In addition, we note that participants in this workshop should bear in mind anti-trust laws and restrictions, should check with your counsel before engaging in certain activities such as collecting or discussing non-public data, evaluating public data about future prices or costs, or discussing topics whose legality you are unsure. We ask you to refrain from disclosing any proprietary company cost, supply, or price information, or any proprietary company information, lastly we want to stress that we do not intend by this workshop to encourage any specific cooperative activity among participating companies that is not clearly authorized by current law.

So, one of the commitments that we have made as part of this Quadrennial Technology Review Process is a commitment to transparency uh, and to outreach. Uh, We have a publicly-accessible website that I am sure you all have seen, energy.gov/QTR. Uh, we are releasing all ex parte communications from outside the government uh that relate to the QTR on that website. We published a request for information and a framing document in March, uh, which I am sure that you have all seen, uh, and we have now published the over sixty comments we received in response to that RFI. Uh, we're doing a whole series of focus groups and workshops, of which this is one. Uh, and we should note that uh that notes and the attendee list from this workshop will be published on the project's website, although the names will be removed from the transcript uh so people can see who was here and what was said, but not necessarily assign uh names to particular quotes. Uh, so as I mentioned, we've

done a series of workshops of which this is the fifth. Um, we did two workshops, in late April and early May on transport sector, and this is the third of the stationary sector workshops that we are doing and we will have a capstone workshop July thirteenth in Washington, D.C.

Uh, you all have picked up a copy of the agenda but I just want to run over it quickly for you. Uh, this morning we are going to focus on is cross-cutting questions. One of the great things about this group is that we have folks here who are experts in myriad different technologies uh, but the department has to be able to look across and prioritize and build a portfolio across all of your technologies, so we're trying to figure out how to do that and we were going to really push you on that this morning. So, in a moment, XXX will come up and give a little background on the QTR uh, then, a few panelists will come in and get into those questions to sort of seed the conversation uh, and then we'll open the floor to everyone to have the, a full group conversation on those, those topics. We'll take a little break, we'll go back over to the other room, where breakfast was uh, and break out into explicitly cross-cutting breakout discussions to make sure we really get to hear from everybody in the room on all of those questions. Then we'll take a break for lunch. In the afternoon, the technology team leads from the DOE will make presentations about uh, the current state and, and future pathways for the various technologies. And then we'll have breakout sessions to dive into those roadmaps and give us some feedback on uh, on that roadmapping process. Um, then we'll have short report-backs back here from both the morning and the afternoon and then open the floor again for further discussion.

Uh, there are sheets on the tables. We passed them around, that have the login name and password and instructions, but if you want to scribble these down, if you don't see those sheets, these are they. Uh, it's a little weird in that you have to, once you log in, you have to reboot your machine before you are on the network. And, with that, I will hand it over to XXX to take us through the QTR.

XXX: Okay, thank you. Good morning and welcome to this uh, fifth and final workshop uh, disciplinary-specific workshop that we've got as part of the QTR process. Uh, before we begin I'd, I'd like to extend a thanks to our local hosts here at uh CU and also to our friends and colleagues at NREL who are helping out with some of the practicalities of, of running this.

Um, let me talk a little bit, what I'd like to do is, is first talk a little bit about where this meeting fits into the QTR process, then give you some sense of how far along we've gotten in QTR, some insights from some of the other workshops that we've been running, and then try to set the stage for our discussion, um, for the rest of the morning. What, what, what we're about in the QTR uh, is to try to tell the story about the Department of Energy's technology programs, energy technology programs, give some framework rationale for them, some sense of the principles by which we form up our technology portfolio, offer some high-level views of the status, technical headroom, and roadmaps for various technologies, and get some rough sense of prioritization among the various energy technologies that we're uh, involved with. We're after a document, which then you'll see a timeline for in a moment, uh framing the energy challenges—what exactly are we trying to do, we the government, in the energy system? Is it reduce oil dependence, solve the greenhouse gas problem, um US competitiveness, there are a number of different uh dimensions here. What are the right roles of the government, industry, the laboratories, academia as we try to make some of these transformations happen? What are the principles by which the department should judge the

priority of the various things it does in energy, uh how do we do demonstration projects well, or at least better than we've been doing them, and what are the connections between technology and, and policy?

A little bit of the timeline for the uh QTR, to give you a sense again of where we're at. Uh, the exercise was uh born with a PCAST report that was issued at the end of November. A task force uh chartered by my boss the secretary of energy, and chaired by Ernie Moniz and Maxine Savits, uh really about how to make DOE more impactful in energy technologies, was the broad charge. And they issued a report that had a number of interesting recommendations in it, but um the one most relevant here was, 'government, you go off and do a quadrennial energy review analogous to the quadrennial defense review that would set out a, with a five-year horizon, a government-wide posture on energy matters, a five-year budgeting uh horizon a set of goals that the government wanted to accomplish with respect to energy. This is a wonderful idea, knowing the now-famous lack of a stated or coherent energy policy in the country, this was essentially asking for that. Um it's also a good idea because it was modeled, is modeled on the quadrennial defense review, which those of you who know the DOD will know that that is an important element in shaping DOD thinking, planning, budgeting um uh on a five-year timescale, and has been in existence for about twenty years, or so.

PCAST also said that while that quadrennial energy review we understand is a massive exercise, it's never been done before, and so you DOE go off and practice, and try to do something of a smaller scope where you would try to concentrate on DOE-specific matters in energy uh and try to create a similar process and document. Um along about January, the secretary asked me to lead that process, and some discussions with OMB, we came to focus the exercise on technologies, and perhaps the policies associated with their demonstration. We're not about policies more broadly in energy, don't want to talk about ethanol tax credits, or production tax credits. Those are important to making changes in the energy system, but frankly they are beyond the DOE's scope, and the scope of this exercise, and anything we can imagine accomplishing in the next couple of months.

We put out a framing document in mid-March, I expect all of you will have at least glanced at it uh, some maybe committed it to memory, in which we tried to set the stage for this exercise. Public comments uh came in through the um middle of April, and uh from that point until the present we're holding a series of public workshops uh on the five or six different strategies, three in transportation, and three on the stationary side of energy. And after this, or in fact even before this is taking place, we've been writing furiously, producing various forms of text that have been flying around inside the department and inside the broader government to try to make some sense and get some consensus on what we should say. Our goal is to submit a I would say quite good draft by the end of July beginning of August to OMB, that starts for those of you who haven't been in the government an extensive and elaborate intergovernmental concurrence process, eventually it will get put out for public comment uh and hopefully released by the end of the calendar year.

This is the logic flow of the exercise. If you start on the left, there are three strands that come together. If you start on the left-hand strand, it is, what is the energy context? What does the country's energy system look like, what are its needs going forward, what are some of the challenges associated with it, and we phrased it in three in the framing document: oil, competitiveness, and environmental impact. Understanding those challenges in the landscape leads you to understand that there are uh six strategies that one needs to deal with um and maybe it's good to talk about this first. So the context: billion dollar a day imports,

geopolitical baggage, oil is a commodity and so any liquid fuels that we manage to produce in other ways beyond the international oil market will perhaps help balance of payments, but are not going to help the price because you are coupled to the international uh market. Um we've come to realize that the primary goal in the transportation side is to reduce oil consumption without changing transportation services. Economic competitiveness and environmental impacts, while important, are secondary here, the main goal is to reduce oil consumption. And contrary to what some of my colleagues in the government often say, it's not to reduce foreign oil consumption, it's just to reduce oil consumption. There is no such thing, just as for you folks there's no such thing as green electrons, there are just electrons, right. Spin, but it's only… Uh and we came to realize that there are three strategies that we can and should be pursuing as a nation, and facilitating as a department to deal with the transport problem. Increase vehicle efficiency, long way to go in internal combustion engines and other vehicle properties to double fuel economy. Uh progressively electrify the vehicle fleet, go from hybrids to plug-in hybrids to uh BEVs as batteries get better, and alternative fuels which can deal with some of the environmental impacts and some of the domestic production, predominantly, I've come to learn, for the heavy-duty sector. The real problem is the diesel fuels. Okay, those are the six strategies, I've just covered three of them. The top three are the ones that are uh more relevant for this meeting, and in particular deploying clean electricity is what we've gathered you all here for. Um I think this is a particularly interesting meeting because there are as you all know even just by looking at the attendance list diverse technologies that play in this space. They rarely talk to one another, I've discovered uh and um yet the department has the job of trying to balance among all of these. It is also, and I can say this without talking out of spool, poorly organized to do that balancing. We have separate organizations, separate budget lines for nuclear, fossil, renewables, alright and that means that that kind of dialogue, cross-comparisons does not happen as often as one would like. aSo we've gathered you all together to have that kind of conversation at least in the morning. Uh I'd like the morning to be as technology-neutral as we can, we can get into technologies in the afternoon, but you will see that there are a number of a questions that we would like to put in front of you that I think everybody can contribute to. Let me see where we go next.

Okay uh you know before we do that, this may be a good time to just go around the room and in a boustrophedonic fashion just so we can see who's who. Let's start over here with Avi.

(Unintelligible introductions from a portion of the room due to lack of microphone amplification.)

XXX: Okay good, so you see we've got a good collection of people from different technologies and different kinds of organizations. Uh promises to be a good discussion, I hope. Uh so I, I talked a little bit about the energy landscape theme uh, we have uh in the last two months uh, inaugurated nineteen different technology assessment exercises about which you will hear some of the relevant ones uh, after lunch. These are meant to describe the state of the art of the technology, who are the players, what is the headroom technically, and in terms of the resource that can allow it to contribute to the problem, and what are the roadmaps, milestones, schedules that one might imagine for a research program to exploit that headroom. So to give you some sense from the transportation side, to give you an idea of the kinds of things that are coming out, internal combustion engine: significant headroom for

performance and cost in both gasoline and diesel. Dramatic increases in efficiency have mostly been used for performance rather than for fuel economy. There are effective public-private consortia, and if you improve internal combustion engines, that's good for all seasons because we're still going to need those as primary power for many of the vehicles that we're going to, to have. Lightweighting, again more to give you a flavor of the kinds of things that have been said, although of course some of the content is interesting. Uh, lightweighting has more potential impact on light-duty vehicles than on the trucks. Uh, aerodynamics has more of a potential impact on HDVs than it does on light-duty vehicles, because they have already been optimized to some extent uh, for that. There are, in terms of vehicle electrification, there's a whole path that starts with hybrids, and ends with battery electric vehicles and fuel cell electric vehicles. The electric grid can handle the plug-ins right now. Electricity and hydrogen are not fungible with oil, and so break the price coupling. There is an opportunity to build a competitive US industry while reducing oil uh consumption and emissions, and battery electronics and electronics costs are significant for the electric vehicles, but can be handled by technology development. And then finally with respect to alternative fuels, the starch-based ethanol is well established, and frankly does not need more technology development. Other feed stocks, other fuel molecules, and other processes look somewhat promising, and there is some private sector involvement in those activities.

Coal gas and coal biomass to liquids are fairly known technologies. They are capital-intensive uh and so have barriers to their deployment. CNG will find a role in fleets as uh seems economic, and of course the infrastructure for that and for hydrogen is a challenge. So with vehicles the infrastructure and the vehicles have to play together uh in a way that is just not the case for the power sector. So uh the discussions we're putting together for all of these technologies include, well pretty much what I've said already so I'm not going to go through these boxes.

Uh most of what we want to talk about for the morning uh is this center line in the logic flow which is about, what are the relative roles of the different players in trying to make energy technologies happen, the private-government balance, within the government there are probably ten different agencies that touch on energy in one way or another: DOE most obviously, but clearly EPA, transportation, ag, um et cetera, interior, uh, what are the relative roles there. If we want to make change happen, what are the potencies, the relative potencies of economics, policy, technology, and how do we get the research performers to play together. You would hope that that would lead to a set of principles that the DOE portfolio might be constructed upon like, just to throw out some, only work on things that are in the early stages of the technology development chain, or other people will say only work on things that are close to commercialization and can have an impact, so it's that kind of balance I'd like to have a discussion about. All of that then should feed into a set of priorities and a portfolio um both within a given strategy, in this case clean electricity, and then across the strategies.

So here are some of the comments, from the transportation side again to give you a flavor: CAFE standards drive vehicle efficiency, they are the most effective short- to mid-term thing the government can do, is to simply raise those CAFE standards uh and in fact we are doing that. The uh fuel standards can help uh facilitate biofuel penetration, uh tax credits and tariffs also help here. We've made some investments in biofuels and batteries with the stimulus money, there are consortia that are working, and we have particular expertise in the department in materials, in non-medical biology, and in high-performance computing that can help out in this sector.

One of the surprising things with the workshops we've run so far is how important the DOE informational role is, that we can be a credible source of information about technologies for regulators, for utilities, for people running the grid, for consumers. Uh we're also surprisingly in my mind a convener: if DOE says uh, you know 'biofuels are it', suddenly you start to see a big movement in the private sector, in the universities, in the labs – you've got to put some money behind it of course—but that convening power is really important, quite apart from whatever technology we need to do. Um, okay, so I've said that already, uh how we doing? Oh, we can spend a minute.

What we hear from people, um, you know in alternative fuels continuing support from the department to supplement extensive private capital is worthwhile, I expect we will hear that phrase again today, um but I'd like to go to the next next level now and say, well you'll see the questions in a moment that I'm after for clean electricity. Um technology assessment someone said is really important in alternative fuels, not technology invention. Um what else is worth picking out here? In vehicles, industry doesn't separate demonstration and deployment, industry thinks of the initial deployment as the demonstration whereas we in the department have a discreet demonstration phase. Other people have said we're entering a decade of experimentation with vehicles whether it's hydrogen, or biofuels or hybrids, other people have said that we're most of the way through that decade already, and it's time to figure out what to do. And when we ask in vehicles how we are going to figure out, no one has a really good answer because of this infrastructure-vehicle connection.

Uh in building and stationary efficiency, the biggest surprise for me is the lack of data. If you look at the famous sankey diagram for energy flow in the US, the inefficiencies of the residential, commercial, and industrial sectors are given as point-two-zero exactly for all three sectors right? Someone's making some numbers up. Okay, so we don't have really good data for that, a surprise. You look at building design, you go out and try to design a building, you can be off by a factor of two in energy use compared to what you predict. So the biggest thing in efficiency is data. Standards of course the department does, very important as well.

The DOE side, I'd call your attention to the lower right, our most important role for the grid is to pull different grid stakeholders together and uh try to get people to shape a uh short-term vision. And you have seen the secretary recently appoint a senior advisor with just that brief.

Some comments we've heard now getting specific to clean electricity which is the subject of today uh you know what, I could read through this but I'll just put it up for a second and you can uh see it. These are some interesting things we thought we would just pull out to prompt some thought and discussion. This distributed versus central generation I think is going to be a theme and a subject for discussion here, um, well you can see. Somebody at the end, you know a lot of these are arguing for a broader DOE portfolio and then someone at the bottom says we're not selective enough when it comes to technologies that will stand the test of market viability. So this is one of the core tensions I'd like to explore: what is the DOE supposed to be doing? Are we supposed to be doing all technologies and then somehow looking for downselect, or are these problems urgent enough that we should be picking just a few and focusing a lot of resources and attention on those. I don't know, I'd like to hear your thoughts.

Okay, to get ready for the panel, I do want to put up some of these crosscutting questions. You know you're all in the same business, you're trying to provide clean electrons, alright you all also care a lot about cost I imagine, and many of you, I don't know about all, are

looking for incentives, early technology development demonstration, whatever it is. And what I'm trying to figure out is how do I talk about all of this as a package, and how do I differentiate among all of these different possibilities because in the end, we have to tell a story about why is DOE doing this, and not that, or maybe we should be doing everything at a sub-critical level. So it's that kind of portfolio management discussion that's much on my mind, and that I'd like to have this morning. Let me just read through this.

What problem are we trying to solve with clean electricity beyond greenhouse gas emissions? Is that all it means, or are there other problems that we are trying to deal with um, uh when we talk about clean electricity? There are many different generation technologies, uh how do we balance the depth versus breadth of investment? Technological R&D versus addressing the deployment barriers—in other words, if we could take a technology and move it forward but still not get it to commercial competition, is that worth it, or should we be concentrating on things that we can really see that will drive to commercial competitiveness, right? You're in a commodity business, so you've gotta be competitive, or you're just not going to see deployment. Um, different time scales for impact: I will say the word "fusion" probably just once today, and simply say it to note its absence in this discussion, that's probably forty to fifty years off putting power into the grid, and so we have ruled that one out of bounds for this exercise. If somebody thinks differently, I'd be happy to have that discussion. Uh so what are the time scales?

Widgets versus systems. One of the ongoing comments that we've heard is the DOE does a great job at widgets, but we don't do a very good job at understanding, or helping to modulate the system in which out technologies get deployed. Uh distributed versus central, as we talked about. So another question, how do we take regional variability of resources into account as we build the DOE portfolio? What about water requirements? That seems to be a big deal for some of the technologies. We don't do water in the DOE, somebody should probably be doing that, whether it's us or somebody in interior. Should technologies exit from the DOE program? When do we declare victory? After all, we have a limited federal resource, these days about four billion dollars for all of energy technologies. When do we say 'alright, we've done it', we've done a great job of bringing down the cost, facilitating deployment, and move onto something else. How does our posture change as the technology gets more mature, and what metrics should we use to measure progress, cost of electricity, greenhouse gas emissions, et cetera, et cetera, you can think of others, dispatchability, cap-ex verus op-ex, et cetera.

Some specific questions: what do you think will happen to the clean electricity scene if natural gas prices drop, or just remain at the current low level of what, four dollars, something like that, as many people in the oil gas business think is likely. Conversely, what happens if they skyrocket, and go back to the historical eight or nine dollars? How does that change both the clean electricity scene, and what the DOE should be doing uh in that business. Um what can we learn from deployments abroad? US is deploying about twenty gigawatts a year of electricity capacity uh that's probably one quarter or so of what China's doing, and you take the rest of the, the rest of the world is building its capacity after all, we are in replacement and very modest growth mode. So obviously deployment is going to happen abroad at a much greater scale than what we can do, how do we learn from that, and what can we learn? What's the relative value of innovation for technology development versus other policies that support deployment? In other words, if you've got a hundred million dollars, you put it into moving

the technologies ahead, or do you put it into facilitating the deployment, and what is the relative value of that, and how do we decide when to do one versus the other.

Um an interesting thought, it would be useful to get your um feedback on: should there be, the department as a number of advisory committees, formal advisory committees, there's one for nuclear energy, there's another one for fossil, should we have a clean electricity advisory committee instead where we bring all of those folks together to get a better dialogue and balance across the portfolio? Would that be useful and interesting? And then finally, as we look for big demos, what are the criteria when you say 'yea it's okay to do a demo, this is the right time', or 'no, it's too early' or 'we don't need it because industry is close enough on its own'. So those are the kind of questions that I would like to get into, both with the panel uh and uh in a little while with the broader audience discussion. So with that point I would just ask the panel to come up and just take uh uh a microphone and seat up here and then we can uh get started. We're going to have a discussion here, so I think that any order is just fine.

So why don't we uh really briefly uh just introduce yourselves and a word about your background and then we'll get into some substantive discussion of these issues. Do you want to start down at the end here?

XXX: Sure, I'm XXX, I've been with Schlumberger for thirty years, but the last six years I've been working in a division of Schlumberger around carbon capture and storage, more specifically storage, and we're hoping that one day there will be an industry around the act of taking carbon dioxide from our plants, et cetera, capturing it, compressing it, and putting into the earth for greenhouse gas mitigation.

XXX: I'm XXX, I'm with Vestas Technology, I'm a technology director in Vestas. I started my career in wind, so I have a long-term perspective on the evolution of the industry and how the machines grew, and what made it successful, and maybe where some of the hurdles are.

XXX: I'm XXX, I'm a professor and I chair the department of nuclear engineering at the University of California Berkeley. For those who are familiar, there is an energy and resources group at UC Berkeley as well, I'm actually, I minored in my PhD in that group, and I chaired it for a couple of years as well. I'm active in topics that relate to nuclear energy and among other activities, currently I sit on a blue ribbon commission for America's nuclear future, which DOE has formed to provide advice about pathways forward on how to manage spent fuel and high-level waste.

XXX: I'm XXX, I'm the chief technical officer of Ascent Solar, one of the founding members. Uh I started working on thin-film PV technology back in 1990 with the help of NREL, and have been developing different technologies. We now manufacture a flexible thin-film CIGS technology that allows us to put it directly into building facades, laminate rooftops and such. And looking primarily at distributed power technologies.

XXX: Let me start maybe with one provocative question. Uh we've got a tremendous amount of technologies represented in the room, and that the DOE supports, uh the fasaw answer is we need them all, right? But in fact uh some are better than others, and in any event federal funds are not going to be plentiful, at least uh for the next few years. We have seen what the House did in the FY12 markup EERE, FE, NE, at best it's going to be flat. Do we need them all? And if not, how do we start to make decisions among these various technologies, or just let the market decide? What's the DOE's role and posture? And I'll just open it up.

XXX: Well um, in um, I guess when we look at the technologies in thin film photovaltaics um there are some technologies that have certainly reached a certain level of maturity and are further down the road, some technologies that have a great promise but certainly have not had the investment. But I was really happy to see, during the discussion on the whole idea of crosscutting technology because if you look at two of the um predominant PV technologies, I mean crystalline uh silicon and say amorphous silicon, both of which have benefitted significantly from say a parallel technology path approach. Crystalline technology of course being the whole foundry semiconductor industry, and amorphous being flat panel display, both of which have been very useful in getting those technologies to the forefront. And there's a number of technologies in terms of patterning and such that have been able to really push the technology envelope with uh say crystalline technology when everybody thought it was just staid and pretty much reached the end of its uh approach. Amorphous silicon, looking at establishment of um high-temperature, uh higher-temperature processes for— so I mean I think that if you can't fund them all, I think what you need to do is use the money wisely, and find out where there's synergy not just within the energy sector, but elsewhere.

XXX: Semiconductors.

XXX: Semiconductors, coating technologies in general, if it's thin film—

XXX: So base technologies, yeah.

XXX: I'd like to add, I'd like to make a plug for the notion of scalability being a factor so, with respect to the technologies we're involved in from an industry perspective, we wouldn't be involved unless it would hugely scale. So I think there should certainly be some consideration on that.

XXX: Maybe it's time to talk to the guy who knows about the bigger-scale technology.

XXX: So on the nuclear side we have experience at scale and of course there are significant benefits to having a substantive fraction of your electricity generation being base load. The current plants are running with less than a two percent forced outage rate, and so the refueling outages can be scheduled to uh mitigate against seasonal variability and that makes for a very desirable type of electricity generation particularly if you couple it to things like charging cars overnight and things of that nature. So we know that nuclear has tremendous potential, the main question is how to, how to leverage that particularly in light of the accident in Fukishima and the need to ensure that this technology remains sufficiently safe. And in general I would point towards what I think is a major success story from the 1990s, which would be the advanced light water reactor technology program and the DOE 2010 program the, the, those programs actually have resulted in the development of passive advanced, large advanced light water reactor technologies that are for example now being deployed in China. They're particularly attractive because they require no electricity for decay heat removal and in the long term that's, we now know that is a desirable quality. The commercial success there in China has been unambiguous, but they have a different capacity to deploy these technologies. It's actually these technologies are in the front for construction in the United States, but I think DOE is looking at can we scale down these reactor sizes in a way that would make them easier to finance and more deployable.

XXX: That's a unit scale opposed to a system-wide impact scale. So, you know we set out I think it was in the framing document, a proposed criterion that unless you think you can get to one quad a year by when? By 2030, so 20 years from now, we probably shouldn't be pushing it too hard. One quad a year for electricity, electricity is about 30, 35 quads primary

energy, so one quad is about 3 percent of electricity. Wind is getting there, do you want to say a word about the scaling of wind?

XXX: I agree with you that scalability is a really important question, and I think that in terms of the role that the department has and different aspects, I think it's important to map out the timescale of what the role is, and I think the role is there all along, but it will change as time goes on. And possibly it is really important to make that plan ahead of time so you can change from the early stages of the industry, to then it starts ramping, and then it becomes more mature. I was looking at the natural gas industry as it's booming right now and looking at what drives the market. I think the market will always choose, but there's a lot of serious players a lot of big players in the gas industry as well as in the wind industry, then there's a lot of entrepreneurial players. And I was quite stunned at the similarities of the problems posed at the industry, and the development of the industry, and the focus of government and the regional interest, because it's quite often driven by very very regional interest, and that kind of becomes the driving force. And I don't think that that is necessarily a healthy process all along if you want to make things come together because it becomes a regional interest, which is important but maybe not for the bigger picture because that—

XXX: So that's interesting, so there are other people that say there is great diversity, no wind in the southeast, lots of sun in the southwest, wind in the Midwest, hydro in the Northwest, that we should take advantage of that diversity.

XXX: I think that there is diversity to be taken advantage of, and then figure out the role of mapping true as the industry grows, and figure out, okay how much more initial development are we going to do in this market? Is it really necessary, the industry has moved on, maybe the needs of the industry is different now. And I think that mapping is really, really important on top of multiple technologies.

XXX: So, we're not doing much in on-shore wind. We the DOE.

XXX: That's right, and I think the role there is maybe evolving, but the step hasn't quite been taken yet. And I think those things need to be mapped out pretty carefully for each technology, then address the crosscutting part.

XXX: Joe, you looked like you were going to say something. No? More on this, or I can uh put another one out in front of you. Let me get my list. So what do you think happens if gas prices stay low in this business? Most of these don't look very economic, or at least less economic.

XXX: A comment on that, but not with respect to the fuel mix but with respect to an environmental issue: since I work on carbon capture and storage, we're often associated with the very intense emissions fuel types, such as coal, and I think that if gas prices stay low, there may be a misperception that gas is clean electricity. It's cleaner, but if gas electricity deployment grows and grows and grows, at the rate it could with these low prices, then we have to think about greenhouse gases, and the greenhouse problem on gas, and carbon capture and storage on gas.

XXX: Nuclear you know needs seven dollar gas, at least for big nuclear to be economic.

XXX: That is correct. I think that one of the issues that we face is that with the deregulation we have in markets, it's much more difficult for us to provide stable electricity prices going forward because the heart of the question actually is that we don't know whether it's going to be seven dollars or four dollars going forward. Our predictive power has never been good, and under regulated markets you have the capacity to provide price stability for residential consumers. Unfortunately, in the deregulated markets, what we're seeing is that

they're the people that bear the brunt of the volatility of the effects, because industry will go forward and do long-term contracts. So if you are interested in providing some price stability, I think that it's important for us to recognize that we don't know what's going to happen with natural gas prices going forward, and we don't want to become overly reliant on the technology because it's treated us badly in the past.

XXX: And could get worse if we become couple to world gas markets through exports.

XXX: Indeed, and that couples us actually closer to oil also in terms of the—in fact in some sense natural gas and oil are becoming more fungible as you couple them together in terms of natural gas being a major input to oil production, given the fact that we are using oil sources that are increasingly poor, the tar sands and such.

XXX: Um, there are lots of people in the room, and I expect we will have more people queued up comments, but maybe before I turn to the audience at large, I'd ask any one of you for further comments on any of these matters before we go public, so to speak. We're good?

XXX: I think maybe I'd just make one note related to nuclear, which is an important point, and it does relate to the question what can DOE do, and what other ingredients are important. And I'd just like to emphasize that the nuclear regulatory commission also plays a extraordinarily important role within nuclear technology. And I think that if one goes back and takes a look at some of the lessons one can learn from the advanced light water reactor program, and from DOE 2010, particularly with respect to the fact that the US now clearly is the leader in terms of passive safety technology for reactors, and the capacity to license those and ask why we have been successful there, whereas with other key technologies such as steel-concrete composite construction we've not been, we've had a much greater set of challenges in trying to license these new methods for building plants that could make the construction much faster and less expensive. I think it's important to be thinking about that, even though that here this program is limited to what DOE's role can be, one in the in has to also think about the major players for each of these technologies.

XXX: I'd like to talk a little bit more about scalability because what it means as in any other sector is reliability is king. And so as the industry gets into the ramping piece, and I would claim that that's where we are in the wind industry now, and the reliability can be broken down into some technology pieces that would enable a supply chain that allows the industry to grow, test standards, and then there is an educational piece, the development of the future workforce, the high-end piece of the workforce. There's a lot of focus I find in the US on the basic education, but I find that there is too little focus on bringing the future research that is needed to enable industry to continue to grow. I found that there is too little focus on that. And then the environment, the environmental impact—to get that across, and to also consider our raw material uses in the industries, and I think that's almost true for almost any of the new industries coming in, because they are a different beast than the centralized kind of uh, um energy producers, so they get more in focus because they enter in multiple places. They are a lot more noisy, so to speak in the public sense, and also requires different mechanisms to nuture the—

XXX: And I there are other agencies that enter, the Bureau of the Interior for example, and the BLM which are roughly analogous to NRC in kind of being a separate agency that gets to weigh in on these things.

XXX: Environmental impact, I mean the office of electricity, I mean it's across the board and gets, and it can be quite cumbersome work sometimes to maneuver through.

XXX: Right. Joe.

XXX: Just a quick comment with regard to your demonstration project question at the bottom there: Certainly with carbon capture and storage, with that, the only way to get out of the lab and into the field is through programs such as those that have been set up by the Department of Energy. So just a plug for the program, because of the costs and the complexity of doing these large field projects, which are happening as we speak, because of that complexity and the amount of funding required um it just wouldn't go on, we wouldn't be involved.

XXX: So if the government wants to see that technology move, it's got to pony up.

XXX: Could I just do a really quick follow on what Carsten said. I think the fact that these other government entities play such an enormously important role does speak to the importance of learning to do this internally with DOE, within DOE. It's really important to think about structuring this such that it could become a government-wide activity because that's clearly what's needed.

XXX: We have been out and about with bi-lateral visits with other departments, and then focus groups with fifteen people around the table, and I gotta tell you the appetite for this conversation is enormous. The government is not as lashed up as you would think it would be, or maybe it is as lashed up, I don't know, yes.

XXX: Along the lines of um, in terms of what to do, the question was what should the DOE portfolio look like as the prices change, and I guess it goes back to vision. The biggest concern I have, and you only have to look at the stock prices of renewable companies, and trust me, I know. Every time the price of drops down, it's like there is a direct tie between stock prices going down when the oil prices go down, and it's the mentality that people perceive a link there. And the reality is that the DOE's vision of saying these are the things we're going to need, we're going to ride the wave of whatever the prices are for the given technologies, but these things can't happen overnight. We talked a little bit about scalability, you have to get to a certain level before you get to that level of scalability, and if you wait until the next time the prices go up to adjust that, and to attack that particular thing, you're already behind the eight ball. And just about the time you are getting to a point where you can really take off with it, the prices drop again and everybody says why are we doing this? And so it goes back to the long-range vision.

XXX: And I would say that that kind of variability is not just there in the media and the public, it's also there with the people there at the end of the mall. And congress again, I think an important part is education, understanding oil and electricity are not coupled, you need the long-term for deployment and R and D and so on. I think that's a very important part of what this exercise needs to get across to people. Good. So I'm going to open it up, but uh I'm going to start with Bob.

XXX: I'd like to play off the comment that you made near the beginning, Steve. Oh, I'm XXX of University of Chicago. You talked about the fact that in the industrial sector the difference between a demonstration and deployment are a bit murky. Now this relates directly to the point that the Department of Energy, and the government in general is one of the largest customers of energy and in fact DOD and DOE are in fact probably the two largest consumers of energy. So to what extent does the department consider itself, and I'm awful curious about the panelists, what they think about the role of the department and the government in actually fostering technologies into the market by basically funding early deployment.

XXX: So let me give the departmental perspective first and then I'll open it up. As always, numbers help first so I'll start with that. US Government, two percent of total energy

use in the country, ninety percent of that two percent is department of defense, and I think about half of that is tactical, and the rest is bases and so on. Another set of numbers, interesting, total oil consumption I think about 350,000 barrels a day for DOD which is like two large platforms in the gulf, as you know. The government also purchases about 60,000 vehicles a year, which is about half the output of one standard-size vehicle factory. So what I would say is yeah the government is the largest energy consumer, but it's not very big. What we can do though is try to use government assets to try to demonstrate. I don't think there's as much demand pull there as people would like to think, my own opinion because of the numbers I told you. But as a demonstration, as a kind of friendly customer whether it's for small modular reactors, or big PV arrays or biofuels, it can help practically demonstrate the technologies. That's my take, let's open it up to the panel here.

XXX: I'd start with the importance of trying to dig into the question well what are the first mover barriers for the different technologies, because that's where you really need to get into the question of how should the government intervene, particularly when it comes to subsidies such as cost share of demonstrations and such. And for nuclear, I think by far the largest first mover barrier is the fact that you cannot patent an NRC regulatory decision. When it comes to things that are patentable, in fact you see commercial willingness to invest and do the development. But when you get to the question of in fact how many operators do you need if you have a multi-module SMR plant is extremely important is extremely important to economics. And in fact the first vendor that works through that question is going to take on enormous risk and it's going to face significant challenges in getting that question resolved and of course everyone else is can free-ride on that subsequently because you just can't patent that type of decision. So think this is the principal place where you need to have some federal intervention through investment in the NRC, it's investment in the eighties in thermohydraulic research that has led to passive safety systems today, as well as DOE programs to support research, but also to essentially frankly subsidize through cost-sharing early site licenses, design certification, those elements that involve clear first mover barriers.

XXX: We've taken advantage of a number of programs over the years from the Department of Energy, everything from the device level, the next generation type of technology, all the way to manufacturing technology, understanding specifically different types of technology to help you scale up, to help you get into full-scale production, and there has to be that, you know there has to be a role where the DOE balances some of the fundamental things that quite frankly a company that is in the developmental stages such as we are can't really invest in without some help. On the production side, certainly it's a partnership between ourselves and the Department of Energy to demonstrate say a particular kind of control mechanism or something else that can benefit not just us but other people in the industry, and in other industries. One of the biggest challenges I think in now the plethora of phovas that have come out, getting to this widgets versus systems approach is that there has to be something there that looks at both that these are great technologies, and in our case with PV you get modules, but the balance of systems with hardware as well as the soft side is very critical. And as a matter of fact the phovas are looking specifically at how do we deal with well, dealing with all certifications, and getting the all of the regulatory things out of the way, very similar although maybe not to the extent of the nuclear industry. You know, certainly the difficulty, and if you break it down if you ever want to see how scary it gets, you get to the SAM model and look at your PV system on a rooftop, and you find out how much goes into getting all your regulatory things taken care of and it's—

XXX: I'm going to go to the audience and then we can come back. Carol is next, and then Mike after that. Walk around the room.

XXX: XXX of the Cassini Mission. I think this question is for XXX. The Chinese have publicly announced that they are going to persue, as I guess a major thrust in their energy policy molten salt reactors based on the thorium fuel cell, uh fuel cycle, and you're smiling so. I want to know, this sounds like a really good approach to me as it gets around issues like proliferation possibilities, and waste removal and so on. And I just want to know what the stance is on the US side of the US nuclear industry, or maybe on the department of DOE, I mean, either one.

XXX: Okay well.

XXX: I really wanted to try to keep this technology generic but—

XXX: I'll answer in just two sentences. I have two hats that I can wear, one is sort of the mainstream advisor to a panel like this and there one really doesn't want to get into espousing longer-term technology directions because it is controversial. If I put on my other hat as to what technologies I'm really enthused about, I have to say I think that is very interesting and it merits the effort that the Chinese are going to be putting into.

XXX: I don't know if I should put my any colleagues on the spot, and ask for their opinion or not, but that may be worth a private conversation. Matt, you wanted to say something.

Audience member: (Unintelligible question)

XXX: Let's take that one up either offline or this afternoon or something. XXX

XXX: Department of Energy's research establishment has really sort of led the way in an enormous number of tools that are sort of driving science, big computing, facilities, a lot of very advanced technology. The question is is that whole set of tools being moved upstream with these technologies, because development needs these technologies as much as discovery science, so how can DOE do a better job of getting those into the hands of these technology communities?

XXX: So uh just to clarify you are talking about the basic science facilities like sychotron sources, neutron sources, but also the more applied things like wind testbeds, all of the above, right? I don't want to answer. In part because I don't want to dominate the discussion.

XXX: I think it's a good question but I don't know what the answer is. I think it's a really good question, and one thinking about.

XXX: So is there value in the department making more accessible the kind of user facilities, I mean testbeds—

XXX: Oh absolutely, we've found that in our research set-up here for the US, and we've found multiple elements. But I don't know how to do systematically or suggest in it a systematical sense, but it's a good question.

XXX: I'd point towards the advanced test reactor national scientific user facility at Idaho National Lab as an outstanding model on the nuclear side for how using that framework to fund activities can make the facility far more productive in terms of the quality of work that occurs. So I strongly endorse the idea of developing national scientific user facilities as the mechanism for best utilizing DOE assets. I assume that that generalizes the to the non-nuclear side.

XXX: XXX we have—

XXX: I would just say that we are collaborating with the labs and universities around high-performance computing applications to the subsurface, which is critical. So I'd say it's happening, it's ongoing, and it's important.

XXX: We also have high-performance aspirations for the above-surface pieces of CCS also that we're trying to—

XXX: To get back briefly to the question of scalability. You noted something that could get up to one quad by 2030, I think was sort of the target—

XXX: We just wanted to put down a number.

XXX: And without knowing how finely you're differentiating technologies and what not, it's hard to know exactly what that means. But I would like to suggest that there is a fair amount of optimism around technologies at early stages and uh it may be beneficial to look for a higher bar there, a larger target as a gating process at some point. One percent isn't a whole lot, if you're talking about nuclear in general, if you're talking about on-shore wind in general. If you get into finer differentiation, maybe it becomes more. But when I hear you say one quad, what I think immediately is that we need to set that at a higher level to make sure that we are prioritizing appropriately.

XXX: You know if you want to have impact, you need to have impact at the twenty quad level or something. And if the country really decided that greenhouse gas emissions are an important, urgent problem, that we let the programs really start to match the some of the political discussion, I think the program might look different, the DOE program, than what it looks like now. Yeah.

XXX: Not to pick on XXX, but this is really about what defines pre-competitive R and D. We know at Exxon Mobil, we are a strong believer in participating in pre-competitive R and D, but we also know that the time cycle of pre-competitive R and D unfortunately extends beyond a lot of political cycles. So back to the development of the advanced reactors, in retrospect it would seem that the reactor companies would have seen that as imperative to their survival, post-Three Mile Island, post-Chernobyl, so why didn't they pick up that type of research, why did DOE need to get involved at all um considering that seems like something that would be beneficial to their survival.

XXX: Well I think that for the reactor vendors again it comes back to the fact that you have these very large first mover barriers that are associated with the risks of getting favorable regulatory decisions and the problem is that all of your competitors can free-ride behind you. And so you see a bit of a peloton effect if you've watched bicycle racing, and about the only way you can move forward in a technology is to try to go as a pack because you have to draft each other, you can't protect a lot of the IP that's associated with reactor technology, the timescales are long enough that patent protection is gone on a lot of elements of it, and you have this issue of free-riders. So, I think that it's a technology where you have to have substantive government role if you're going to see it move forward and be developed, or you will just not get investment.

XXX: So I want to maybe sharpen the question and generalize it beyond the nuclear. One of the discussions that goes on in the government about DOE research in oil and gas extraction is that, and having sat in the industry for many years I have some sympathy for it, those guys have got plenty of cash. And if they think it's worth developing a technology, they will do that. CCS of course is different because there's no market right now, but for things where you can see a clear economic benefit, you just do it, and in fact you don't want the government funding because of all the strings. So you know, I'll pick on wind but we can

pick on others also. Wind we put in, what six gigawatts last year at three dollars a watt, two and a half dollars a watt, that's a six billion dollar industry in the US, internationally even bigger, shouldn't you be able to stand on your own? And I can do the same kind of numbers for solar, we can do it for nuclear, where does, what is the government role here when there is already cash flowing in these industries?

XXX: That's absolutely correct, I think the like I said, it's back to the change of the role, and you get into the ramp-up phase. The needs and the partnership also needs to change and I think that's moves back to my list. In the scaling phase I think they need changes and the technology piece also that piece change. Because you're coming out of the demonstration or the deployment phase where you may have had some demonstration elements, there have been public-private partnerships around the demonstration. Wind sites have been instrumentive, for example at NREL and so on, but the next phase simply becomes more focused on enabling thhe supply chain, because the next phase is you want the manufacturing to take place in the region, and you want to enable your supply chain to be innovative and supply that. So it becomes a more component-level piece. And there is a like a said some elements, environment, education—

XXX: The regulatory scene—

XXX: The more regulatory, and still the moni—I don't like the word monitoring, but you neeed to keep a handle from the government perspective on the industry and maintain some competencies on a very very very high level that can monitor and still make sure that the industries are moving forward, and take it into a portfolio because it's a new baby in the portfolio.

XXX: I would point out that the elephant in the room is of course that while many people, most people believe that there is a problem with carbon in the emissions, if you don't have a price on carbon, then you will have a distorted market. And what we've found is that it's much more popular to try to manipulate the market with subsidies and technology mandates because both of those will generate concentrated support from stakeholders that will drive through the political system whereas the most efficient things with markets that benefit everybody the most probably are the toughest too do. So instead we don't have a price on carbon, instead we are trying to manipulate the market through these other tools and that's the way it is.

XXX: This field, clean electricity, has much more technology partisanship than the others we've seen. Yeah.

XXX: XXX from Princeton. I would like to make comments on two of the crosscutting issues. One is the widgets versus systems approach and I think the DOE really has to put much more emphasis on systems approach. I read through the document you know the scoping document and the various assessment pieces we were asked to read for this and it was really all widget-oriented. And uh let me give a couple of examples here, in the wind area I think there is no need to talk about storage until you get to penetrations of fifteen, twenty percent on the grid, and the industry is not really interested in thinking beyond the twenty percent because that's the long-term for them. But I think the government really should take a longer-term view and the interesting numbers that came out of the wind assessment is that there's enough wind, high quality wind in the United States you know to meet total electricity needs for the long-distance future, but you have two different problems with the good wind resources in that they are, first of all the wind is intermittent, and second the good wind resources are remote from electricity markets. And so you really have to think about storage

if you're going to look over the longer term, and there's really nothing in the DOE portfolio relating to wind in this area that takes that seriously. And if you're going to look at storage, there are really only two options that can convert this into baseload or load-following applications and they are either pumped storage, pumped hydro or compressed air energy storage. I served on the 1997 PCAST energy R and D panel and one of the things that we did is we reviewed the storage portfolio of the DOE and there's nothing going on in the area of compressed air energy storage. And the reason that was given to us is that there's no advanced technology there. However, if you look at, consider wind in the context of, or if you consider compressed air energy storage in the context of coupling to wind you're not going to do very much with salt dome storage, because the salt dome storage geologies are not well-correlated with the good wind resources. Okay—

XXX: I know a couple of you folks want to respond to that.

XXX: Okay so that's one example, and I'm very, and there are others that I could get into but in lieu of the time I won't do that. And I'm very sympathetic with one of the comments that you showed on the original document of the reviewer that suggested that DOE should spend less time on invention and more time on assessment. And I would agree with that but I'd say that the assessment should be systems oriented rather than widget oriented. And the other point I want to make is how do we do commercial-scale demonstration projects? And you I think were hinting that we don't do that very well, and I think that that's an understatement that we don't do it very well at the present time. I think we probably need some new institutional framework for doing these things. I work in the CCS area and I tell you that the long, strung out ordeal we went through on future gen , you know seven years before we finally, it was a national embarrassment that it, and there are all kinds of reasons why it was an embarrassment. But one of the things is that these commercial-scale demonstration projects that require investments of hundreds of millions of dollars, or billions of dollars really should be carried out in much more of a business-like environment than I think the DOE is capable of, and one of the criticisms that has been given of the future gen program is it was, the reason it was strung out so much was that it was loaded down with all kinds of bells and whistles of slipstreamed research projects, and that really is not a good feature of a demonstration project.

XXX: I'd like to comment on the storage piece in general because I think as we go to distributed generation for most of the renewables in one way or another, there are several mechanisms that you have to have in place, and it's a market obviously and the market goes to mobility and transmission, so storage piece is nice, but it doesn't necessarily go with the generation, per se. I don't know what the economic model is for putting it together because the market is not there, but what I can say is that there's also a forecasting piece and not just for wind but for solar and any other. That is important, and then the last piece is co-generation. If the technologies for this can play together and you have a market and the mobility in the market that allows for that then you have a system. So I don't think the question is storage or renewables, renewables and storage, or whatever it is, I think it's to figure out the right mechanisms. And I think we are missing opportunities, we might be missing opportunities if we focus uniquely on the technology in that aspect. It has to be a holistic solution. We have done a number, taken a number of looks at this and every time it ends up where the storage piece is not needed, we can just build more wind turbines and put them a little bit apart. So because of the financial model doesn't allow us to do it, it doesn't allow us to sell it in any formal format, so that is not there.

XXX: So it's not only the physical system, but the business system—

XXX: The business is not there and there's no piece that connects it.

XXX: Yeah.

XXX: XXX with EPRI. First of all, I just want to applaud the department in looking at the road map going forward at this time. It's something that we're doing in the private side as a consortium non-profit group with the electric utilities. One thing I'll say right at the outset is that I notice among the membership that you've only got two utility members in the room. And as you move forward on this, it might be useful to bring that community in, and I'd be happy to help you with that--

XXX: Good, not to make an excuse, you're right, but when we did the grid story, I think we had more of those--

XXX: Quite a few there, yeah. I think one of the things that you'll need in order to substantiate a long-term and durable plan for R and D is something that resonates both sides of the aisle, all regions of the country, all technologies, and this notion of clean, affordable, and reliable electricity with innovation at the core of it is something to maybe grab your arms around. It's backed up by your analysis at EIA, our analysis at EPRI, all the folks doing macroeconomic analyses trying to reduce carbon, but do so in a cost-minimized way. They all show this full portfolio of technologies where largely you have renewables and efficiency in the near-term, and you have nuclear and CCS and other technologies sort of in the longer-term. One of the questions that that implies is how do you sustain R and D momentum for things that you might not use today, but you might need going forward. One of the things that I think you can do that is showing by the modeling, the analysis, the great work that the NREL group has done, that you need different parts of that full portfolio at different times and in different parts of the country. So you've got wind in the Midwest, you got solar out West, but you've got the need for nuclear and coal in other parts of the country. So I think this geographic and technologic diversity has to be one of the key arguments. And I think one of the ways that, my last point, one of the ways to buttress that is to show for all of the different technologies, using something maybe like the TRL scaling, here's what's expected of the government, here's what's expected of the private sector, here's what the universities are doing, here's what the financial institutions are doing, for all of the different actors in the space at each TRL stage, sort of what's the role? And as technologies move through that life cycle, it becomes pretty clear that all of us, we know how to place those scarce resources, because we're not going to have the monies that we've gotten used to. And all of us, both public and private are going to be pressured to be efficient, and I think having that TRL or some similar lifecycle is one of the best things that you can do.

XXX: Okay good, thank you. In the back, yup, all the—

XXX: I'm XXX from Harvard. In the weeks leading up to this workshop, I've been thinking really hard about the DOE as an organization and especially as an organization that doesn't have many dollars relative to the size of the problem.

XXX: A little bit closer to the mic.

XXX: Sure, so the DOE is not a rich organization relative to the size of the energy problem it faces. So I was thinking about what it's other assets are, and two that struck me are privileged access to government and regulators, and the appearance and the actuality of impartiality. And so speaking now to our panel of industry representatives if you like, are there ways that the DOE could use these particular assets to get you through regulatory pain

points to do things like defeat not in my backyard that would be more valuable than a DOE dollar in your pocket?

XXX: CCS is a good place to start on that question.

XXX: Yeah um well certainly with respect to carbon capture and storage, and specifically the storage piece, the storage piece is the absolute critical component and regulatory, so to the extent that the DOE can help with those I think that yes it's very important, but at the end of the day without the dollars it's um, I think we would just delay and delay and delay and just never get there, but I would agree with you that we could use public acceptance and regulatory help.

XXX: We can just go right down there.

XXX: I agree with the statement and it is taking place. One of the current topics in wind is the radar interference with the radar systems of various kinds, and there are activities going around that. And in terms of the public acceptance, absolutely. I did a review in the UK, of the UK research programs recently, basic research, but the research groups that articulated their research the best way are the ones that put the social, economic and environmental impacts at the center of how to articulate what the technology research was. I absolutely agree that they had a much better story to tell than anybody else.

XXX: This coupling with the social aspects is something again that at least from the comments that we've heard in previous workshops is something that the DOE is particularly bad at. We've been trying to build some bridges to the social side.

XXX: To elaborate a little, specifically like on wind, you know there's a lot, and natural gas I've learned as well, you have a lot of local, regional work to do in many many different sides of this aspect. It's super important for the wind industry and industries that are disperse. So we have a lot of grassroots work we do every day in that aspect. But the top-down is maybe not quite there.

XXX: There are social issues with nuclear as well.

XXX: I think that there's a lot to this point. I don't think that it's the money that's important with respect to the commercialization of nuclear technology than it is the various things that DOE does in terms of organizing a coordinated effort. I'd like to point to the 2010 program as an example—

XXX: So you've mentioned that several times. You might explain, do not assume that everybody knows—

XXX: So the DOE 2010 program created a consortia of about seventeen different utilities that collectively decided to co-fund and cost-share the development of three early site licenses and work through all of the site-specific issues associated with deploying reactors. It turns out that the first ones that are going to be built will not be built at the original sites, but it was going through the process. And in the case of the utilities, it is much easier to get them to act as a peloton in the bicycle racing analogy where everybody has to move forward collectively because no single entity can afford to try to push against the wind although you can usually easily spot who's positioning themselves to break forward, and they're the ones dedicating more resources, and have better capability. And this capacity to create these coaltions works really well on the utilities side when it comes to nuclear. And frankly what needs to be done and I think OMB is standing in the way of it is to create a similar peloton around processed applications for SMRs, or cogeneration applications for SMRs, collocated with heat load, and if you could do that, you would have a customer base for those technologies where you are

trying to generate, you actually have now created a peloton of companies that are moving forward seriously on SMRs, and are putting their own money into it, too.

XXX: There are a few challenges I think that DOE can help with. You know certainly everything from, in our case, you're talking about the actual PV installations. You do have again the regulatory issues that can certainly be helped along, but the general challenge that we have is that these are both local as well as federal types of regulatory issues. Whether DOE can be as effective dealing with one instead of the other, I don't know. Certainly the other challenge is certainly anyone who has ever had to evaluate building a plant, and um the certainly a four-letter word is NEPA in trying to deal with all the paper work and all the paperwork associated with it. You know certainly the going forward any type of help along those lines, trying to make sure that we maintain the controls and maintain the understanding of what we're trying to protect, but to keep in mind that especially for development stage types of companies, it's very difficult to go through that paperwork.

XXX: XXX with NREL. I'd like to explore the different systems for just a moment, we haven't talked a lot about systems. All of the utilities today have invested in portfolios of production, so they've made decisions not exclusive on low cost, they have other issues, reliability, availability, that they've made as their basis for decision-making. We've been doing some very interesting analysis at the laboratory around the integration of renewables with the traditional baseload technologies, which would indicate with the new combined-cycle technology systems, small modular reactor systems, new coal systems, that it could actually be a role reversal that could be occurring here where you would generate the wind and solar electricity when the resource is there, and you would begin to fill the gaps with the more traditional technologies because they can become more load-following in the new design systems. So there's a whole new paradigm in a sense that would show up here, and that's a systems analysis in a sense where you have to see the systems working together in unison. So we haven't talked much about that. I would like to ask the panel a little bit about their view of systems, each as an individual technology promoter, but how do they link together?

XXX: Sounds good, anyone want to take the bait?

XXX: I say just absolutely yes can integrate more cogen in so that you have heat load that you can also deliver or not deliver, but this question of integration is key to making the system work.

XXX: Again specifically vexing for DOE particularly since we are not organized like that. The budget lines make it hard for us to do that. Let me bring a new voice in down in the back there.

XXX: Hi, XXX, Wind Logics. I certainly agree with both the systems view, and the review of DOE and the one thing that I think is critical for all of us in the room is the transmission infrastructure. And if DOE is not going to take a national view of building up the transmission system so that we can deliver competitive, cost-effective electricity to the citizen, then I don't know who is. And I know it's a political minefield, but—

XXX: So we have maybe um unfortunately separated the grid from the generation in this exercise, but let me assure you that we had two days in phoenix a week ago on the grid issue, generally.

XXX: I think it benefits all the technology in the room here that we can have more of a national view here and not such a state-by-state and regional view in terms of the benefit to the average citizen.

XXX: Okay good, XXX.

XXX: I just want to remind everybody here that by definition, a national transmission view is the responsibility of those entities who deal with transmission and sale of energy across state boundaries. So as part of our deal, we are focusing on the things that the DOE can control.

XXX: And what is the DOE office of electricity doing? Is that part of their role as well?

XXX: Anyone want to speak up for OE who has a total of a hundred some odd million dollars? We're working storage, grid phasers, grid modeling, right. Not a tremendous amount of effort. Bob, real fast since, yeah.

XXX: This is a quick follow-up to my Harvard colleague's comment here that is not just about money here, and that is that I criticize the future gen demonstration, but the one big success of future gen one is that there was a high level of public acceptability, and DOE gets one hundred percent of the credit for that. Okay and the way that program was designed, so DOE can do those things.

XXX: (Unintelligible question)

XXX: We like the program, loan garuntee program a lot, as you probably know it is not without controversy. Yeah.

XXX: XXX from FuelCell Energy. Last month I was at a DOE meeting in Washington, and there was some brief presentators from Japan, and they were from TEPCO and Japan Trade Organization. They made a presentation on how many megawatts they immediately lost after the tsunami, and it was like 20,000 megawatts, and systematically they are about to bring it back, but they still have about 3,000 megawatts power of shortfall. And they're looking at distributed generation as a way to fill in. The question I have is there opportunity to learn from their experience in this planning process, and is that being addressed?

XXX: Um that particular aspect I think is an interesting one we have not thought of before. You know, what happens when a significant portion of your capacity gets knocked out for one reason or another. You know I'd personally, you know I've seen two things recently. Of course the German decision to shut down immediately you know how every many reactors, and then over the next decade. Seven immediately and then twelve or something, so what's the plan? Where do you get the electricity from? I think we're all interested in that. And I saw in the local paper today the city of Boulder is going to get ninety some odd percent of their energy from renewables or clean, what's the plan there? I'd also be interested in seeing that. So you know, lots of people setting goals, we who understand the technologies have a responsibility to ask, how are we going to do that? So I, you know, I'm not sure I can say more than that. Who's got the mic next?

XXX: XXX again with IEEE energy policy committee. I'm going to throw something on the table since it is a cross cutting issue, and we're all technology people in the room but the US trade deficit is a major consideration to some in DC and I'm just sort of curious to have the panel, and perhaps you XXX. In the context of trade deficits and international trade and doing what we need to do in this room besides energy security, you know ecominomc security, where's the place to focus, and how does that problem fit in to the overall vision that this panel has. Thank you.

XXX: So let me give you the sort of the way at least we talk about it in the DOE. 360 billion a year in the red on trade from oil, so we gotta stop some fraction. Beyond that the vision beyond that is to have the US as a venue for high value-added manufacturing. That means we need to innovate, develop some of these technologies. Significant manufacture here at least at the beginning, and that link here between the innovation and the manufacturing

seems very important, which is why we want to do that. You hope that helps the balance of payment problems, but I don't know. Let me turn it to our for-profit sector colleagues.

XXX: Certainly the one thing that with us, we made a conscious decision when we chose this particular technology pathway of looking for flexible, lightweight, something that can be rolled very easily and transported just as easily. And especially you start looking at the distribution of PV, and trying to go to different countries, different types of regulatory issues within those countries as well as in some cases a demand for local manufacturing content. So in our case we specifically looked at how to make the smallest quantity that you can ship out and possibly create that. So it's not that we're going to be making everything here, but we can be making the heart of the technology here and ship in elsewhere. In this case, it's been a very attractive package for a number of people looking at trade equity and trade balance.

XXX: Anyone else on balance of trade? And then we'll just take one more question and then have to wrap up.

XXX: I can talk for the wind industry. We're moving big pieces of components around and so being in the region is very important, and it's a fallback routine from developing our products and manufacturing and deploying. So when the time is right to enter into a new region, that's what kind of decides it.

XXX: I'd also just like to make a quick note on the question that immediately preceeded this with respect to nuclear generation reliability and what's happened in Japan to note that we face a set of challenges around our existing energy infrastructure, much of which is old and debilitated. We have 23 reactors in the United States that share the design of the Fukishima reactors and are approaches to how it is that we move forward with this existing infrastructure has to be pragmatic because it's baseload and we face question of do we shut down old coal plants first or old nuclear plants first. We also have a responsibility to ensure that new infrastructure is substantively better but that's actually not hard to do, the new designs do not share some of the key deficiencies that contributed to the Fukishima accident.

XXX: I'm going to take one more and then we'll call it. Yeah.

XXX: XXX, 1336 Technologies. My question concerns nautral resources, and the intersection of natural resources and scalability. You mentioned natural resources in your introductory remarks, and the example you gave I think is that some generation technologies require access to water, and that water is outside the purview of the DOE. And it seems to me that I've seen this bubble up, if you will, in a number of different technologies. For example, some thin film photovoltaic technologies rely on the use of scarce metals, and there's a real question about their scalability. And what I think I've seen is that DOE, it's a very hard judgment call to make, and DOE often tends to shy away from weighing it, and I think that the question of resources and energy technologies is a very broad question. There are very few technologies in fact that have a very clean bill of health on this. I wonder if we can envision some sort of a bill of health on technologies as they concern natural resources so that investors at least have that information when they make a decision.

XXX: It gets back to two aspects; one is the systems thinking, and then again thinking more or understanding more how the for-profit sector will approach these things. I mean if you were going to deploy a business that you thought would be resource constrained, you'd do a careful analysis of the cost curves, and so on. And that's not the DOE way of doing things, that's not been part of thinking. Many people think it should be, and I do agree.

Alright, we do need to take a break for fifteen minutes, and I think the plan is break for fifteen minutes, and then continue this conversation, which I think has been very interesting for another hour in smaller groups. Okay? Thank you. Where is Asa?

XXX: So there are, there should be snacks and such in the room where the breakouts will be, which is where breakfast was, which is room 235 down the hall. In an ideal world, there would have been numbers on your nametags but that didn't work, and so we will put a spreadsheet up on the projector in that room, if we can that says— at least the attendance list as of last Thursday, people assigned to different groups so that we can try to get each of those discussions as diverse and wide-ranging as this one has been.

(Time Break)

XXX: We're going to get going. We have an action-packed 90 minutes of every, most of the major or all of the major potential clean electricity technologies. The purpose of these presentations is to have our tech team leads give short overviews of essentially overviews of the assessments that they are contributing to the QTR process, with the hope then of using the breakouts following to get feedback on those assessments, and also to have a different take on some of the questions we discussed this morning, but with more of a technology-specific flavor, as opposed to the exclusively crosscutting discussion this morning. We'll start with XXX with DOE who's going to talk CCS, and I will try to be a good enforcer of the time to make sure that we get through all of this in time for us to actually have the conversations afterward, which is important.

XXX: Thank you, and thank you all for being here, again. XXX from the fossil energy office in DOE, and I was going to quickly run through sort of what our current portfolio is, and how we see CCS contributing to these general goals moving forward. Since we have a diverse audience, a couple of high-level things. For those of us who don't know what CCS stands for, carbon capture and storage, it's a process of pulling the CO2 out of the flue gas from hydrocarbon resources, capturing it, compressing it, putting it typically in a pipeline and storing it safely and permanently in the subsurface.

Technologies exist for all three of these major components of CCS, we've been doing a lot of these things for a number of decades, just not integrated at scale, and at the price points required for large-scale applications to the power sector to combat climate change issues. We've been pulling CO2 out of the flue gas stream since the 1930s, that technology exists. The petrochemical industry pulls CO2 out of mixed streams all the time, but they have higher-value products, and the prices they can handle are not economically viable to power plants.

Transport. Right now in the United States we've got over 3,600 miles of CO2 pipeline infrastructure already built. We move over 50 million tons of CO2 every year for our advanced oil recovery operations. So that exists, and there's not a lot to be done in R and D for pipelines. Storage, we've been putting CO2 in the subsurface since the 1970s for enhanced oil recovery, we know how to do that well. But again that has not been done with an eye towards the permanence and the monitoring rigor that will be required to validate long-term carbon storage in a carbon-constrained world. Our current demonstrations in the DOE are focused on proving the integrated aspect of all these technologies at scale, and we've got a number of projects going on to do that with current technologies. These technologies currently available are not economically viable for large-scale deployment and our R and D

portfolio is really focused on bring down the cost, bringing up the performance of these technologies going forward for the capture and compression aspects, and proving the long-term and permanent storage for the subsurface injection aspects.

Last year the president requested a report on his desk that DOE and EPA six months to take a look at what are all of the barriers and things in the way for CCS to be a prime-time and viable solution to mitigate climate concerns. The task force involved most of the federal agencies, over 100 federal employees, went out and talked to several hundred people in industry, academia, and the general public, and the key takeaways are on this slide, I'm not going to read them to you. But the group found that there are no insurmountable technical, legal, regulatory or other barriers to allowing CCS to contribute to part of the solution we all seek. The lack of the carbon price was the number one barrier. All the other technologies we're talking about today in the room have merit on their own, absent climate issues. The only reason one would want to do carbon capture and storage is to avoid putting CO2 into the atmosphere. Alright, right now we've got a thirty percent parasitic load to capture and compress and store the CO2. Absent climate change mitigation, no one in their right mind would do carbon capture and storage, or maybe in a few niche locations if they wanted that CO2 for EOR, the economics might play out. We have a number of demonstration projects that demonstrate current technologies as I said, and there are a lot of other soft issues that are beyond the scope of what we are dealing with today; providing legal clarity, regulatory certainty, EPA put some regulations out to say how you treat CO2 in the subsurface once you capture it. And so the federal government continues to smooth the path forward beyond just the technology.

So why are we doing this, right? So if you look at coal generation worldwide, it can contribute substantially. Not just coal, but coal and gas. Right now, I think the US, 46 percent of our electricity generation is from coal, 25, 26 percent from gas. In China, over 70 percent of their electricity comes from coal. In India, 70, 75 percent of their electricity generation comes from coal. IF you look out into the decades that we're all grappling with, say 2030, 2035 timeframe, our coal fleet probably capacity wise will probably look the same as far as total generation capacity. China's probably going to triple from where they are today, and the world is going to more than double unless there's a large price on carbon between now and then. So that's one of the reasons why we have this program. If you look and say okay how does this compare to other technologies, again there's no magic silver bullet, and we need them all. The IEA says that in order to meet mid-century climate stabilization targets, perhaps CCS can contribute up to one fifth of meeting that mid-century goal. Obviously we need to pick the low-hanging fruit and do as much efficiency as we can. Nuclear, renewables all have to play, but it's tough to see a global scenario where you can close that climate solution so to speak without some amount of CCS. Whether applied to coal or gas, depends on what your assumptions are about gas price going forward vis coal price. Suffice to say, there is enough of a driver there for significant deployment of CCS and that's why we have our current program.

So what's in, what's out? Our focus is primarily on CO2 capture from existing coal power plants, although most of the technologies we are working on are easily applicable to gas and if you need gas to balance some of the intermittence of some of the renewables, we hope to see further penetration moving forward of carbon capture and storage applied to gas assets becomes an even more important part of the overall equation. We haven't considered biomass feed stocks exclusively under our work here at the QTR, although there's a lot to be said

about the synergy of the low carbon footprint of gas, and the economy of scale, and the economics of coal-based systems. And we're not looking at any other beneficial uses of CO2, except the economic benefit of using it for EOR in the near term.

So in general there's a couple technology options to pull CO2 out of a power plant. Off of conventional pulverized coal, post-combustion typee of approach. After you burn the coal, it generates steam, put your electrons to the grid. In your flue gas coming out the back, CO2 is 12, 13 percent on a mole fraction or volume fraction. You use a solvent to extract the CO2, you compress it to about 2000, 2200 PSI and put it in the subsurface away from the atmosphere. If you want to look at an oxycombustion approach, you can spend some energy and capital up front to instead of burning or combusting your coal or hydrocarbon in air, to do so in a relatively pure oxygen environment. You pay the piper up front for separating that oxygen out of the air. You get return in the back end because your purification step is basically compression; you knock out the water and you have a fairly pure CO2 stream. Alright we are looking into both of these technology options in the current portfolio, both on the R and D side, and on the large-scale demonstration side of current generation technologies.

Another application is what we call pre-combustion, so if you take your hydrocarbon, you take your coal and you partially oxidize it, you gasify it in a gasifier, you can then shift it from carbon monoxide, CO2, hydrogen more towards CO2 and hydrogen, and pull your CO2 out there. You got a much more concentrated CO2 stream at that point that's under pressure. Your chemical separation driving force is greater, so your cost is a little lower. But the overall gasification system is more expensive to begin with, and so there's tradeoffs. But we're looking at a post-combustion approach, a pre-combustion approach, and then an oxycombustion approach in our portfolio. We're working on developing second-generation technologies that have increase performance and much better economics than what is conventionally available off the shelf. There's a long list of technologies here, not just looking at advanced solvent sorbents and other ways to pull the CO2 out, but also looking at advanced technologies to increase the performance of that base power plant facility. So that's better materials to increase the steam temperature conditions, better handling for some of the materials, advanced membranes that you can reduce that parasitic load if you want to go with some oxygen-fired system instead of cryogenic oxygen separation in the current technology which is expensive and hugely energy parasitically expensive as well. Looking at a membrane application where you can separate oxygen out of the air to bring down your Cap-ex, your op-ex, improve your system performance.

So we have a number of technologies we're looking at in order to help optimize the capture and the overall efficiency of the plant. In terms of the electricity, cost of electricity estimates, you know first-generation looks to add 30, 40, 50 dollar per megawatt generated to the cost of power delivered from one of these coal-based systems. For our second-generation technologies, systems studies at national energy technology laboratories that folks do show that with technologies that we have in our R and D pipeline, we can get those additional incremental costs of adding CCS to your base coal plan to the configuration into the 15 to 20 dollar a megawatt cost adder. And you can see the numbers here as well. Transformational technologies as well when you look at integrating say a fuel cell into some of these advanced coal concepts can drive that price down even lower although one might argue that that would be beyond the timescale of what we are looking here, at the 2020, 2030s and what can be done by then.

If you actually look at how these technologies stack up on top of each other, you can see that we reduce the incremental adder for the cost of electricity delivered, and I've got an active slide here, by sequentially adding some of these technologies and adding some of these advanced technologies together. In the interest of time, I'm not going to go through all of these, but you can see that increasing the operating cycle, the steam cycle by going to a super-critical conditions using some of these membranes to reduce the parasitic load and improving the performance of driving these with an oxygen-blow system, and going to some of these advanced solvents and sorbents to more efficiently pull out the carbon dioxide from that mixed gas stream, all of those when added together can really drastically drive down the cost and increase the performance of the overall pull to electrons in a carbon capture system.

On a gasification technology side, we also have a parallel R and D path again looking at some of these membrane separation processes, can we come up with a dry feed pump to feed these gasification processes without adding a lot of water to go along the way that you just have to heat up and separate out, that will make that much more efficient. When you are starting to clean up some of your pollutants, not just CO2 but some of the criteria pollutants, can you do that at elevated temperature? Right now you've got to drop it down to lower temperature on the order of about 100F or so to pull out your criteria pollutants, that's an inefficiency in the process. We have R and D in the pipeline that looks very promising, it's scaling up now, to try to pull out a lot of these contaminants at higher temperatures and pressures and therefore make the process more efficient.

Globally there is a lot going on in R and D on carbon capture and storage. The US is by far the world leader in terms of overall CCS technology portfolio, but there's on the order of 234 last we counted projects going forward, 77 of those are what we would call large-scale, and it's a mix of pre-combustion, post-combustion, oxyfuel approaches. Here's just a schematic of the about 9 large-scale integrated projects we have going on in the United States, and again we're trying to put all our eggs into one basket here. We've got some post-combustion approaches here, pulling CO2 out of the back end of a conventional power plant. We've got some of the IGCC or pre-combustion approaches, using gasification or IGCC technology moving forward, and also several industrial projects where were pulling carbon out of flue gas streams from industrial processes being steam methane reforming for hydrogen production, or ethanol production. WE have a project there with AGM, and a methanol facility down in Louisiana where we're going to pull CO2 out of that process.

Besides working above ground, you also have to look at the below ground aspects, what you're going to do with the CO2 once you capture and compress it. We have a large program that's been going on now for over a decade, we are moving into a large scale demonstration phase where we have nine injections planned, some are ongoing, where we are going to inject on the order of a million tons per year of CO2 in the subsurface, test the fate and transport of CO2 and make sure it behaves as our models product. Again we are looking for long term, safe, secure, and permanent storage of CO2. All the engineering, geoscience, geochemistry to date says that this is possible and this is what should be expected. We're trying to prove that at scale and again push the permitting side and public acceptance part of the equation as we move forward.

And finally, trying to optimize this R and D program going forward, we're looking at what we can do to accelerate all these technologies in this path through large scale simulation and all of the computational sciences that are currently available to us. On the above ground see if we can couple R and D simulation, computational simulation at the same molecular dynamic

scale to see if we can understand what's going on at a molecular face. How does CO2 interact with solvent, or a material interface, take the input, the output from that in a computational flue dynamic, module type of simulation to say how would a separation component behave in a plant, and integrate that at scale with a plant simulation to say okay what's that mean to overall performance of the plant. Along this whole process we're also trying to bring through what's the risk quantification of all of these aspects as we move forward. We simply don't have time to do things the long, drawn out it takes several decades way to demonstration like we've done in the past, and hopefully we can accelerate that process through computational processes. And in a broad nutshell, I think I have half a minute left here so that's sort of at a 10,000 foot level the DOE carbon capture and storage program, how it fits into the context of the QTR, how do you prioritize doing this versus the other energy technologies we're all here to discuss? And with that, I think I will introduce the next speaker which is my colleague XXX from the Department's nuclear office to give you the same high level overview on the nuclear technologies, so thank you.

XXX: I'll go ahead and get started while they work on that. Thank you Jarad, my name is XXX, I'm in the office of nuclear energy and I am going to give a very similar high level look at how we treat nuclear energy in the context of the QTR. One point I want to make at the outset is something that Doctor Peterson touched on in the morning session. It's that I'm going to talk about this in the context of the role of DOE but it's the, in the nuclear field so much of the government interaction also takes place in the regulatory side in the NRC. Ill touch on this point repeatedly, but it is a known limitation to what I'm doing here that I'm not going to discuss in great length the NRC's perspective on these matters for time if nothing else, but I want to recognize that it exists.

I've got five categories of technologies I'm going to briefly walk through. What I'm not going to talk about for the purposes of QTR are the front end of the fuel cycle of the fuel cycle in particular. Uranium mining and enrichment is a fairly robust, mature industry. We've got commercial deployment of new plants going on currently, the mining field is very well established. The possibility of replacing uranium in the fuel cycle is certainly discussed. I didn't focus on it here for want of time and space, but in the breakout session if we want to revisit this, I'm happy to discuss this for some time.

So let me just paint the entire nuclear field in the US in four pictures. First of all, just to reestablish the baseline, we have 104 operating reactors in the US, 65 plants, provides about 20 percent of the electricity, about 800 million megawatt hours of electricity a year. Those plants, I'm going to move over to the right now, have produced about 60,000 metric tons of used nuclear fuel and as they operate through their lifetime, it will be at least 100,000. If we have expansion of the nuclear technology, it's going to be more. As I work down to the bottom left, one of the things that's happened with the current fleet of reactors has been a pretty remarkable rise in the performance of these plants. The capacity factors at the US reactors on average were around 60 percent in 1980s, that's the black line here. That has grown to about 90 percent availability of capacity factor over the last decade. One of the consequences of this is that the cost to produce electricity from these reactors has gone down over time, and that's the blue one. So in general these have been very profitable machines, so only for the relatively recent past. And as we look though towards what new nuclear construction is going to face, and the new hurdles there, the main element here is not the scale of the LCOE breakdown, but rather the big wave of blue and yellow, and that is the capital cost of these to be overcome. The challenge, you look at the deployment of new technologies

in the nuclear field is almost entirely on the cost to construct new plants. I don't think that's a unique consideration.

I'm going to frame the discussion in terms of our generations of reactors for most of the technologies. The first generation were largely prototypes, we don't have any operating in the US, I don't think any actually in the world. Those transitioned in about the late 60s towards what has now become the current plants, the generation 2 plants. These were, whereas the prototypes had a lot of different technologies being considered, there's some standardization that took place in the 60s and in the 70s, and the US is almost entirely on light water reactors, the boiling water reactors, precious water reactors. There are a couple other technologies that took root in other countries, but I'm going to focus on the US primarily.

As you've moved towards the 90s and into the 2000s, there was an effort on improving these nuclear technologies. The ALWR program that Peterson referred to earlier, tried to incorporate passive safety and improve the construction techniques. And those are the generation 3 plants that we're talking about. And finally, we'll touch on the generation 4. These are the more revolutionary designs. Longer term, but 2030 timeframe to begin looking at those coming online.

So let me do one slide on each of these. I mentioned that these are all generation 2 plants in the current fleet. There was a consolidation onto light water reactors, but the reactors themselves had a great deal of variation, size and configuration. We have some that are 600 megawatts, some well over 1000. And the plants are all fairly uniquely structured, as well. Of the 104 reactors there were all licensed for 40 years of operation by the NRC, almost two-thirds have already received a 20- year license renewal, and almost all of the rest of them have either applied for, or are expected to apply for a license renewal as well. Since the late 70s, the capacity of these plants has grown through upgrades. The NRC allows you to get more power out of the same plant. If I do the arithmetic, and simply say okay with the plants that are currently expected to get renewals and upgrades, how much electricity are they going to produce, I come up with something like 2700 gigwatt-years between now and the end of their lifetime. And you can divide out to get quads if we need to. So then I ask, what might happen beyond that?

Well, one way to look at it is, let's assume for the sake of simplicity that all of the current reactors get a 20-year license renewal. And then beyond that, R and D program enables almost three quarters of the current fleet to get a second renewal. Additionally, we can conceive up to 10 gigawatts of upgrades, and mind you this is a very aggressive goal, but it's trying to describe the potential for the technology. You combine those two factors, and you get another 1700 gigawatt-years of production. That's the basic landscape of where we are now and what's possible. To get there we are going to have an R and D program at a minimum. Material aging is a key component, fuels, but one thing I want to highlight from the comments this morning's discussion, is a modeling simulation hub. The question was asked how can DOE capabilities be applied to these kinds of technology development issues, and one attempt we have is to use high performance computing to better understand the fundamental processes in the reactor to get at these aging questions and the operational challenges that would enable toe regulator to have the information they need to decide whether license renewals are prudent.

Generation 3. These are the, I mentioned already the basics of them. Improvements on the current technologies. So far there have already been 4 built in Japan, advanced boiling water reactors. There's construction going on in China, Taiwan, Finland, France, pre-construction

in the US, both plant Vogel in Georgia, and the Summer plant in South Carolina are well in the process of trying to begin the actual construction process. The first movers are expected to come in something like 4000 to 5000 dollars a kilowatt. Which, as you look at the size of utilities that are trying to finance these projects, that's a challenge. We could look towards improvements both in terms of having exercised the regulatory process. One of the key uncertainties right now is no one has had a new reactors licensed in the US since the 70s and the 80s, and we have new processes in place, but none of them that have actually gone through successfully, these are the first movers to establish that. And the expectation is that learning affects among other things should improve the cost of successive waves of plants moving forward.

Doctor Peterson mentioned the NP2010 program. This is the attempt to get these first movers into the process by cost-sharing this licensing effort. That project is not completed; the licenses have not yet been awarded. Most of the R and D that is applicable to the generation 3 plants is also applicable to the generation 2, aging fuels, and I think that has implications for R and D programs.

I also want to call out small modular reactors. These can be thought of as a subset of the generation 3 plants. They're less than 300 megawatts, and the generally-held, built underground, they have a lot of water for the amount of material there, has desirable safety features. But the key question is understanding what is lost economically by going to smaller sizes. The generation 3 plants generally have gone up to 700 megawatts to take advantage of the economies of scale. Can you make the economics work at say 100? These are in the early design phase US and abroad. To get to the point these can be actually purchased you have to go through this licensing process, which will take many years and hundreds of millions of dollars, exactly how many we will figure out a little later. But the hope is that factory construction of nuclear reactors can result in greatly increased efficiencies for cost and quality as well. We are in the process of trying to send up a program to get the two designs through this licensing, that's just getting under way. And there's an R and D basis behind this as well, that can we improve the materials and understanding of how these reactors will operate going forward. That is idealized.

I want to talk about generation 4. This is where we get past using water as the, for the most part, that past the basic light water reactor structure. The possibilities for coolants and fuels are varied to six basic designs. The generation 4 program has some ambitious goals for safety, economics, nonproliferation, sustainability; I won't list all of them. But this has been so far largely an international collaboration on R and D. The generation 4 international forum, we'll call it. We have seen national programs to try to develop prototypes to demonstrate them, both in the US and abroad. The focus in the US so far has been on high-temperature reactors for process heat applications, as well as improved electricity efficiency. And fast reactors for fuel cycle management. These reactors have the potential to be dramatically different, and perhaps dramatically improved, but we are still quite a ways out from seeing them deployed. We know there's a great materials R and D effort, and fuels effort, these are very different concurrent plans, for the most part. And there's likely a need to demonstrate these technologies before you can get them licensed, and that's a key component to the program.

So having rifled through the reactors let me now pivot just a bit to talk about used fuel. I mentioned how much we have, and how much we are likely to have. The waste policy act says that the DOE has responsibility for the long-term management of used fuel. The blue

ribbon commission on America's nuclear future that was mentioned early is helping us to define the strategy that will hopefully be able to apply going forward with how to do this, I don't want to put too much pressure on. Right now this fuel is stored at reactors, either in pools or in dry casts at the site. The historical policy has been aimed at direct disposal, which would be Yucca Mountain, that's no longer the policy. There's still a great deal of contentiousness around that, but this has not been the only way to move forward. There have been recycling approaches deployed in France, the UK, Japan has been working on one as well. The US emphasis has been on focusing on advanced R and D to do these kinds of possibilities. Which means no separated plutonium, and trying to minimize the waste implications of the resulting high-level disposal.

Within the department and R and D space, we're looking at three basic approaches. One, the direct disposal, a modified open cycle in which some of the material is used a handful of times before being disposed, or full recycle in which material continually run through reactors to give more energy out of them and also to minimize the waste implications. This is still very much in the R and D phase, and it's been an effort through our advanced fuel cycle initiative, and our fuel cycle R and D program. And this is going to still require a repository at some point for whatever high level waste does need to be disposed. And at the same time we can expect that dry casts will be a key component to used fuel management going forward, and that's going to be one of the challenges to understand exactly what needs to be still understood with those technologies and how long they can be applied. With that, my very rapid run-through, I will turn it over to our next speaker. Thank you.

XXX: So first of all I would just like to go over so everybody's acquainted with this, this is the wind resource map in the United States. The big wind resources are right here where nobody lives, right in the center of the United States. So that's obviously been one of the issues for land based wind is getting an electron that's produced there to somebody who can actually use it. Offshore wind has also been a big topic of, in the last couple years. We have real good offshore wind resources, and we're starting to see a bunch of planned developments in the northeast part of the united states where the water is shallow enough that we can do shallow offshore wind, and it's not as susceptible to hurricanes that we get as we start to get a little bit farther south in the United States.

The offshore is also quite good on the west coast, it's just that you're going to need the deep water offshore wind at that point, and that's a little bit farther down the road in terms of technology development. Kay, so the point of this slide this graphic is showing over time what has happened to the wind resource that people have been putting up their wind turbines in. What has happened initially back in the 80s, early 90s, people were putting class 5, putting their turbines in class 5 wind resources, their taking up all the places where the good transmission lines were and it was kind of you know they kind of picked the low hanging fruit. What has happened since then, and we've been trying to maintain our costs of energy is that the class, the wind classes has gone down to class 3, so you're trying to deploy wind turbines in the less windy regimes but also still have access to transmission lines and you know other barriers, reduce barriers to wind deployment.

So that has been the impact, we've been, you know the industry has been trying to cope with maintaining those costs of energy while those trends have been going on. This graphic shows kind of the development of wind turbines over the years. Small wind turbines, the land based wind turbines start out at the 50 kilowatts, up to today they're up to about 2 and a half megawatts, and you see the kind of dotted line going up even higher than that. So land based

wind turbines are fairly mature industry. There still are some technology innovations that can occur, but for the most part the, if we could overcome some of the major barriers to wind deployment, we'd be in pretty good shape with land based wind. We're starting to get at this point this 2 and half megawatt size is starting to get to the limitations of transportation of large objects in the United States, and so that's kind of an innovation point that has to happen to go any larger than that. And up in here, up on the top here as you start to see offshore wind turbines coming in. Bigger wind turbines, much more technology development is still required, it's a much different area for deployment, and so that's you know in terms of our research it's kind of a totally different look at the maturity of the technology.

So US wind power market, I really only want to point out on this slide, this is really, wind industry is very much a policy-driven industry. If the production tax credit is on, wind development happens, if the production tax credit is off, it doesn't happen so much. And you can see that here, the production tax credit expired in these years, had very little wind deployment. Over the last 5 to 6 years, policy has been pretty consistent, and so you see that the wind deployment has been pretty good over the last 5 or 6 years.

In terms of cost, it's another interesting graphic. What's happened over time with costs, the capital costs of wind, land based wind turbines, generally it went down, the trend was down, up until about 2005. And then costs started creeping up, so commodity prices were going up, there was more demand for wind turbines, and so the costs, the price of wind turbines started going up, so you can see that. It went down to about 1500 dollars per megawatt, or per kilowatt, has gone up to about 2500 maybe. And, but we do see that leveling off, and maybe coming down here as some of the commodities pressures have eased.

This graphic shows the cost comparisons between land based and offshore wind. I'd like to point out on this is that for a land based, for a land based installation, over 50 percent, probably 60 percent of the costs actually goes to buying the wind turbines, so the capital cost of the wind turbine is a very big factor. And then there's the other costs are kind of over in here, that you would expect, construction costs, operation and maintenance, that kind of thing. It's totally different for the offshore wind environment. So the turbine cost actually is only about 28 percent of the cost of doing the installation. So there are a lot more that factors into the offshore wind environment. For example, the support structure, what's the foundation going to be. That's 11 percent of the cost. Operations and maintenance is a much bigger deal in the offshore wind world, so 20.5 percent there. So it's a, and electrical infrastructure, you know putting up the transmission lines and electrical systems is also quite big. So a lot of different areas for us to address, and we are putting a program together to take a look at those things.

Alright so what I want to highlight here, in terms of reducing cost of energy, there's really three factors that have to happen. One is lowering the capital costs of the wind turbine itself, so that's number one. Two, increasing the capacity factor or increasing the amount of energy that a wind turbine is gathering over the year, so that also will reduce costs of energy. And then finally scaling up with larger, lighter-weight wind turbines that can produce more energy given the same footprint. And you'll see that really reflected in this graphic which shows costs of energy, which is these blue bars, is what we want to achieve over by 2020, by 2030 excuse me. And capital cost is only making up a portion of that. So you've got to make up the difference in cost of energy by getting more energy through annual energy production, and scaling up, getting larger, more lighter-weight wind turbines.

This graphic shows how we look at the, this is the graphic of the land-based wind energy, kind of the current costs versus where we want to go with costs, and it gives you an indication of how we make our decisions, investment decisions on R and D. So we're looking at for example, a big portion of the cost is on drivetrain and drivetrain and control mechanisms, so we're putting a fair amount of research and development investment into that part of the program. Rotors is also another big area that can have an impact on cost of energy. So that's reliability, operations and maintenance, those are all factors that we all, that we're putting investments in and ultimately trying to get down to 4.8 cents per kilowatt hour.

This shows a similar analysis of the offshore wind costs and as you know there is, as you may know there is no offshore wind sites actually in, you know installed in the United States right now, so this is much more open to interpretation. But through the Europeans, we have been able to get some cost factors. I think what's interesting about this is that I actually show two bars here, this one bar that shows 27 cents per kilowatt hour, and then another bar that shows about 14 cents a kilowatt hour, and that change alone is just due to the financing. So if you could finance what we think the financing rate is really is about 17 percent, that's what it's going to cost to do offshore wind development. In terms of kind of looking at this in a standardized way across our office, we move everything down to 7 percent, so just reducing the cost of money from 17 to 7 percent basically cuts the cost of wind in half on offshore wind.

So the major reduction pathways for reducing those costs of energy again ill summarize those. Larger lightweight turbines, increased energy production through better understanding of individual wind turbine performance as well as the array of wind turbines operating together, improved reliability, and then particularly for the offshore wind, demonstrating the technology, actual technology demonstration project in the offshore wind world. In terms of how much money do we put into the offshore wind program, this has been the last five years. This is actually a significant increase over the, I think it had been more, I think actually this is the next slide, yeah.

So anyway, we're requesting 127 million dollars in fiscal year 12, we had 80 million dollars in fiscal year 11, and this has been a, this shows kind of what the appropriations have been over the years. WE had some really good years back in the early 80s, and had some leaner years in the late 80s and 90s, and generally we have been about 40 million dollars a year, and in the last few years we have increased that significantly as well. Not included in here is about 130 million dollar, or 110 million dollar investment through the recovery act that went into the wind program. Some information sources, I just threw this in for our discussion afterwards, how we actually look at the performance of various components of the wind turbines, how we measure our progress in terms of improving those as well as our work breakdown structure where we actually have activities going on in the program, so that's really for later on. So I will be followed by the water program presentation, which is also me.

So you may ask why is the wind and water program combined. There are actually a number of things that overlap between the two. The water program is at, when you look at the wind development over the year and the number of wind turbines that were originally created back and the different kinds of designs that were created back in the 70s and 80s. The water program, you'll see that, it has very similar attributes to that as well, as well as some of the modeling and design kinds of tools that we put together for the wind program also translate over to water program. As well as offshore wind, we're trying to deploy ocean-based wave energy kinds of things. There's a lot of overlap in terms of infrastructure, environmental,

regulatory, permitting, so it does actually make some sense in terms of why the two programs are together.

Funding profile, the water program actually is two components, there's a conventional hydropower side of the water program, characterized as very mature, been around for 100 years, and then there's a more of an emergent technology; the marine and hydrokinetics, which I'll talk about second which is totally opposite of conventional hydropower, so very much just starting out. So our request, this is kind of our budget prfile, 40 to 50- million dollars. You can see just as recently as 07, we registered at zero. So congress zeroed us out and it has gone up since then. So it's been some very interesting developments, we've had to ramp up very quickly with a staff. IN fiscal year 11, we most, about two thirds of the money went towards marine and hydrokinetics development, and then it looks like about 50-50 in 12 is our plan.

So I'll talk about conventional hydropower first. Just to give you an idea, hydropower makes up about almost 80,000 megawatts of installed capacity in the United States. There's also about 20,000 megawatts of pump storage that's installed in the United States, so those are two very nice assets. It is the biggest renewable energy that we have in America. Where are all of these hydropower plants located? They are all over the place, but it is kind of characterized that about half of the 80,000 megawatts is federally-owned hydropower, and you;'ll see that the federally-owned ones are the big ones. They are the big pink dots. Up here in the Northwest you see lots of them, down here Tennessee Valley Authority, you see them up here in the Midwest. And then the smaller dots, the green and the blue dots tend to be the private develo0pments, smaller not as big as the federal side, but more numerous. So when you add it all up it's about half and half between private and federally-owned.

This is a very interesting graphic. So if you look at the conventional hydropower and the status of the existing fleet, it's old. It's about, over half of the wind turbines, excuse me, half of the hydropower turbines are over fifty years old. Fifty percent are over fifty years old, which you know so what that means to us is that there's a really big opportunity if you—I get double time right? Jeez.

Alright so there's a big opportunity for replacing these with more efficient wind turb—with efficient hydropower turbines, and that can be a sort of an immediate impact in terms of energy production, renewable energy production. Pumped storage, this is another graphic that shows generally the pumped storage has been on the east coast and west coast. The blue dots are showing the pumped storage plants that are proposed, and that shows you kind of, it's indicative of maybe the renewable energy interface there and how people are looking at pumped storage as an enabler of wind energy and solar energy. So in terms of deployment you see some esasy stuff, additional generation from existing power houses, we can get 16 gigawatts out of that, fairly substantial. New generation from, at unpowered dams where there isn't currently a hydropower turbine, 12.6 gigawatts. Both very straightforward. And then new development in terms of small hydropower. In terms of non-powered dams, this is where they're located, and if you look at that, do kind of a visuyal assessment, a lot of that is located in the Southeast where they don't have a lot of renewable energy assets. So this can be a great enabler of them needing renewable standards and other goals that they've got there.

So why aren't they developing this, the hydropower that's available? Often expensive, uncertain regulatory processes, may not have the technology to do it, technology costs are high in some sectors. There's a perceived at least, and real impact, environmental impact of some of these wind turbines, or, jeez, hydropower turbines. I think I'll go over this in the

breakout session, same with this one. Costs, this is how we model our costs and make our decisions in terms of small hydropower. Summary. There are some easy opportunities for generation via upgrades and unpowered dams, I think that's a key message to take away.

I want to go into marine and hydrokinetic real quick. So what is marine and hydrokinetic? Really it is anything that produces energy from the flow of water, either water current or water waves. Here's some examples of those technologies. There's current technologies, so that's river current as well as ocean current, more kind of a wind turbine kind of look to them. And then wave technologies that are taking energy from the waves, the up and down motion of the waves. Resource-wise, this shows that there is a really nice resource on the west coast for wave energy. We got a real nice resource, this is the gulf stream right down here for current energy, and a decent resource for wave energy on Atlantic, but you can see 110 terawatt hours versus 440, so it's about one-fourth of what's on the Pacific side. It's a very diverse industry right now, 40 marine and hydrokinetic concepts currently being developed. So we are investing in technology readiness levels across the whole board in terms of trying to develop this industry. Test centers, they've got a real, Europeans have kind of taken the lead in marine and hydrokinetic energy, so they have a real nice center over in England and in Scotland. And we're starting to go down that path to having tests, having good places to actually test your prototypes has been a key, and will be a key enabler to the industry, so we've got three areas we're looking at to do a test center, provide a little bit of funding for them.

These are the pathways for marine hydrokinetic energy. Wave, tidal, ocean current, in-stream, so river flow hydrokinetic and ocean thermal. And I think our goal is to try to figure out through resource assessments, figure out what are the major, which are the best opportunities, and try to narrow down the technologies as to which ones DOE should actually be investing in, which ones can have an impact. Costs are high, we will go over this in the breakout session. And how am I doing on time, am I about. So I guess the summary for this is that the marine and hydrokinetic as you saw from the resources can be a good regional energy source and close to population centers. We need to understand better what the baseline costs are, what the resources are associated with them. The DOE's investment can accelerate those improvements. And then the regulatory and permitting process are going to have a great impact on that industry. Next.

XXX: Yes I'm on, can you hear me?

XXX: Yes. If you want to indicate to me when you want a new slide.

XXX: Okay, let me know when you have them up. Am I, can you hear me loudly enough?

XXX: Yeah.

XXX: Okay.

XXX: So let me just introduce you. XXX is our acting program manager for geothermal technologies. She's also a senior advisor to the Office of Energy Efficiency and Renewables. She and much of the geothermal community are currently at our annual merit review, and she is going to present remotely. So XXX, do you want to start?

XXX: Okay, I'm going to fly through these since I only have ten minutes, so I'm on slide 2, which shows that the DOE investment in geothermal R and D peaked in the late 70s and early 80s and the growth in installed capacity of geothermal energy coincided with R and D investment coupled with policies. Policy activities are shown at the top of the graph. So the PURPA, Public Utilities Regulator Policy Act I think most people in the renewable energy community are familiar with that. It requires that utilities buy cheaper power from independent companies and at a time when natural gas prices were really high, and so that

really prompted a lot of renewable energy growth at that time. Geothermal capacity growth flattened during the 1990s, and this data shows an apparent drop in capacity around 2000, and that's due to two factors. There was a change in the reporting methods, data collection and reporting methods within the EIA, and so it shows an apparent reduced capacity, but the capacity didn't actually go down. However there was some retirement of geothermal plants during that time. So it's a little unclear how much the capacity actually dropped. So moving on to the next slide, this shows the budget history for the DOE geothermal program. The red bars have been converted to 2011 dollars so that you can compare apples to apples, and you can see once again that the investment peaked in the late 70s early 80s. It was relatively flat you know between I don't know 30 and 50 million dollars from late 80s until 2007 when the program was almost zeroed out. It got a budget of 5 million dollars. And then in 2009 there was a big boost from recovery. And then lower budget since then, and the FY 12 request is 100 million dollars. So during that thirty years of investment from 76 to 2006, there was significant technical progress made. The cost of drilling was reduced through the development of the polycrystalline diamond drill bit, which actually benefitted the oil and gas industry as well. There was some progress in exploration technologies, and in exploration success. Power plant conversion cycles were improved during that time and reservoir models were developed to support the work at Fenton Hill, during which time the first enhanced geothermal system was demonstrated though at very low power. So that's the history.

Moving on to the next slide, slide 4, over the past decade geothermal capacity growth has significantly lagged that of wind and solar, averaging about 1 percent per year over the past ten years while wind and solar average is in the 30-40 percent range. So this has been a cause for concern for DOE and to the industry, and a little later on ill talk about what we're doing to address that. So slide 5 shows that there are a lot of different geothermal resources. There's the conventional hydrothermal, I'm not going to go through all the information on this slide, but conventional hydrothermal which is reasonably well-developed. So the industry has developed the low-hanging fruit, so to speak. They've developed most of the geothermal resources that have a surface expression, and now they are tackling the so-called undiscovered huyrdothermal, the hidden resources. Which are more expensive because there's more exploration involved, or it's riskier to confirm those resources. So there's the conventional hydrothermal. There's low-temperature and co-produced resources. An MIT report indicated about 12 gigawatts of co-produced, but in addition to that there is approximately, according to the USGS, about 120 gigawatts of low-temperature resources. There's a geopressured, which includes the co-p[production of natural gas. There is permeable sedimentary resources which are in the same geology as oil and gas, and therefore the thought is that they might be lower cost, or they would be lower cost to develop. It says TVB there, but US Geological Survey estimates 240 gigawatts, and I think they're updating that in 2012. And then finally there is enhanced geothermal systems in which we inject water into hot dry rock and we're developing those near-field sites and greenfield sites. Near-field sites which are near conventional hydrothermal fields. So you can see the huge estimated resource for greenfield ETF, that's an NREL study that shows a 16,000 gigawattts might be possible and I think that what the include in that study are 4-10 kilometers.

So the 400 million dollars in recovery funding enabled the DOE program to invest in just about all of the resources, moving forward we realize that we're not going to be able to do that. And so we need to focus our program and I'll talk about that in a few more slides. So on slide 6, this shows just some information on the current status in 2010, only one power plant

came online in the US, and that was the Oramax 15 megawatt plant in Jersey Valley. Currently, I already showed that there's about 3,000 megawatts, 3 gigwatts installed, and the GEA, the Geothermal Energy Association estimates that there's about 5 megawatts under development. And as you can see from the maps on the right side of the slide, most of the geothermal development, not surprisingly is in the Western US. Although there are almost 200 projects that are under development in 15 states, so it is starting to expand and that was the one of the objectives of the DOE program with the recovery money was to try to expand geothermal into other geographic regions, and of course if enhanced geothermal systems are successfully developed, we'll be able to tap geothermal resources in hot dry rock, which is virtually ubiquitous.

So on slide 7, this shows the current DOE program portfolio including nearer-term resources, and longer-term resources as well as lower-risk and higher-risk technologies. So enhanced geothermal system is definitely a higher-risk technology, has not been technically, the technical feasibility in the US has not really been established. We haven't' really demonstrated here. There is a commercial plant operating in Landau, Germany, and there was one in France, I don't think it's online any more, but it was producing power. In Germany of course geothermal benefits come from a 23-cent per kilowatt hour feed-in tariff. I think it's 23 cents. So obviously the commercial potential for EGS has definitely not been demonstrated.

A large part of the program is focus on developing innovative or new exploration technologies to enable the industry to tap the undiscovered, the 30 gigawatts of undiscovered resources, those without a surface expression. And then we invested some money in lo-temperature and co-produced, and there we are focusing on demonstration. We are not investing yet in permeable sedimentary, but we may be investing in that in the future, at least to some extent. We are interested in that, in those geologies because they may be able to use CO2 as a geofluid, and there's synergies there with carbon capture and sequestration technologies and resources.

So as I mentioned, we're not going to—oh and then we have about 170 million dollars invested in crosscutting R and D. R and D in technologies that crosscut all resources, so advanced drilling technologies, like hydrothermal foliation, technologies, to improve materials, high-temperature materials, and wear-resistant materials. So we're not going to be getting 400 million dollars a year, obviously, again in the foreseeable future. So in March we convened a panel of experts and wee expressed our concern about the lag in growth in geothermal and we wanted to know how we can help, what's the appropriate role for DOE, and how should we structure our program moving forward? So the recommendation from the panel was that we should narrow the focus of the program and invest in a quality, high-quality resources and only those areas that had critical R and D challenges and in parallel, we should pursue near-term resources as well as long-term. So they talked about the issues they haven't been getting financing as a result of the risk, the up-front costs and risks of exploration, of confirming hydrothermal resources and suggested that we develop and inventory of high-quality prospects again. So we're not talking about low-temperature resources here. Using existing technologies. So we're tapping the technologies, the exploration technologies used in the oil and gas industry and trying to determine how to modify those for geothermal environments. We're also working on reducing the costs of drilling and they also suggested that we invest some money, not a whole lot, but some money in reducing L and M costs by developing hybrid cooling or air cooing systems.

For the future, because of the high potential, the large potential of enhanced geothermal systems, they recommended that we first define the optimal conditions for EGS and identify the best geologies, the best prospects for demonstrating the technology that we enhance our modeling efforts to be able to assist our reservoir creation activities, and then wee develop the tools, demonstrate the ability to create and maintain a reservoir in a number of geological environments. There were a couple other things, important things that came out of the panel meeting. They stressed the need for some policy in the form of some sort of cost-shared drilling program. Not as part of the R and D program, but as part of policy to assist with the upfront costs of exploration. They pointed out, which we have long known, that the geothermal industry is small and has limited fundinf for R and D, so it's really up to DOE to lead here in fudning the high-risk R and D.

XXX: So XXX we are actually running out of time, do you think you could wrap up in maybe 2 minutes?

XXX: Okay so, well let's, so let me just go to the next slide, and I'll finish on the next slide. This shows how we determine where to make our investment in the program in terms of reducing technology costs. This is a cost-reduction scenario for undiscovered hydrothermal and it shows, what it shows is a discount rate is by the way the wrong term on this slide, that really should be called the cost of capital. And it shows how the cost of capital is impacting the levelized cost of electricity of hydrothermal what it would be if we factored in the cost of capital. And so the program is grappling with how we help the industry bring that cost capital down by improving the success rate of exploration, by helping to reduce the site exploration costs, and by identifying high-quality prospects as the panel recommended. So I'll finish there then, if I'm out of time.

XXX: Okay, well thanks so much XXX for dialing in and talking through that. Can we give her a round of applause? And now fuel cells.

XXX: Hello I am XXX with the fuel cell technology program, DOE. First, I'd like to give you a quick overview of the technology characteristics of fuel cells. Number one, it can contribute significantly to greenhouse gas reduction relative to the electricity from the grid. With heat recovery, it can also displace boilers, for example, that are used in building to generate heat, in addition to generating electricity which can displace electricity from the grid. And of course some of you may know fuel cells virtually eliminate criteria pollutions. For those of you versed in mechanical engineering, mechanical efficiency is a limiting factor in internal combustion engines, and fuel cells are not subject to that kind of limitation. As you can see that fuel cell efficiencies can be quite high as far as electricity is concerned. But it is on some very rough estimates that we have at this time, there are approximately 50-70 megawatts of electricity from fuel cells in the United States. Two and a half times that for the world, in total. Market value of annual production is project to be in the billions in the very near term. This is a quick view of the energy consumed by the commercial, residential, and industrial sectors, including electrical losses through loss of thermal energy and transmission, distribution losses. Fuel cells can expect to place in that arena. In addition, we haven't emphasized in this presentation, but as you know, fuel cell can be used also reversibly, in other words it can use hydrogen or some feed stock that can be turned to hydrogen, or vice versa; it can turn the electricity into hydrogen. So it can serve as support to the grid, it can be a companion to intermittent renewable resources. Fuel cells is an interesting character, in case you don't know about it, there are fuel cell fork lifts being deployed right now by FedEx, Whole Foods, the Department of Defense, huge logistic centers, they ship tons of equipment

to Europe and Afghanistan. They found out that the battery fork lift that we use tend to cost too much in terms of charging time, and plus the performance of these battery-powered fork lift drop as soon as the charge is no longer fully-charged, which makes a slight shortfall in charge, you see a huge drop. Whereas the fuel cell fork lift works perfectly until there's zero drop of fuel, so all they have to do is just switch the canisters. So they estimate that it is 70-some percent improvement in efficiency relative to the fuel cell fork lift. Even if fuel cells is used for fork lifts, for example, you can consider it at least with generation because it displaces the need for using grid electricity to charge these batteries, so that's why I said it is an interesting character. It has multifaceted applications. Someone mentioned that heavy-duty trucks is a very tough sector to reduce the oil. Recently we learned that the port of Los Angeles is cost-sharing with a fuel cell battery truck manufacturer for adding fuel cell to the fifteen battery heavy trucks that they have. The reason is that in ports, not just in California but throughout the country, the criteria emissions, the air quality is a huge problem, so the emissions of greenhouse gasses, those ports are forced to look at zero emission vehicles. Yes. And so the companies that are working with the port of Los Angeles actually they also have operations in other ports for example, port of Norfolk, Seattle, and the view that why look at LNG trucks, because they know that the other ports will be only a few years behind California in requiring zero-emission trucks for a number of their trucks, so they jump right into fuel cell slash battery heavy trucks. They told us that they are about actually 2 million short-haul trucks in the country that could use that technology and so we just barely started to look into this. So fuels cut across many industries, many sectors. The DOD is interested in fuel cells. They are very interested because it is provided submarines with white operations, trucks and tanks and other things, so we are partnering with DOD as well. This slide shows the growing production in both the world and the United States of the various types of fuel cells. Next slide, an example of early market deployment. The food industry is deploying fuel cells, Whole Foods, Price Shopper, Super Value, and so on so forth. I will not bore you with the details of this slide, that shows the four main fuel cell technologies, but all you need to know is that some of them are low-temperature, some of them are high-temperatures. High-temperature fuel cells have some advantages, such as they do not require reforming natural gas or biogas into hydrogen because they are hot enough that they can, there is some kind of auto-reform that can go on there. And some of them do not require platinum and other scarce material, but they are also negative as well. Like the high-temperature fuel cells may have problems with durability, corrosion issues, and so on so forth, so work is needed to improve all these types of fuel cells. Fortunately we saw that a lot of progress being made on this chart, it is a bit hard to see, you can see that a number of patterns for fuel cells really have been shooting up lately, compared to the patterns for the other renewable technologies such as wind, so on and so forth. This slide gives you the estimates that we got from working with various industry representatives in terms of the potential for cost reduction through these activities. So we came up with this cost-docket potential chart for industry. You can see that the ability to process raw fuel, biogas, landfill gas for example, and natural gas, come at a price. You have to invest in a significant capital cost for gas clean-up because these low-carbon gasses require clean-up more so than regular natural gas. Yes, uh huh. This slide gives you a portfolio of fuel cell activities, we cover the whole water front in terms of materials research, transport phenomena, we work closely with Office of Science on this. What are the roles of DOE and various performers such as national labs and industry? There's pre-competitive research, and there's cost-shared with various companies and

technologies, and then the national labs play a critical role in terms of, and so do universities in terms of pre-competitive research. National labs also support a testing and validation. Additional slides, well I think I will stop here. I'm done. Thank you.

XXX: Thanks Tien. Good afternoon everyone. My name is XXX, I'm with the Sunshot initiative with the Department of Energy, and I'm going to be covering or two technology pathways today, photovoltaics and concentrating solar power. So, to start off with a little bit of basics. PV, photons from the sun converting directly into electricity. Concentrating solar power, photos into thermal, and then into electricity. So now that we've got that stuff covered. The US is very rich in solar resources, one of the richest solar resources in the world. Photovoltaic can work everywhere in the US. It can be deployed on everything from residential and commercial rooftops to utility-scale systems in the field. For comparison, Germany currently has 2-percent, currently gets 2-percent of its electricity from photovaltaics, yet it has a similar solar resource to that of Alaska. Whereas the US currently gets 0.2 percent of electricity from there. And concentrating solar power has the same, the Southwest of the US has one of the richest resources in the world for concentrating solar power. In 1954, Bell labs created the first silicon solar cell. It had a 4.5 percent efficiency. About 4 months later it came out with a 6 percent efficient cell. 4 years later the Vanguard satellite was the first commercial application of photovoltaics with a 10 percent efficient cell. Since then the process of scientific inquiry and discovery has led to ever-increasing, or has led to increasing cell efficiencies. The US has been, US researchers have been the leaders in most of these. Throughout most of this, with significant or most funding comeing from the DOE. There have been improvements coming across multiple technology pathways, from everything from semiconductor materials to organics and inorganic materials. While this laboratory research has been going on, engineering and manufacturing scale have been doing there part to bring down the cost of solar. Just as we experience in other industries, with increasing scale, as you produce more widgets, the cost of each widget goes down. The solar industry has experienced for every doubling in cumulative production capacity, we've had about a 16-20 percent reduction in costs. This slide shows two stories, the first story that I'd like to touch on is the exponential market growth throughout the globe. Last year in 2010 there was about 140 percent increase in production in the US, or globally sorry. In the US we had about a 90 percent increase in deployment. The other story that this graph shows it the decreasing market share of US manufacturing. And so you know we could ask ourselves if we've been the leader in developing this technology, and the first company to develop the solar cell was an American cell, or an American company, why is this? And more importantly, what can we do to regain some of that market share?

Okay so we've talked about the exploding market growth around the world. Let's talk about some of the ways that we can help continue to bring down the cost structure. Simply put, the cost of the photovoltaic module is proportional to the manufacturing costs, and inversely proportional to the efficiency of the cell, the cell and the module. We can't leave out of the equation the importance of reliability for levelized cost of electricity, the current industry average for a warranty is about 25 years, so especially as we are making technology improvements, we need to make sure that we continue to research the reliability aspects of the technologies. There is across all of the technology pathways there's significant headroom for improvement in efficiency, both in terms of moving the research. The best laboratory results towards the theoretical maximum, and I would argue more importantly moving typical production closer to the research, to the laboratory results. There's also significant

improvement, significant room for improvement in manufacturing costs, both through the traditional engineering, learning through scale, and also through new processes that take costs out of the manufacturing. So here's an example, and to touch briefly on the importance of roadmapping, and this is one SIGS example that we are developing with NREL and it talks, it goes through the pathways for improving efficiency of one of the variable, the short-circuit current that affects efficiency. We are in conjunction with NREL we are developing these sorts of roadmaps for all of the different technologies, and to address all of the different pathways for all of the variables within efficiency and also manufacturing costs,. This is really important to make sure that we're on the right track, and to make sure that we don't miss opportunities.

So we've talked a lot about module costs, but they're only half the battle. Module costs are depicted in the upper left-hand graph in blue, the other half of the battle is what's called balance of systems and power electronics costs. These can be broken down into multiple different segments, which you can see by the kind of stack, it looks like a Smarties tube. Anyways, so we can break these down into hardware costs, and soft cost for balance of systems. So in terms of hardware costs, or hard costs, we are looking at improvements in power electronics and increasing the size, efficiency, reliability, and lifetime and also in terms of making these, enabling these to have smart grid technology with them. In terms of installation, we can have cost improvements through automation, through more prefabrication, through reduction in the amount of wiring and racking and hardware that we need when we install systems. In order to enable high penetrations of systems, we have to work with the grid and grid operators to incorporate them into a grid that designed for one-way power flow. For soft costs, just like all politics are local, all solar installation companies have to deal with the permitting and different requirements across jurisdictions. So imagine you were trying to start a company and for every one of the 18,000 jurisdictions on here you had to tweak your processes. Just imagine the time and the money and the paperwork that you would have to go through to do that. So how do we help meet this challenge? We are working to drive standardization, we are working to develop IT and software tools, and also create information databases that can take some of the complexities out of the installation process for these companies, with the overall goal of a 70-80 percent reduction in balance of systems costs. Oops, that was not the right direction.

So in February, the DOE Secretary Chu announced the Sunshot initiative with the goal of a 75-percent reduction in cost by the end of the decade. To do this, we are taking a whole-systems approach and we're working at taking costs out of all of the different pieces of the, out of all the different elements that we've talked about. Over the last decades, the DOE has made successful investments in both photovoltaics and concentrating solar power, and we're going to be continuing this with the Sunshot initiative. There are several advantages to concentrating solar power. It can easily combine with thermal energy storage. It can hybridize with natural gas, and with combined heat and power, and it also has an overwhelmingly domestic supply chain. So, CSP. People have been fascinated throughout, for centuries about concentrating and harnessing the power of the sun. And you know this can be evidenced by a little kid's fascination with a magnifying glass on a sunny day, and it can also be evidenced by this image of a solar-powered printing press at the 1878 world's fair. Current technology, there are three major current commercial technologies today. The first one the one that is the most mature technology is the trough systems. The first system was commercially developed in 1985, again mostly by US researchers and with significant funding

from the DOE. It uses a parabolic trough on a one-axis tracking system and for the power conversion it uses a commercially-available steam turbine. Its current heat transfer fluid limits its operation to about 400 degrees Celsius. Power towers were commercially demonstrated in 2006. They used a heliostat field with two-axis tracking and also use a commercially-available power conversion device. The current heat transfer fluid for towers limits its operation to about 600 degrees Celsius. Dish systems use a parabolic dish with a two-axis tracker, and on each of these systems there is a conversion, there's a motor on each of the individual dishes. So for trough and tower, there's one central conversion device, and for dishes it's on each one. For trough and tower, easily combine with thermal energy storage, and there are companies that are working with combining dish technology with thermal energy storage. So just like in PV, and everything else, cost drives deployment. As you can see in this graph, there's been a steady decrease in the cost of CSP systems, and the industry roadmap puts CSP competitive with intermediate load by 2020, and the Sunshot initiative ramps up that goal to have CSP being competitive with base load coal by 2020. And this is on an LCOE basis.

So thermal energy storage, I mentioned that before as one of the key benefits of concentrating solar power. It reduces the overall levelized cost of electricity by increasing the usage of the power conversion device. It also is able to offset the reliability of other renewable energy resources, and this benefit becomes increasingly more important and increasingly more valuable as there is higher and higher penetrations of renewables on the grid. One of the detractions from it is that it does increase capital cost.

So let's take a look at some of the subsystem reductions. Again simply the cost is the proportional to the capital costs, and inversely proportional to the efficiency. One of the main ways to drive efficiency is to move towards higher operating temperatures. In order to do that we need to develop new heat transfer fluids, and we need to develop advanced power blocks that can work at that level. By going to higher temperature, you're also able to reduce some capital costs of the thermal energy storage because you can make, you're delta T in the thermal energy storage is great, so you can have a smaller thermal storage. There's also a lot of cost reduction improvements from the solar field that can come about from things like improved drives and controls and support structures and just taking some of the material out of that. So this waterfall chart shows that there's opportunities for cost reductions in all of the different subsystems. Kind of the two major ones are in the solar field and the power conversion device. So, also as with PV, there are market barriers that reduce, that slow down deployment and increase costs. One of the accessing transmission is essential, both in terms of accessing transmission lines that are already close to capacity, and also in terms of building new transmission lines from areas of high DNI where CSP works best to electricity load centers. Another market barrier is the technology, the technology risk and the high cost of capital that comes with trying to finance these large multi-tens of megawatts, or hundreds of megawatts systems. In terms of approvals, most solar project developers will say that it's a lot easier to get projects approved that are under 20 megawatts. CSP plants that are most efficient or most cost-effective at much higher, like ten times the size, find this securing permits and the approvals to be a challenge, to be costly and time-intensive. So you know the Sunshot initiative also covers concentrating solar power and again with this goal of a 75 percent reduction by the end of the decade. Again, with CSP we are taking a whole-systems approach and we're going to be monitoring our progress based on roadmaps. So, thank you.

XXX: So we're going to move to breakout sessions, thanks for your patience sitting through a hour and a half firehose of all the electricity-generating technologies. It's fascinating the full breadth of what potential we have at our future disposal. So we're going to spend about an hour now talking in technology-specific groups just to dive more deeply into the presentations, work with the presentors, and us on the QTR staff to make sure that we're really grasping everything that we need to get about these technologies in order to woirk with them in the QTR. So I think it worked well this morning to have at least one group stay in here to help keep the noise level in the other group, the other room down and let people here. Because of the, just the numbers who are here, these are the six groups, please feel free to self-assign, there's no way I would be able to know which group you belong to, so please self-assign. Let's do the first five of these in the other room, and then fossil including CCS and geothermal here. And just basically if you look for the presentor of the relevant area and, yeah. Who's doing water and wind, XXX? Alright, so follow those guys for water and wind. And we will go until 3:30 in these breakouts.

(Time break)

XXX: So now we will hear a set of report-backs from the technology sessions we just concluded so that those of you who didn't get to sit at my table, for example, weren't so lucky, will get to hear a little bit about what went on at our group, and all of the other groups that you weren't able to join in. In the interest of time, these will hopefully be short and maybe sweet, in order to get back to discussing these bigger crosscutting questions from the morning and reopen the floor for further conversation.

So I had the pleasure of sitting in on the few, the proud, the water table, an unintended pun. So the challenge in that space really is the sheer number of different technologies and the different uses of those technologies. There's conventional hydropower, there's emerging marine and hydrokinetic technologies, and so the DOE's main challenge is figuring out how to use a relatively small dollar figure to have an impact in a very disparate space. So on the conventional hydro side, one of the areas that was really interesting to me was how much the value in a new hydropower is really as a flexibility resource, and as a using you know advanced pumped hydro technologies and such to provide not just generation services, but also grid services. And there's an emerging challenge that we had, it came up a couple weeks ago in our grid workshop as well, of the financial models and how to value things that are not metered kilowatt hours. And so conventional hydro now that is acting as a flexible source is not actually really necessarily was not designed to be operated in that sort of ramping up and down mode. Maybe new technologies coupled with new financing models may be able to navigate that space more clearly. On the marine and hydrokinetics side, there are some challenges in resource characterization, although that's more of a matter I think subsequently for this conversation, more a matter for not a resource characterization for a particular point you know where it can be well characterized, but in trying to understand national, international potential when there's a whole bunch of other kinds of risks that play into what might shape the size of a resource.

We talked about the kinds of metrics that might matter for marine hydrokinetics, and essentially because costs are overwhelmingly in the materials, you can almost think of energy per ton in addition to energy per dollar really playing in that space. And definitely an interest across both conventional hydro and marine hydrokinetic in challenges of permitting, and the

amount of costs that really comes in from that step of the process, not maybe necessarily from technology development, but proving out technologies, and then handling the permitting processes. So I'll hand over to XXX who will do wind.

XXX: If I could not kill myself on that speaker. So my, I had a great discussion in the wind section and so I'm going to ttry to fly through this really quickly. But if I miss anything, don't hesitate to speak up. One of the main themes that came across today is that you know we keep talking about moving to offshore wind but really we shouldn't give up on onshore. It's so close to being parity or even surpassing parity with fossil that to really to leave it now would be a shame and that there are still opportunities to leverage DOE assets and do tech development in order to get onshore wind there. So assets such as high-performance computing, and the materials capabilities of the DOE would be really helpful here. Tech development again for materials, component reliability, are still major areas for for growth. There was a lot of desire to think about wind in terms of the systems perspective. A lot of time the components have been optimized on the component level but not on the system level. We need to think about wind as power plants, about wake effects, all these different things, kind of think beyond the turbine. Some of the unknowns in this space were the long-term effects of unsteady loads and especially actually the environmental effects because there's so, there's not quite enough data about downstream effects of wind and wind plants. And basically doing wind at scale that that's going to be a major barrier to maximizing deployment and getting the permitting that will be required. There is also a feeling that some of the cost metrics are out of date for on shore wind and that we've already passed some of the goals that DOE has for a decade in the future. For offshore, permitting was going to be a big barrier and that foundations will be a challenge and one thing that was expressed was that there's a continuum in the foundations, it's not just floating for deep water, and fixed-bottom for shallow, that's there's really more of a continuum there and to divide it that way would be, would not do it justice. There was a general feeling that supply chain is going to be a really big issue in this area, and that DOE could help again with the materials development, manufacturing, to really get that off the ground. And then in terms of ground-breaking technologies there was a feeling that DOE really should have a role in kind of doing the evaluation or the assessment of some ground-breaking technologies. We don't necessarily need to invest in them, but to have an opinion is really important for DOE just to show that we're kind of up on what's going on. And with that I will turn it over to whoever wants to go next. I don't know who's going next.

XXX: So in the solar team first we talked about the DOE taxionomy. There was agreement in how we broke down photovaltaics into silicon, thin film, and high-concentrating PV. In CSP there's disagreement so, we had kind of had the trough-tower-dish model, there's a proposal to do it more based on ranken cycles versus stirling engines that there's a view that we had too narrow a pathway on storage that focused on sodium and that we should consider other pathways, and other types of sodium as our salt dome storage. There was a view that when we come up with pathways we tend to pick pathways that are novel and exciting, that have high theoretical potential. We don't apply a raw-material filter early in the process that asks can we scale this? You know, is there enough raw material for cad tel or CIGS to ever scale? And are we going to hit a resource wall that we could have avoided had we thought of raw materials earlier in the selection process?

There was a question, should we be setting a bar for efficiency? So we have a dollar a watt goal, should we just cut out all pathways that can't achieve let's say t10 percent efficiency?

Or would that kind of cut out some creative solutions? And so that was a debate that we didn't resolve, but it's something that we'll certainly bring back to our program. There was a view that the dollar a watt target which I think everyone is DOE would agree is aggressive, that there are when we set an aggressive goal, and it's good to do that, we should also know that there are consequences. So there are lower-risk, more achievable pathways that have loess credibility in the private sector among financiers when DOE sets a goal that that pathway can't achieve. So let's say there's some technologies that can get a dollar fifty a watt, but is highly likely to get there. All of a sudden a very aggressive goal makes them look less favorable in the yes of investors.

Then on CSP there were some arguments that particularly around competitiveness and manufacturing. There's a lot, there's a huge opportunity in CSP to leverage some tier 1 auto suppliers, that we can kind of get to gigawatt-scale production in the US, as these parts commoditize. There's a view that we'll stil be above a dollar a watt, even when these parts are commoditized, so there's still more R and D to do in CSP, but that piece of the puzzle, competitiveness, manufacturing jobs, is very attractive in CSP. There was a lot of consensus, maybe the only topic where there was a lot ov consensus, is that soft costs around permitting and siting, like we heard on the nuclear this morning, that there's a first-mover barrier to anyone solving permitting and siting at the local or national level, and that's a great place for DOE to intervene. And that would unlock a lot of distributed gen, and a lot of utility-scale CSP.

Finally, there was a view that when we produce prototypes, we produce prototypes, we produce prototypes for the sake of producing a prototype, and we need to end that process, develop prototypes that can scale. So as we think about the photovoltaic manufacturing initiative, when we think about the various Sunshot manufacturing initiatives, to think of designs that can scale earlier on in the process. And with that, I turn it over to Mike or to Avi.

XXX: So I have kind of a sort of a slap-dash sort of bunch of notes from the nuclear breakout session. The discussion seemed to center around, a large part of the discussion was dedicated to facilities. And we started off citing a need for more high-performing computing facilities and better software for modeling. That said a need for a full-scale test facility that can accommodate entire fuel bundles was cited. The ATR at Idaho National Lab being, is great but is limited, and it takes a long time to get new technology into production in nuclear. Rather than getting dollars from DOE to do work, DOE should build a full-scale facility to test rods and bundles, and it would shave up to maybe 8 years off the production cycle. Such a facility would have to be able to survive or accommodate fuel failure, and be cleanable and reusable afterwards. A user facility model is something, kind of what they have in mind there, that provides incentives to invest in new technologies, perhaps something along the line of a small modular reactor. That's because no real reactor operator would allow tests of fuels that only pass muster in simulation. But then again, the models have to be validated, so there's a definitely a thread there that they have, that there was a real need for that.

Also mentioned were a fast reactor test facility, and improved separations facilities for reprocessing. Also discussed were alternatives coolants for reactors, like high-temperature gas reactors, and other helium-based reactors need more investment. MHRs, for example have great power density, but their cost is excessive, sometimes two times the cost of a light-water reactor on a per-kilowatt basis. And that rose the question that was not answered, but something to be considered, is what technologies have a realistic chance in the US market, especially given that natural gas is, well it seems to be the biggest competitor right now, that

seems to be what the group saw. That was their arch-nemesis, or however you want to look at it. LWRs just can't beat natural gas right now. There are other alternatives, like looking at, we discussed the possibility of using processed steam from light water reactors. At one point I mentioned taking out the low-pressure turbines and using the steam from the high-pressure turbines as perhaps for processed steam. Perhaps someplace where nuclear could compete with natural gas because the natural gas is not, would not be as an effective source to get large volumes of steam.

Also mentioned, sort of shifting gears a little, was a need to get large early buy-ins from stakeholders for small modular reactors for early site licenses. Also, some thought, not necessarily the majority of you, but some thought that the DOE should not necessarily try to pursue a LWR industry in the US. Some are feeling that that ship has perhaps sailed, rather alternative designs should be pursued, such as the small modular nukes for example. Now that said, the United States generally won't license a reactor design without a utility sponsor, and that's usually a domestic company. And other countries won't usually license design without an NRC license, so there might be some leverage and some play there. Also the question was raised as to whether or not there should be a, is there a need for a used fuel management program to sort of handle the, as many of you might may not know that there is a large amount of, oh actually now that I think about it XXX covered that this morning. There's a large amount of fuel that's just being stored on-site, and does DOE need to get involved with a fuel management program? Also, very, this was stressed too, the need to know the desired end point, what's the end state for fuel disposal? Where do we need to go, and that'll give us a better idea of what to research in order to get to that point. Right now it's, we don't know, especially with the Yucca Mountain situation that's off the, it's probably completely off the table. Let's see what else. Oh and also, and this wasn't exactly the order that we talked about them but, we were also, we did discuss briefly possible, the need to consider the possible impacts of the Fukushima catastrophe on the US industry, and it would be interesting to see some studies of the transport of released material in the environment and the effects of the, the health effects of the material that was released, so. That's about it.

XXX: Okay so I had the fuel cell technology assessment. So in working through our discussion, with the effect to the question of whether we got the taxonomy correct, I guess the answer, or the opinion was partially. Clearly there;'s a role for fuel cells in clean electricity, grid storage and vehicles. Visibility, we haven't, we're not, haven't well understood how well fuel cells fit into the DOE strategies or into the DOE programs. The thing that the department can do very well is to undertake the analysis that can show where fuel cell technologies can be deployed successfully. There was, several people mentioned that that was an area where that can be an enormous help to various companies. When it comes to looking at the headroom, several comments were that DOE has the tools to do this, we just haven't properly assessed the headroom. When it comes to milestones, near-term milestones in particular, the department seemed to do a better job in establishing near-term milestones for the mobile application, and did that less well for stationary applications. When it comes to the DOE role in fuel cells in different markets, whether it's a mass market, say light-duty vehicles, niche markets, heavy-duty vehicles, or smaller parts of the stationary sector, how DOE parses its role in those various things was somewhat less clear. I think that was, I mean we had a very robust discussion, but in the interest of time and getting on to the broader discussion, let me then summarize some of what was heard in the crosscutting breakout sessions this morning. Couple of quick slides, here DOE's primary value that we heard is through this informational

role, as an information clearing house, provision of test facilities, being a referee or an independent assessor, being able to point out where that technology headroom is, what market potential is, validation of technologies, or component performance. That one of the great things that the Department brings is this lab expertise that allows technologies to ride over fluctuations in money or policy. What we within the QTR group and having a lot of these discussions is what we have referred to as a capability mode that the Department brings this deep technical knowledge and capability and is perceived to own a national energy strategy. So that is something that we the various people encouraged us to recognize, maintain and leverage. There were comments that roadmaps are important, and that DOE should both shepherd their development and drive technologies along those road maps. DOE endorsement or in fact the lack thereof was seen as having enormous signaling power. That the Department should work with various industries to identify technology needs, and that sharing these needs helps direct private R and D funds and sometimes can be particularly influential with small companies. That the department should do pre-competitive R and D and then furthermore, mature technologies, DOE should focus on reducing non-technical barriers, whether it's regulatory or something, whatever the case may be. And that everything in the middle, the industry can do that well enough on their own. There was a view that DOE should take more risks and that we undervalue reporting what doesn't work. And that there's real value in the failed efforts. People learn a lot of what not to spend money on, and that actually can increase efficiency overall. The DOE should make these negative outcomes and the reasons why the outcomes were negative more available. On appropriate role of government there were several different viewpoints; that we should invest and support anything that is not commercially available, that we should identify what an industry is not doing and understand why they're not doing it as a way to determine what we should do. Others thought that we should pick winners all the way through to commercial-scale demonstration, but we have a responsibility for explaining and justifying why we make those choices. In figuring out how we should spread our portfolio, the Department should focus on technology a couple of generations out and that anything that has impact more near-term than 3 years isn't really practical. I guess the contrasting viewpoint was that the Department should really focus on these pre-competitive R and D and knocking down the non-technical barriers. That these test facilities, user facilities, technical work at the national labs are great assets, but partnering is made somewhat difficult by variability in requirements, and that we can make that interaction with our assets more effective by focusing on that. And with that, I will turn it over to XXX.

XXX: So we are to the end of a long day. One of the things that I always look for is to what extent there's a buzz in the room, and the fact that we had to intervene to stop the breakout sessions suggests that people were pretty much engaged, and that's great. I've got a set of concluding remarks that I will go through at the appropriate time, but I would first like to throw the floor open again. You've now had two breakout sessions, you've heard some of the summaries from the technical sessions and these crosscutting thoughts. What are your own reactions? Again our goal as a QTR team is to try to put some framework around this, tell a story, as well as lay down some principles and try to make some programmatic priorities, recommendations, and so on. In those directions, any of you have any clear signals during the day? Or thoughts? No, it's late in the day. Maybe some--

XXX: (Unamplified response) -- Going all the way back to year one, and one of the important things that I think is coming out of this is that both on the part of the DOE presenters, and on the part of the those who were invited to participate in this review process,

there seems to be a one good thing coming out of this is a consensus that we need to break down those stovepiping barriers, and there seems to be a real willingness to do that in a serious way, which has not been easy to do in the past.

XXX: Good, alright, thank you. We'll see how far we get. Alright, okay, right, we haven't asked for consensus. Maybe we'll say a few words just to say where I am, after the day. This has been an interesting day but of the 5 workshops that we have done, at the moment it feels to me the most problematic. And that's a little bit ironic because you're all after the same goal in the end, which is clean electrons. Yet I am frankly bewildered by the diversity of maturity of the technologies and by what you all feel the government should be doing to move those technologies along. As I try to frame the problem, one of the issues of course is incumbency. There are already actually pretty good ways of generating electricity, some of them cleaner them others, but some of them certainly quite clean. And another is the maturity of the US generation system. I'd hold up, and it would have been interesting to open a discussion this morning with some of this data I pulled up while I listened, and the ability to find the information just wonderful these days. The EIA projections for generator capacity additions in the US for last year and the current year, and in round numbers, the US is adding about 20 gigawatts of capacity. Let me take 2011; 19 gigawatts of capacity, 2.5 of that is coal, 11.5 of that is gas, so a little more than a half is gas, wind is 4 gigawatts, solar, both thermal and PV is 1, and all of the rest is small potatoes. Alright, so in round numbers, 20 gigawatts added, and if I count up dollars, that's about 50 billion dollars a year that the US is investing in capacity additions both to replace the aging fleet, which probably has got a mean lifetime of 60 years or something, which would be a 1.5 percent a year increase, and then another one percent addition, so 2.5 percent, it works out about right. Most of the technologies are not mature enough to be competing with one another in the marketplace. In the end, the country is spending about 50 billion dollars a year on this stuff. It's not a tremendous turnover rate. You do a calculation, and you can say if our goal is to get to 80 percent clean electricity in 25 years, if you're turning over at 2.5 percent a year, in 25 years you'll turn over 60 some-odd percent. And if none of that is coal, at least unsequestered coal, then you'll probably get to that standard. But everything else is going to be in many ways fighting for those same dollars. And perhaps as several people have noted, increasing electricity prices.

In many ways I come back to the question, a couple of the questions that were posed at the beginning, frankly again without satisfactory answers. What is the DOEs purpose in doing what it does? Are we supposed to solve the problems? Greenhouse gases, US competitiveness, this is less about energy security in the clean energy sector. Or are we supposed to just do great technology development? If it's to solve the problems, we had a good discussion at my table, I think this morning, how do we balance US competitiveness against greenhouse gas reductions? And clearly if you favored one or the other, you would have a different portfolio mix. If it's just technology, if our goal is only to do technology, it's probably a somewhat easier task, we'd just help facilitate technology development, some of the things that Mike was talking about, we've all talked about. I don't know, I haven't gotten an answer to that yet, or at least a clear sense of what it is we're supposed to be doing. And if clearly we are supposed to be solving the problems, if greenhouse gases were that important, I think we as a country would be doing a lot more and a lot differently than what we're doing at the moment. And somehow we've not decided collectively to take on that challenge yet. Mike has emphasized our informational role, I think that's really important. We actually do it

pretty well for technologies. I think we don't do it very well at all for systems issues, and in particular there are three issues, or two other issues that I think we need to bring in. I think the social issues we have discussed, we are not very good at the social aspects of what we do, and I think also we're not very good at understanding the business context. And in many cases we've developed things only to see them effectively stillborn because industry won't take them up. So we need to do a better job I think of understanding the business context in what we do.

Of the technology discussions, the notion of hybridization of diverse power sources in a single facility seems to be particularly interesting and useful. You know, combining CSP with geothermal perhaps with gas backup, perhaps with wind, with the heat from SMRs, all of these things perhaps there are novel ways of getting extra value out by collocating these or using the heat from some of the thermal systems. Also the notion of what the Chinese call polygeneration, the idea of using facilities to produce eelectricity and chemicals at the same time, whether it's fuels or something else. Bob has long been an advocate of that and there are probably some deals that will make sense even on their own economically, and still enable CCS if you're making chemicals, it's pretty easy to capture the CO2. What's going to happen in the future, and how we position ourselves the DOE, I think there are two big unknowns: one is gas and what's the price of gas going to be, and will the US continue to have cheap gas, or will the prices go up either because production becomes constrained, hard for me to believe actually, given the US resource, domestic nature of the jobs, the domestic nature of the resource, relatively low cost of extraction, I don't see how that's not going to happen frankly. But what the price will be remains to be seen. Whether we couple to the international market or not is a big unknown also. And then carbon regulations or carbon price, whatever you want to call it, another big unknown. And somehow the DOE has got to maybe make the technical base of the country and our understanding of the technologies robust enough to handle those contingencies. I don't know, that's a kind of rambling summary, but you know, I'm happy to throw the floor open before I say goodbye to everybody. I've got to go give a talk in a while, so the day's not over for me yet. Thoughts? Yeah.

XXX: (Unamplified response)

XXX: So I would ask some of the products of this process, we haven't you know. I think the DOE doesn't do a very good job of telling its story frankly. I think when you look at the public face we present it's not a very coherent one. We don't talk much about the science, no we that's not fair. We do talk about the science we do, but it's not out there in the same way that NASA for example, or NIH is out there. We have a very mixed and confused message about energy and what we do, and part of this process is to try to get that straight within the DOE community as well as starting to tell it to other parts of the administration and congress. So I would hope, I mean you ask me what success is in this process, it will be to be able to lay down, first of all to help the department tell its story, to lay down a framework that we can continue to use through multiple administrations about how we think about energy and maybe it's the six strategies, maybe it's something else. And then to be able to give a sense, a rough sense of priorities as to what the department can be doing, which has enough rational analytic basis to it that it can endure for a decade or more, and we can get some consistency. As somebody said, you know consistency is maybe even more valuable than the absolute more dollars itself than maybe the funding, yeah.

I think also maybe a realization within the government that maybe you know the technology loan is maybe not going to do this, and we need to get a good interaction and

synergy between the technology and the policy. So part of what we're doing is trying to educate the policy folks about technology. Yeah.

XXX: (Unamplified response)

XXX: Yeah, XXX, yeah.

XXX: (Unamplified response) Thank you. If you can really provide a good catalyst role and that can enable and one part I really liked is for the generation was creating a higher-value proposition for solar, wind, other forms of clean energy, they usually offer so much value. As a portfolio can you make one plus one equal three?

XXX: Yeah, I think that's the challenge that we have as we try to think through this. So I, let me just contrast, I mean you mentioned greenhouse gases as the problem, and I think that for this audience that is a major, maybe the major focus. You go to the transportation side, the oil is the problem. And there it's much easier to get everybody to agree that there's a problem. On the transportation side, the problem we have is getting people to understand what are good solutions or enduring solutions and not enduring solutions. And you know just for example, drill, fine, that's jobs and it's balance of payments, but it's not price. And you can't produce enough oil in the US to make a difference on the price; just the market's much too big. So I, you know, I, but even there where you can get everybody to agree on watt the problem is, the government doesn't seem able to do much. Alright, (laughs) alright.

XXX: So one thing we we've kind of walked around is resource consumption. And you kind of say well that's not our department, but in a way the energy converts resources to electrons, or whatever they convert to. So the resource piece is really really important, and it impacts environments. So greenhouses or not, the resources are still and the assets are for people of the United States, it's theirs. And so the management of those resources, and the conversions of those resources could be another way of addressing the identity of what it is that the department does. Instead of saying we have to work on greenhouse gasses, and that's it period. Or we have to wait for that to come in as a policy. But I don't think that you can dispute that the resources, you can't really argue about that either, so that's another way of, so finding another way of approaching the element without, you don't need to take ownership of the resource, but you need to say we are using them and converting them, so our job is to use them wisely, efficiently, and convert them with a careful environment.

XXX: That's an interesting way of thinking about it.

XXX: So I want to encourage, I think the political environment is really not to discuss greenhouse and carbon, and even if it was I'm not sure it would drive important developments. But if you look at it from a fundamental perspective, what would you do if you were 100 years ago and you didn't' have anything that you consider your resources? That's a fundamental thing in human behavior. And so, taking resources and looking into how we convert them is really the key, and my view from the wind industry is so well, why don't we take some of this wonderful oil things but it has a seriousness that we are mindful of using the resource first for something, and then for something else afterwards, so it has a recycling element.

XXX: That's a different frame. Anybody else? It's the end of the day. Good. Yeah.

XXX: XXX, AREVA Solar. Given the resource constraint within DOE in terms of the funding, I think the issue of widgets versus systems and so forth is likely to tilt toward widgets. And that means we need to think about how we make best use of those resources. And I was thinking this morning about a successful model that the DOD used in the 60s when semiconductors were not sole-sourced, and there was a combination of a cross-license which

facilitated rapid knowledge exchange and diffusion with this strong commercial incentive because basically the information was kept proprietary. So I think that we really need a model that allows a strong commercial interest to be retained by a company or companies and use the DOE as a catalyst to facilitate and convene and facilitate this knowledge so that we can really grow this up very rapidly.

XXX: I think we're ripe for a collective engagement of industry more than we do in various, you know the Sunshot is some way of doing that. We probably haven't gotten the formal IP issues sorted there. The automobile industry does this a lot already there are good consortia that work well in the automobile industry. Nuclear I think is well-tuned to that already. So yeah, a more collective engagement of industry to, what was it the pack, who was talking about the pack in bicycle racing? Per was, and so, a good way to proceed I think. Anybody else? Okay.

I want to thank you all for contributing your thoughts. We are as you've heard scrambling really to put this whole thing together of which this is a one out of five, or one out of six if you count the other matter. We will be back in touch in various ways to engage you into what we're generating. There are all kinds of constraints about both openness, but also what needs to stay inside the government, but then what gets formally released. We are also navigating the interdepartmental and intragovernmental thing which is frankly by far the hardest part of the process. But I want to thank you for your thoughts and discussion, and look forward as I said to engaging you all as we go forward in this. Alright, okay, Mike is reminding me, there will be a capstone meeting in which we hope to talk about a lot of the things that we're finding out on July 13th in DC. And that's just about to hit the Federal register Monday, and we'll be publicized more widely throughout the DOE community, so watch for that date, and that announcement as well. Okay. Thank you all.

XXX: Two tiny logistical things as we're packing up. First of all, if you have a hand-written name tag, it means that we didn't know you were here, and so it would be really good if we did know you were here, so if you could find me and get me your card, your name, your information, that'd be really useful. And second of all, XXX is giving a talk at 7:30 at Old Main here on America's energy challenges, and you are all welcome to attend. Thank you.