EIA Energy Conferences & Presentations, April 7, 2010

Session 10: "The Energy-Water Nexus: Availability and Impacts"

Speakers:

Howard K. Gruenspecht, EIA

Shahid Chaudhry, California Energy Commission

M. Michael Hightower, Sandia National Laboratories

James Richenderfer, Susquehanna River Basin Commission

Jeff C. Wright, Federal Energy Regulatory Commission

[Note: Recorders did not pick up introduction of panel (see biographies for details on the panelists) or introduction of session.]

Howard Gruenspecht: Okay, we're going to try to get underway here. We're still catching up on schedule from yesterday lunch, but I think we're making it back. Well, good morning, and welcome to the conference session on the Energy-Water Nexus. I'm Howard Gruenspecht, your moderator. Since it's going to be one of the last two breakout sessions in the conference, I think it's been a very interesting conference. We've covered a lot of ground. This session we're going to be going into a topic that EIA has not paid a lot of attention to in the past, and it's an opportunity for us to learn more about a topic that's increasingly important. I would like to thank you all for your participation in the conference. I'd like to thank SAIS for working with EIA on this effort, and this is our first time in this venue. I think there were some challenges but a lot of good things as well, so we appreciate your participation. We appreciate your input. The conference doesn't work well without you, and we appreciate any comments so you might want to provide down the line on how we can make this a better, more informative experience for all involved, but it is important for us to reach out to our customers, and we do appreciate your interest. I'd like to exert moderator's privilege, if there is such a thing, and change the subtitle of this session to Energy-Water Nexus Impacts and Availability. I think that change reflects the bi-directional nature of the Energy-Water Nexus, as pointed out, I think, by Steve Bolze of General Electric in his remarks in the opening plenary yesterday. I said it in the Smart Grid session this morning, and there was even a side comment about needing to change the way we use water as well as the way we use electricity. I think the comments that our panel will provide, which look at both the energy implications of water requirements and the water implications of energy requirements, really reflect the bi-directional nature of the nexus. The Energy Information Administration certainly recognizes this as a topic of growing importance, which is why this is on the program. SAIS thought it was important, we thought it was important, and we want to learn about it along with you. There was a time when EIA's focus on the energy-water nexus fell primarily with variations on the availability of hydroelectricity, the electricity supply mix in the Pacific Northwest and other regions with significant hydropower capacity. It was and is very dependent on annual precipitation, and snowpack build, variation and the availability of hydropower, and the need to generate power from other sources clearly had impacts on electricity and fuel markets in that area, but more recently, our concerns related to the nexus have broadened in part due to the increasing interest of our key customers. Among others, Congress has shown an increasing interest, notably the American Clean Energy Leadership Act — it was reported by the Senate Energy and Natural Resources Committee last year — includes an entire subtitle on energy and water integration. As you know from yesterday's sessions, the legislation is in a temporary holding pattern pending a decision regarding whether to proceed with energy-only legislation, the combined energy and climate bill, or some hybrid approach. I will not comment on what will happen there, but the energy and water integration provisions in that bill would launch numerous studies and assessments of various facets of the energy-water nexus including development of an energy-water research and development program and as part of that effort, the legislation requires enhanced information collection by EIA on water-related energy consumption, which I think we'll hear today is significant. The General Accountability Office, at the behest of Congress also identified the need for more information on energy-water nexus in a recent report. They recommended, to both us and the Geological Survey, needs related to a different aspect of the nexus: the use of water for cooling power plants; I think that also came up in Steve Bolze's presentation. It's one of the major uses of water in the United States, and there's increasing interest in both cooling efficiency and the use of alternative water sources such as treated effluent or ground water that's not suitable for drinking or irrigation for these purposes. We do think that better information on power plant cooling would be useful and would not impose undue burdens on our respondents who are therefore responding to GAO's recommendations with a series of changes in our power plant survey forms to collect more information on cooling water technology and cooling water uses beginning in 2011. Again, clearly these are not the only two areas where the energy-water nexus arises at EIA. One area that we're paying attention to is water requirements for possible increase in the use of biofuels as EIA revises and refines biomass energy supply curves, use in its long run energy modeling systems, the importance of water as a potential constraint is increasingly evident. Another key area is impacts of energy development on water. These impacts can involve both the use of water and possible effects on water quality, and recently there's been considerable public discussion of this issue in the context of shale gas development, which has itself been a recurring topic of discussion at this conference. I could go on listing more areas, but that would really serve little purpose to use our river analogy, the energy-water nexus is truly a mile wide. Over time, it will need to be addressed and probably much more so than an inch deep. Today, of course, we can only make a start with the help of our distinguished panelists. The concept of the session developed in discussions with the panelists is to start with two big-picture overviews of the nexus and then drill deeper, and I didn't really intend to pun when I thought of that, into two specific issues: the nexus between water and shale gas, and the use of cooling water by thermoelectric plants. With that road map or swim lanes laid out, let me briefly introduce our panelists with me. Actually, I won't go through the bios because they're in the program. Mike Hightower's a distinguished member of the technical staff in the Energy Security Center at Sandia National Laboratories in Albuquerque, New Mexico. He has a lot of experience in this area, focusing on among other things, security and protection of critical water and energy infrastructures, and he is one of a group of scientists from a wide range of labs in other organizations that helped write a report to Congress on current and emerging energy and water interdependencies and challenges. Shahid Chaudhry is a Program Manager at the California Energy Commission. He has more than two decades of experience working on a wide range of water-energy relationship issues. I guess the experience in the United States often suggests that California is not like Las Vegas in that what happens in California often ends up affecting things and the rest of the country. It's often a leader. So Shahid has been a leader in that area in California, and we welcome his comments. Jim Richenderfer is the Senior Scientist and Acting Chief of the Water Resources Management Division at the Susquehanna River Basin Commission. His duties include supervision of engineers, geologists, hydrologists, environmental scientists, and biologists. He focuses on the long-term sustainable utilization of the Basin's shared water resources. Of particular interest today is the fact that the Susquehanna River Basin overlays a significant portion of the Marcellus Shale, which is one of the hottest shale gas plays in the country. I guess the word "hot" is probably a bad thing to use — one of the most important shale gas plays in the country. Last but not least, we have Jeff Wright, the Director of the Office of Energy Projects at the Federal Energy Regulatory Commission. The Office is responsible for the licensing safety administration of nonfederal hydroelectric projects as well as the processing of applications, the construction and operation of natural gas pipelines and storage facilities, siting of LNG terminals. We are fortunate that Jeff will be able to address the use of water for cooling of thermoelectric generation facilities. So with that, everyone's introduced, and we anxiously look forward to your comments. So, Mike, do you want to kick it off?

Mike Hightower: Thank you, Howard. Let's see. I was asked by Howard to give a short overview of some of the energy-water issues. I'll talk about some work that a group of representatives from the National Laboratories have done in support of the Department of Energy at the request of Congress to look at the issues around energy and water. So I'm going to spend just a few minutes highlighting some of the trends that we see we've been able to develop over the last several years with the data from the U.S.G.S., the Water Reuse Foundation, desal coalitions, biofuel organizations, oil shale organizations to kind of give you a feel for how water is used for the electric power structure for the transportation fuel sector and how energy is used in the water and wastewater sectors. So I'm going to try to go through these fairly quickly. The other people behind me will go into detail in a number of these areas. So first of all, just to talk a little bit about how energy and water are interdependent, we use a significant amount of water in this country for thermoelectric power generation. Over 50% of the water withdrawn on a daily basis in the U.S. is for electric power plants as cooling water today. We use a lot of water in certain parts of the country for hydropower, and as we look at climate change issues and environmental and ecological issues, how we operate hydropower facilities and how we do a small-scale hydropower and kinetic hydropower in this country could be impacted by that water availability. We use a lot of water for minerals extraction, specifically the refining sector uses a significant amount of water in the refining process, and as we move into things like the hydrogen economy, biofuels, gas shales, oil shales...those also require significant quantities of water, and I'll talk about the numbers there. So we have a significant need for water to support energy development in this country. On the other side, energy for water, we use a significant amount of water energy in the United States. For the water sector about 3% of our energy reduction goes to the water and wastewater sector, for pumping convenience treatment. As we look at new trends in water treatment requirements, the use of nontraditional water resources like desalination, brackish water desal, seawater desal, wastewater reuse to address some of the water shortages in parts of the country, we will see an increased need for energy to treat that water or convey fresh water from different parts of the regions of the country to other regions. So it's a huge interdependency on both sides, as Howard mentioned, both water for energy and energy for water, and the trends are that we're going to see an increased demand for water for the energy sector and an increased energy demand for the water and wastewater sectors. Not all the water that we withdraw in the United States is consumed. We'll talk a little bit about that. In the United States, most of the water that's withdrawn is withdrawn for irrigated agriculture, so efficiencies and improvements in irrigated agriculture could free up some significant water supplies. Most of the irrigated agriculture in the United States, though, is in the Western U.S., so water demands in the Western U.S. from a regional standpoint may be met in the future by transfers from irrigated agriculture. But there's not that much irrigated agriculture in the Eastern U.S.. So, where there are water shortages, we may not be able to use some of the efficiencies in agricultural water utilization for energy requirements in the Eastern U.S., but if you look at the water consumption that we have, if you had the thermoelectric sector and the refining sector out of the industrial sector there, we're using somewhere around the order of four to five billion gallons a day consuming 45 billion gallons a day in the energy sector in the United States. You compare that to the domestic sector which is about seven billion gallons a day. Currently, we're about on par with using the same amount of water as the domestic sector does in the United States. And here's the issue: the bottom line is as we grow our energy demands, as we grow how we change our transportation fuels, we could see the water demands in the energy sector double, triple, or quadruple in the next 25 or 30 years without some major changes on how we utilize water. That would suggest that the energy sector would become the largest nonagricultural water-use sector in the country, and we're going to have to address that, figure out ways to make sure that the energy sector is not impacted by water availability. So real quickly, here are some limitations that we see in the research that we've done for the Department of Energy. On the left-hand side, what you see is surface water availability in the United States of reservoir capacity and withdrawal capacity. And essentially, since about 1980, we have maxed out on our fresh surface water supply availability. We have not built any new reservoirs in this country in the last 25 years, so we're essentially using all of our fresh surface water capacity that we have available. If we start looking at concerns over climate change, especially in the U.S., our expectation, as in many others, is that the fresh surface water availability will actually go down in the next 25 years by 10 to 20%. If you look at the ground water supply availability across the country, what I have shown here is information on major aquifers in the U.S. that have been impacted by over-withdrawal or over-pumping, are dangerously already stressed by over-pumping, or aquifers that have salt water issues in the sense that we're getting down to the bottom of the aquifers, lower parts of the aquifers which are more saline or that have seawater intrusion issues around the coast. So in the middle of the U.S., you see the overall aquifer in the high plains which is a poster child for non-sustainable pumping practices and ground water utilization practices. But what I'd like to point out when I talk to audiences is that if you look at many other aquifers in the Southwest and the West and even in the East and Midwest, we have major aquifers in this country that are being over-pumped and unsustainably utilized...in places like Wisconsin and Minnesota and Illinois, in Montana, Idaho, in Florida, South Carolina, and North Carolina. So this issue around water availability is not a Southwestern United States problem. It is a national problem, and many of the regions of the country are going to see water stress and water shortage issues in the next 25 years. I'm just trying to lay this out. So as we try to do energy development in the country, both in the southeast-northeast, southwest-northwest, we've got to look at water supply availability issues as they will impact energy development. Here's just a report by the GAO from few years ago where they asked water managers across the country whether they expected to see water shortages for the next decade under average conditions. There's another VRAP that talks about underground conditions, but even under average conditions, the point I'm trying to make here is that the water managers are beginning to understand the water issue and the lack of freshwater availability in the U.S.. So you can see that in regions of the country that we don't normally think of having water stressed issues, of the Pacific Northwest and the Southeast, the water managers are saying we have some water issues that we need to address. We need to take these into consideration as we move forward in planning energy development in this country. I'm just trying to show here from this videograph, this is from NETL, some work that they did, where the major growth is expected in electric power generation. I know that these numbers change every year from EIA, but I think the general trends are there, whether we're going to see actually 80% in the Southeast it may not be that with economic issues currently. But the fact is that we're going to see major growth in the need for water use for electric power generation in the Southeast, about 80% in the Southwest, almost 100% increased in the Pacific Northwest. So those are places that are already experiencing water supply issues and water supply problems, so those regions of the country could see some major stress and competition between water resources for the energy sector and other sectors that need to be looked at. What I have here is, real quickly, the water demands for different types of power plants. The issue I think that you need to look at is the water consumption side, and you can use a fossil fuel or biomass plant as kind of your baseline if you will...something on the order. Closed-loop cooling is essentially evaporated cooling. Open-loop cooling is where you bring the water through the power plant and go back out. We're seeing a lot of states that are moving away from open-loop cooling because of the thermal issues associated with the surface waters, and so I think in the future you will see most of the new power plants will be closed-loop cooling or some combination of hybrid cooling, which is dry or wet cooling. But the baseline there is something on the order of 400 to 500 gallons of water per megawatt hour. If you look at things like nuclear power plants, they are about twice that. Natural gas fire powered plants are about half that on water consumption. If we look at carbon capture and sequestration, which a lot of people are looking at, that's an additional increase of 40 to 60% in water demand for some of the fossil fuel power plants, and there is a large demand for water for some of the renewable energy, specifically the concentrating solar in many cases, has something on the order of 700 or so to 800 gallons of water per megawatt hour. So we're looking at some significant water demands for different types of energy solutions. So I think what we have to look at in this country is how do we mix those to get the right energy reliability and long-term sustainability from a water supply standpoint. Transportation fuels, I just wanted to mention, that we're going to see major competition for water supplies for transportation fuels, in my opinion, in the Midwest and the Southeast and the Pacific West. As for most of the biomasses, our expectation is you'll see mostly biomass plants, and where you'll see much of the demand for water supplies for those biomass plants. Also, if we look at the oil shale, EIA is projecting some large increases in oil shale. The oil shale in the United States is predominantly in three states — Wyoming, Utah, and Colorado. Those are states that already are stressed from the water supply availability standpoint, and so the water demands for oil shale will be focused in those three states.

This is to try and put water demands for alternative transportation fuels into perspective. Top right-hand corner, we have conventional oil gas for oil refining at about 1 to 1½ gallons of water per gallon of fuel. If you look on the right side, what I've tried to do is put this in gallons of water per gallon of fuel and be consistent so I can compare apples to apples, but if you look at some of the biofuels, if you look at oil sands, you look at the synthetic fuels, what we're essentially seeing is anywhere from four to ten gallons of water per gallon of fuel rather than the one. So as we move to transportation fuels, alternative transportation fuels, we're expecting to see some major increases in water demands for those transportation fuels.

If you look at energy development, produced water is something that we generate a lot of, and where most of the produced water comes from is in oil and gas regions right now. So there are some opportunities to use to produce water for other uses so it may become a resource. The gas shales that I have there on the left, right now, a big place in Texas and Arkansas for the Fayetteville and Barnett Shales, but you can see the Marcellus Shale there on the left all the way through the Eastern U.S. — a large possibility and a large resource, but it has produced water issues and water demand issues that are going to have to be looked at so we can develop that.

I think this is my last slide. That was mostly water for energy. Here we're talking energy for water. What we're seeing in the U.S., around the country, is the trend to add nontraditional water resources to supplement current freshwater supplies. The left-hand curve there shows that the increase in both water reuse in the United States and desalination in the United States, they're growing at 10 and 15% respectively. Currently though, those technologies require a lot of energy, and I've got a curve there that shows the kilowatt hours per cubic meter of water. So we're looking at, for desal, something on the order of five to ten times as much energy intensive as regular freshwater treatment today. So we're going to have to look at as we move in many parts of the country to more and more utilization on traditional water resources. The treatment for that is going to have to be reduced from an energy standpoint to be long-term sustainable, and I think that's my last videograph. Hopefully, I set the stage both for water supply availability issues for energy, some of the produced water that we will get from energy development in the future — things that we have to look at there — and then as we look at nontraditional water resources to supplement supplies in many parts of the country, the energy demand is associated with that. Thank you. *[Applause]*

Shahid Chaudhry: Thank you very much, Howard. Thanks for inviting me. I'm so honored and privileged to be here. Thank you, Mike. You set a really good stage, and I think this is a good segue for me to move along the other side of the nexus which will be called, in common terminology, Water-Energy Nexus. But I think Mike did explain this supposed relationship very wisely, so I don't need to spend much time on this except mentioning that, on one side, that water and wastewater treatment in our body is also needed for energy production. And I'll be talking about the lower part of the nexus in my presentations. Just to put things in perspective, here is a typical urban water cycle. What we do is that we take water that's already available. We need to move it from point A to point B, and we need to extract it from the ground. So we will move it to the water treatment plants, we treat it, we supply to the end users whether they are industrial, agricultural, residential, or commercial. And then the wastewater that is collected from these end users, we will again take it to the wastewater treatment plants and to treat them. And in every step of the way, you see those big pumps. They are the machinery and equipment that we generally use either to extract water or treat water or distribute it and again to collect water and treat it and dump it. So in the bigger picture, water pumping is really a huge challenge, a huge challenge especially on the water side. The water side is pumping and pumping and pumping, and generally 90% of the time, the energy consumption on the water cycle is associated with pumping. Nonetheless, on the global scale, this is about 7% of the energy which is consumed by both the treatment plants and the total energy consumed by the water cycle. And this is pretty much equivalent to the energy consumed collectively by Japan and Germany. In the U.S., 3% of the energy is associated with pumping, and only 1% is consumed by water and wastewater treatment cycles. We have got about 60,000 public water treatment systems in the U.S. and about 16,000 wastewater treatment systems, and quantified with the energy consumption, that's a huge amount of energy. For U.S. water cycle, this is pretty much in the order of 520 million megawatt hours a year which is approximately 13% of the total energy consumption in the U.S. and generates about 290 million metric tons of carbon dioxide, equivalent to greenhouse gas emissions. And to put things in perspective, this 290 million metric tons of CO2 equivalent is about more than half of the whole state of California's greenhouse gas emissions, which is about 429 million metric tons of greenhouse gas emissions. Okay. Again, just to give a better idea in a different format, here's what the cycle looks like and if we take it a step beyond, that's where we put energy component in this. Pretty much every step of the way, energy becomes part of the process, and even though we do not realize this, but this is embodied energy which we come across on a daily basis. And how much energy we can use in every step of the way? Just a few years back, the Energy Commission in California quantified the energy consumption by the water cycle from cradle to grave and frankly speaking, the outcome was even mindboggling for us as well. On the electricity side, we are using about 19% of California's total energy consumption in the water cycle, and 32% of this natural gas is consumed by the water cycle. So in simple terms, 1/5 of electricity and 1/3 of natural gas is consumed by the water cycle. And again, the most interesting fact was that on the end user side most of the energy is consumed by the residential sector. On the electricity side this is about 28% and on the natural gas side this is about 50%. So there's a huge chunk of energy which is used by the end users, but at the same time it does provide a lot of opportunities as well to make this energy consumption more efficient. For example, the natural gas side, all that natural gas which is consumed by the residential sector is by the water heater by and large; so what we can do is we can reduce a significant amount of energy consumption in this sector by making water heaters a lot more energy efficient. And in that context, I believe that there are some layers going on right now that our electric water heaters should be 47% more energy efficient and gas water heaters should be 30% more energy efficient by 2015. As I've mentioned, the pumping is a big issue in water and wastewater sector. 90% of the energy in the water sector is consumed by pumping, pumping, and pumping, while on the other hand, radiation, which is 50% generally, and secondly wastewater treatment processes, and again pumping and solids handling, which includes a significant component of pumping as well. So in that context, this is close to 70 to 80% of pumping also on the wastewater side. But ironically, where we buy this equipment is on a low-cost basis. The fact of the matter is that only 10% of the cost is associated with the upfront capital investment on this equipment while the remaining 18% is associated with energy costs and operation and maintenance costs over the lifespan, so I think we need to look into a different perspective when we look into the things from an energy perspective, at how we could change our purchasing and procurement practices. Also from an availability standpoint, energy consumption and energy cost are second to the step, both on the water side and wastewater side, and that's becoming a bit challenging for the energy utility manager. This is one of the top five concerns to most of the utility managers. So what are these utilities doing to make their utilities more energy efficient? I think the lowest-hanging fruit starts from water conservation and water-use efficiency. If you remember from a couple of slides before, I showed you the whole cycle concept that this starts from the water consumption. The more water we consume will be embedding more energy in that, so that is still hanging fruit. If we conserve water and use water more in a sensible way, there'll be less water demand. Consequently, there'll be less energy requirements, and, of course, there'll be less greenhouse gas emissions. One of the biggest challenges for infrastructure is the old and aged infrastructures especially in the East Coast because we believe that most of this infrastructure was laid down soon after the world war and it's perceived to be in fit quality, number one. Secondly, this has fulfilled its useful life so there's a huge problem of leaky infrastructure on the West Coast. Not only on the East Coast; we are having the same problems on the West Coast as well. In California, for example, we are losing about 220 million gallons of drinking water quality to leaky infrastructure on a daily basis, and that's a huge chunk. In Toronto, California, for example, they are losing probably in the order of 70% of the treated water to leaky infrastructure. There are a lot of other different statistics all across the nation and all across the globe that a big chunk of water we are losing through this. The other aspect that we generally look into is lighting, heating, ventilation, and air conditioning systems and reducing process energy use and also replacing and replicating old water and pump equipment with more efficient technologies like variable frequency drives, efficient pumps, and water systems, and so on and so forth. And one sink probably does not reduce energy consumption but nonetheless that's helpful to reduce the cost associated with energy, and that's load management. Because they are expected in a way that during the peak hours when the energy demand is at its highest, you end up freeing almost three to four times versus during off peak hours, like during night times or during evening times when the energy demand is not too high, the rates are much lower. So that's a similar trend where water facilities are getting in that direction to reduce their cost associated with energy. And then the last one, but not the least one, is the flexibility additions through additional storage capacities so the pump water of the reservoirs, during off peak hours and that water during peak hours not only for water supply purposes, but use that head to produce additional power at the water-wastewater facilities. Okay, so that's the state of affair as of today. Now there's a lot of concern about climate change, but my take on this is let's put climate change aside just for a second. If we just consider population increase, that itself is a big threat to all of us. Right now, globally we are about six billion people, and by 2030, we're expecting to be nine billion, and the amount of water is still the same as it was on day one, so there's a stiff to have additional supply to fulfill the needs of these additional folks. But the fact of the matter is our traditional water supply sources are dwindling; the quality is deteriorating. There are new contaminants so as we become more health conscious we need to treat it to the higher levels. What that means is that traditional treatment technologies will not be helpful, so we have to come up with new technologies which are inherently energy intensive, like UF, ultra membranes, microfiltration, UVOs on membrane bioreactors, desalination, etc, etc. So even though both water and energy demands are on the rise in proportion to the population increase, water-related energy demand is increasing at a much higher rate, and it's anticipated that by 2030, probably, we will be needing more energy, by an order of 50%, just a little bit of water. And now if we bring climate change into the picture, that's impacting our water supply sources, and the biggest challenge of the climate change is its impacts are uncertain. We really don't know how the weather effect will be setting. Will rain and snow packs be having the same water? How temperature increases will impact the melting glaciers, which are basically one way of preserving water. And then the carbon neutrality issue and also sustainability, that how and what amount of water energy sources we are leaving for our future generations. So in that sense, I think, what we need to do is really take really aggressive measures to conserve water and water use efficiency and water leak detection. That is the lowest hanging fruit. In addition, what we need to do is to come up with new water storage basins whether these are underground or up-ground and then to have good coordination between these two resources of when is the good time to coordinate with these. Conjunctive use, where we treat wastewater or additional water and we dump it back into the aquifers to recharge our aquifers and then we pump it out when we need it, and in some cases this serve dual purpose. Again, along the coastal areas where we have been over pumping our aquifers to get water, the aquifer table has been going down and consequently, there's a tendency of sea water increase, which basically is making our aquifers unable to use. So it can serve two purposes. Water efficiency in the agricultural sector, as I've mentioned, that almost 45% of the water we throw on a daily basis is used by the extractor, and then there's some runoff as well, so there's a good potential to save water from there. I'll talk about recycled water and desalination in a minute, but let's jump to the next one. So in the long run, I think we need to evaluate what are the long-term effects of climate change on these resources. We need more research and development, and we need more observations to keep track how this climate change will be impacting our resources and then to identify research needs. So in that sense, I think, the future water-wastewater treatment systems will be really different than what we have today on the ground. They'll be more sustainable conscious. They will be working on a holistic approach, considering both water and energy inter-planning and construction processes, and at the same time they will have a much broader region. It's not that, once we put that plant on the ground, this is good for the next 30 years or 35 years. In fact, they will really be flexible in the sense that we will be able to change the systems and processes in a much easier way as we move along and as our demands change. So we'll be having a different capacity on a modular basis. One of the benefits of such modular systems is that we will be investing low on the plant end as well as on operation and maintenance cost as long as we do not create additional capacity, and they will be more robust to source water quality. As I've mentioned, source water quality is deteriorating, so we need to change the treatment systems, the treatment techniques and processes as the water quality changes, and so on and so forth. On the wastewater side, my understanding is that they will not be wastewater treatment systems anymore. In fact, they will be considered resource centers where we will be recovering water, energy, nutrients, and heavy metals, and, in fact, in many parts of the world, on these approaches, these processes are being implemented and these resources are being recovered. So these are some of the ways which will be considered in future water supply systems including water and wastewater. Okay, one slide I would like to draw your attention on is that future systems again will be considered on a case-by-case basis. By and large when we talk about desalination, our mindsets are that this is very, very energy intensive, and I do agree with that on general basis. This is very energy intensive. By the way, as Mike mentioned, that desalination is about five to ten times more energy intensive, but at the same time, ground water extraction is 30% more energy intensive as surface water, so it's not really one solution for all, and I guess the point here is, for example, in desalination, which is second from the right, desalination is around in the order of 4500 kilowatt hours per acre foot, but that's the peak or the max, right? On the other hand, when we transfer water in California from the northern part of the state to the southern part of the state, at the very end of the state water project, we are consuming about 6500 kilowatt hours per acre foot which is more than desalination. Let me give a future scenario. In New Mexico, a few farmers, they requested last year that they wanted to transfer 2 billion gallons of water from the farm land to Santa Fe and if they do so, they have to have a pipeline of about 140 miles and there will be elevation of about 4,000 feet. In this process, they will be using about 18,000 kilowatt hours per million gallons of energy just for water transfer. And putting in perspective, right now, the California State Water project, which is about 400 miles long, and as of today the world's biggest lift station which is about 2,000 feet elevation, in one stroke, it consumes about 2,000 kilowatt hours per acre foot which is roughly 6,000 kilowatt hours per million gallon. So in Santa Fe, they'll be using three times more than what we are using right now in California just at one pumping station. Similarly, a couple of other ways renewable energy could be helpful in reducing your energy demand, but, again, there's a catch. We are talking about renewable energy projects, but we have to have some water, and in some cases, in California, again, I will mention that either the developers have to change their processes or they have moved their project from point A to point B, simply because there was not enough water available even to implement renewable energy projects. And when we talk about thermal versus hydro, it's again a very interesting fact that for a long time we never considered our water losses in hydro systems, but the fact of the matter is every kilowatt hour of energy we generate on hydro, we are losing about 18 gallons per kilowatt hour versus thermal, we are losing about half a gallon per kilowatt hours. So again, the bottom line is shifting. Things are really changing, and I think in the future, water-wastewater systems and, for that matter, our energy supply sources, need to consider it on a case by case basis. I think in this whole arena, the Government has a role to play. They can really support research development and demonstration activities because unless we keep developing more and new technologies, we will be stuck with the existing technologies and most of these existing and new technology at this stage, there are energy intensive, so we need to keep working on that, and then at the same time the government can support technology transfer activities and information because, as I said, there's a lot of work being done all around the world but, frankly speaking, everyone is so busy. We don't have time to look outside the box and see what the next person is doing. The fact of the matter is the right hand doesn't know what the left hand is doing and vice versa. And then again, education, information dissemination, and outreach are really key points where the Government can support all these activities to make our water and wastewater systems more energy efficient. With that, thanks so much and I appreciate your listening. I'll be here to answer your questions. *[Applause]*

Jim Richenderfer: A few housekeeping rules: Since I represent probably the smallest Federal compact agency in the country, Howard has given me 10 minutes, so I'll try to stick to my 10 minutes. Also, the subtitle of the conference not only perfectly describes my perfect state of mind which is short-term stress, yet also clearly identifies the condition within the Susquehanna River Basin Commission. We are under great short-term stress conceivably for a long-term change, and the whole reason we are under such short-term stress is because of the Marcellus Shale play, which is going to be the focus of my talk. We are the proud owners of a number of energy sources. We've got three nuclear power plants within our Basin. We've got five major hydroelectric facilities. Obviously, coal is a big part of our history and a current source of energy within our Basin. Natural gas is growing. We've got other sources, some biofuels, but for the most part at least two-thirds of our energy within the Basin are nuclear and coal, and we are a net exporter of energy out of the basin. Again, the topic of my conversation is going to be the Marcellus Shale play. Just a brief summary of the Basin I represent: We are a little over 27,000 square miles. 43% of the Chesapeake Bay Watershed falls within our boundaries. 60% of our watershed is forested; that becomes important in a moment, and I will explain. About 32,000 miles of waterways from Cooperstown, New York, all the way down to the mouth of the Bay at Havre de Grace. We comprise 444 river miles. We supply about 28 million gallons per minute to the Bay so we are the single largest contributor of water to the Chesapeake. The outline of the shaded area is our river basin. The shaded area to the top part of the Basin is that portion of the Basin underlain by Marcellus Shale, so you can see the Marcellus represents a significant part of our Basin. In fact, about 72% of our Basin is underlain by the shale. Some statistics that may be up for debate; these are the statistics that we are aware of at this moment in time. About 30 trillion cubic feet per year of natural gas is produced in the U.S.. With respect to the Marcellus Shale, the estimates vary considerably for the 200 trillion cubic feet to 1,000 trillion cubic feet of natural gas. Thus far, about 10% of that gas is expected to be recoverable, so we’ve got between 20 trillion and 100 trillion cubic feet available within the Marcellus. That’s the good news. Here’s the bad news: If you look at the portion of the watershed underlain by the Marcellus, you’ll also note that some of our most pristine waters exist in that area. We’ve got wild and approved trout streams in the Susquehanna. We’ve got exceptional value high-quality trout-spawning streams within that portion of the Basin. So we’ve got this dilemma. We’ve got the Marcellus Shale that represents a significant source of natural gas. At the same time with respect to a Commonwealth, we’ve got some of our most pristine waters in the Commonwealth located in that same area. Tourism in the Commonwealth of Pennsylvania is the second largest industry, so we’ve got this dilemma of trying to essentially encourage, accommodate energy production while we’re trying to preserve the pristine nature of the watershed that enjoys such valuable tourism dollars. To give you some perspective on the rate at which we are both stressed and changing, we can summarize some of the statistics. In 2008, before our world changed so dramatically, we had about 50 approvals of drilling pads. The Susquehanna River Basin Commission approves pads. We don't approve specific wells. The Commonwealth of Pennsylvania permits individual wells. So the year 2008, we had about 50. In 2009, it jumped up to 321. Thus far in 2010, we've processed about 220-230, so we're expecting by the end of this year to have somewhere around 1,000 pads approved. What happens in the future? Anyone's guess. My guess is 2011, 2012 we'll see something greater than what we are experiencing now in 2010. So the trends are clearly upward. There are 25 to 30 different energy companies that are operating within our river basin. New drill rigs are being brought in all of the time, so there is great activity going on within our Basin and that's the reason I'm here. I'm really representing kind of a microcosm or case study. Mike gave you kind of a general description of the country. Shahid took it out to the West Coast to tell you about something California. I'm now dragging you all the way back across the United States, talking a little bit about the mid-Atlantic, specific with my river basin. So you're travelling a great deal this morning. I think I'm here to kind of give you a case study, if you will, of what's going on in the world of energy. With respect to the Marcellus Shale play and water, the total amount of water that the Susquehanna River Basin has approved since, essentially, June of 2008, when this whole play began, through March 10th of this year, is about 443 million gallons. Again, that's about 200 wells, perhaps a little bit more than 200, that have actually been drilled. Of that total 433 million gallons, about 41% came from public water supplies. The balance came from surface water withdrawals. There has been, thus far, very little activity with respect to ground water supplies. We expect that to continue. We also expect there to be more increase in mine drainage water where quality water is being used for fracking. We're also looking forward to the opportunity to use treated wastewater, whether it be municipal wastewater or industrial wastewater, to offset some of the use of the freshwater that's being used right now. These statistics are based upon 194 wells that we have permitted thus far and have data coming back to us. 2.8 million gallons per well, about 86% of that or 2.4 million gallons is freshwater. 14% is flowback or recycled water coming back out of the well. So right now, the proportion between freshwater going down the hole and the reuse of the flowback water is relatively skewed. We're hoping to take advantage of more of the flowback water over time, and instead of using freshwater, try to make it up with either low quality mine drainage water or wastewater. Average recovery of fluids, for every 100 gallons that's pumped down, essentially 12 gallons come back. Of that amount of flowback water, about 60% is reused, 40% is outside, treated and discharged to the surface stream. Surface water, we've used the kinds of things that the River Basin Commission looks at when an energy company makes application for a surface water withdrawal that's going to be used for either drilling or hydrofracking of the well. These are the kinds of things we're looking at: the classification of the water body from which they want to withdraw water, an aquatic resource survey to get a sense of what the quality is like in that stream, and also potential impacts on those resources, pass by evaluation. We have come up with a relatively sophisticated method by which we determine, what's the minimum flow that needs to be maintained in that surface water to support the aquatic ecosystem that exists? So there will be periods of time during the year when an energy company cannot withdraw any water from that surface stream. We want to essentially protect that low-flow scenario to protect the aquatic ecosystem, so there are times during the year, specifically summer, early fall when the energy companies will not be allowed to withdraw any water from the stream. Once the stream levels come back up, late fall or early winter, then they come back and start withdrawing additional water. Our permits are written such that there is a maximum daily amount that can be withdrawn. There is also a maximum instantaneous rate that can be withdrawn. So those are the pass-by evaluation, land access. Of course they've got to convince us that the point where they're proposing to withdraw water is either owned by them or they've got legal agreement with the landowners so they have the right to withdraw that water. Cumulative impact evaluation is critically important to us because while no one withdrawal may have an impact, when you start looking at the cumulative effect of the multiple withdrawals, we want to make sure that there is enough water left in the stream so that the aquatic ecosystem that exists in that stream can be adequately supported. Aquatic invasive species, we're concerned that if water is pulled out of one stream, that may have an invasive...It's struck to a drilling site, it's injected, or perhaps some of that water, or perhaps not all of that water is used and subsequently discharged into a different drainage way. We are concerned about the transport and reintroduction of an invasive species from one watershed into another. So that's part of our concern. And finally, the intake design and metering plan which is a method by which we try to ensure that the permit limits the maximum daily, the instantaneous maximum rate of withdrawal that there is kind of a built-in safeguard so that the guy that's driving the truck, it's not at his discretion to change the terms of the permit. So metering and intake design are kind of engineering characteristics that decrease the chances of an over-withdrawal being realized. I'll give you some sense of the consumptive use associated with the gas well industry. On the left is water supply that's public water supply. Recreation — golf courses and ski areas, gas wells — of course, manufacturing, and mining, and these numbers are all 1 million gallons per day. Energy use to include things like nuclear reactors would probably fall somewhere between water supply and recreation.

Finally, current considerations: What we are trying desperately to do in all our decision-making process is have it based on science rather than speculation. Cumulative impacts, data driven. We're trying to quantify water that's being withdrawn, water that's been treated and discharged back into the system, needs to be part of that cumulative analysis. Timing and location of withdrawals, terribly important. Disposal of produced fluids and brines. While the Susquehanna River Basin Commission does not permit treatment and disposal, we're clearly concerned about the adequate treatment and the proper disposal of the flowback and brine waters that are produced by these wells. Remote real-time water quality monitoring; we are, as I speak putting whole network of remote water quality monitoring stations, sensors that will be in the various water sheds. Those sensors will be continuously monitoring things like pH, specific conduction, temperature, dissolved oxygen, a few other parameters, with the hopes that any unregulated discharge of some of these flowback waters into any portion of the watershed will be picked up by these remote monitoring sensors. They are charged by solar cells. They are connected essentially to the same system where cellphones are; so they are not only recording these data on a regular basis, they are uploading it to our website. And actually, the website is available for public scrutiny; you can get on our website and actually call up this real-time data. So we're doing that in the hopes of trying to monitor what's going on in the entire Basin so we have some sense of what's going on out there with respect to not only the gas industry but other industries as well. We also expect the regulations to change. Right now we're going through the exploration phase but as the industry matures and we start looking at gathering and transmission lines, pipelines, there will be kind of a different change in the water needs of the industry. And that's about it. Thank you. *[Applause]*

Howard Gruenspecht: Jeff?

Jeff Wright: Last and hopefully not least. I guess you've heard some kind of scary things here. I'm here to give you one message after all this: Turn off your water while you brush your teeth, okay? Do that for me. Can I say that? Good afternoon. Thanks to Howard and EIA for inviting me to participate. We have some pictures here. I realized earlier this year I've worked in parts of five different decades at FERC, so that's one of my earliest co-workers there working the little small generator. Seriously, I'd like to speak about the importance of water to the thermoelectric generation industry, coal, primarily coal, natural gas, nuclear fire generation — those systems draw water from nearby sources to cool the condensers in their plants, and I'll get to the details of that in a couple of more slides. But first I'd like to start out with some obvious generalities. I still think they need to be emphasized. Water is critical. That's an axiom. That's an easy thing. It seems apparent but it's critical in many ways. What I call human consumption is everything from drinking, bathing, to washing clothes, dishes — all-around-the-house issues that you can think of. Also, there's industrial, there are commercial uses. There's irrigation of farm lands. Irrigation was so important that at the beginning of the 20th century, the Government started the Bureau of Reclamation, in large part to capture water in the West and use it to irrigate the dry lands and promote economic growth. Recreation, you heard Jim talk about skiing, golf courses, you've got boating, you've got swimming, and you've got fishing in all the nation's water bodies. It's an important and continually growing use of water. In addition, many of the nation's water bodies are home to all types of plants and animals, and this must be considered when any use of water is contemplated. And of course, my fellow panelists said water is important — more than important — it is necessary to the production of energy. The many uses create many concerns, and how do we deal with the growth of the population and the necessarily increased demand for water? Going forward, we're seeing an increased concern for a new environment in our water resources and this is not going to be going away. And the major concern of our water relates to scarcity, whether it's due to drought or just too much demand on a particular water body. And I go back to population growth. In part, there will be a demand for more energy, especially electricity, and this is not just turning on more lights, but it's all the new gadgetry that requires charging and I'll go off on a little tangent here. In their 2009 report, the International Energy Agency estimated that the new electronic gadgets — your TVs, your iPods, your PCs, all the other little home electronic gadgets, will triple their energy consumption by 2030 to 1700 terawatt hours. This is the equivalent of today's home electricity consumption of the

U.S. and Japan combined. Electronic gadgets already account for about 15% of electronic home consumption, a share that's rising rapidly of course as these gadgets increase. And last year, the world as a whole spent $80 billion on electricity to supply these gadgets. The IEA predicts a 5% annual increase in energy consumption between 1990 and 2030 just from televisions alone. Enough of that tangent, and back to how this all ties in with water. Everyday, we withdraw over 400 billion gallons of water from various water bodies — fresh and saline. Thermoelectric generation, the largest user, takes about half of this amount, and of this amount there's a 70-30 split between freshwater and saline sources for thermoelectric facilities. Cooling gas fire generation needs about 70% of the 200 billion gallons that are withdrawn. And just to give you a little perspective, coal fire generation counts for a little over 50% of the U.S. generation, and each kilowatt hour of electricity generated from coal requires about 25 gallons of water. So plug in a few devices, run your house normally a day, you're going to use in effect, thousands of gallons of water.

So what are the methods or technologies for cooling a thermoelectric generation plant? First, there are once-through cooling. This is characterized by a high withdrawal of water but very low actual consumption, and to distinguish that, when you withdraw, you're taking water out of the water body, you're putting it back usually. The actual consumption is generally through evaporation. Most of these plants were installed before 1970. They're still using about half of the generation capacity in the country. The range of withdrawals are about 20 to 50,000 gallons per megawatt hour produced, and 300 gallons per megawatt hour are lost to evaporation. Now while the water consumption is fairly minimal with this technology, an incredible amount is withdrawn, albeit it's temporary, and the returned water is returned to the water body, but this actually runs somewhat afoul of the Clean Water Act and more than that a little later. The second major method is called recirculating cooling or closed loop cooling, which is characterized by an actual load withdrawal of water from the water body but at high consumption of that water. These systems were installed after 1970. In general, it's about 600 gallons per megawatt hour that needs to be withdrawn, but up to about 480 gallons per megawatt hour is lost to evaporation. In this situation, the plant takes a minimal amount of water from the water body but does not return the water. Instead, the cooling water is recycled between a cooling tower and a heat exchanger. The downside of this, as I kind of mentioned, is that while less water is withdrawn, more is lost to evaporation and the makeup water has to come from the local water supply source. So while the recirculating, our closed loop, system withdraws less water, it actually uses more water in the end. A third cooling method is called dry cooling, which is characterized by basically the air cooling. There's no water involved. However, it's costly to build, operate, and maintain.

This slide provides information about the number of each of the common types of thermal power plant condenser cooling systems and about the average cost of each type in dollars per kilowatt. The cooling pond system is similar to the recirculating closed loop system I described, so you can, kind of, combine those two. We can see here that there are over 600 once-through cooling systems installed at a relatively cheap cost of $19 per kilowatt, mostly of the pre-1970 vintage. The number of recirculating and cooling pond systems exceeds the amount of once-through systems due to post-1970 installation, albeit, a higher installation cost at $28-$27 per kilowatt. Finally, we see that the dry cooling method has not really caught on due to the high cost — about 10 times the cost of once-through cooling, about 6 times the cost of a closed loop system. So how does this affect the capital cost of a 500-megawatt plant? Information here from the Electric Power Research Institute, or EPRI, shows that the once-through technology using that as a base, the closed loop system adds a little less than half percent of the capital cost. However, the dry system adds over 12.5% to the capital cost of that particular type of generation station. So why does anyone use dry cooling, or, better yet, why will anyone install such a system in the future? And the answer to that lies in the Clean Water Act.

As you can read in the first bullet, the Clean Water Act requires the best technology to minimize adverse environmental impacts. So where are the consequences of the statement? Well, open-loop systems are strongly discouraged by the Environmental Protection Agency because we require most new power plants to use closed-loop recirculating cooling systems or dry air-cooled systems, and we've kind of seen that trend since 1970. Of course, a greater alliance on closed-loop systems will result in changes in water withdrawal in consumptive patterns over time, and the greater use of closed-loop systems will result in lesser water withdrawal levels but a substantial increase in water consumption. So continuing this train of thought, if there's more consumption of water, this would probably be considered to be an adverse impact in the eyes of EPA running afoul of the Clean Water Act again. So what we may ultimately see is a dramatic turn to dry cooling for new plants, and the higher cost of these dry cooling plants will get passed on to repairs. Looking to the future, Department of Energy's National Energy Technology Lab examines five scenarios on water trends up to 2030 with regard to thermoelectric related water withdrawal and use. Freshwater withdrawals are predicted to range from 113 billion gallons per day to almost 147 billion gallons per day. And the low end is achieved by converting 25% of existing once-through capacity to that recirculating capacity, and the high end is due to maintaining the status quo. A daily consumption could range from 4.2 billion gallons per day to about 4.7 billion gallons, the high-end result from climate change rules and the conversion of once-through capacity to that recirculating capacity. On a regional basis, it looks like the Southeast will have the highest water withdrawal, maybe due to the continued use of once-through cooling at aging plants, while ERCOT — that is Texas — and New York will probably go the other way, probably attributed to an increased use of closed loop and dry cooling. Also, wind is accounting for an increasing amount of generation in

Texas, and there are no water requirements for cooling at wind turbines. Why do all regions out in California and New England show increased water consumption? Probably due to increased reliance on closed-loop cooling coupled with increasing energy demand. California and New England may have declining water consumption due to dry cooling inroads in these regions as well. And also by 2030, these regions may be receiving substantial amounts of incremental electric supply from outside of their borders. Since the generation of electricity is inextricably tied to water availability, water shortages pose an especially difficult issue for thermoelectric generators due to the large amount of cooling required for power generation. Further, carbon capture may reduce greenhouse gases going to the air, but it will, as was said earlier, increase the amount of water needed in thermoelectric plants, coal plants especially. Also, renewable with the exception of wind are no real panacea for water use in the future. Solar, thermal, and biofuel plants will use over 700 gallons per megawatt hour, which is actually comparable to coal and nuclear at about 800+ and 700+ gallons per megawatt hour respectively and far more than a gas-fired combined cycle generator at a little over 200 gallons per megawatt hour. The consequences of growing power and water demands will result in pressure on electric power sectors to use less water, and we should see greater integration between water and energy planning. This integration will necessarily lead to more intensive regional watershed planning, and finally technology will continue to advance. We hope to support planning and management needs.

EPRI offers several strategies for more efficient water use and the generation of electricity. Now the first is obvious. If you give more production with the same inputs, you'll use less water per unit of power generated. And as I mentioned to you before, beware of the renewable you choose. If the country goes heavily to wind, there will be considerably less water use. Of course, dry cooling utilizes no water, hence no water withdrawn and used. However, this comes with that higher price tag I mentioned. The next point of all is reducing the use of water in closed loop systems which will require an

additional investment, and, finally, EPRI advocates using wastewater from various sources. Such water sources cannot be used at once-through systems but rather in closed-loop systems. In conclusion, thermoelectric generation is the predominant form of electric generation in the U.S. It's also one of the primary users of water in the U.S.. Electric demand will increase and necessary increases in the supply of electricity will have to be met with renewable sources. However, these sources are intermittent in the electric grid, in order to maintain reliability will require stable formed generation. Now I will submit that this will probably result in water utilization of gas-fired electric generation and a probable construction of new gas-fired generation necessarily resulting in an increase in the demand for water for cooling those generators. Without some thought, this demand will clash with our other demands. I think the demand for water for thermoelectric generation can be relieved, in part, by moving from once-through cooling to closed loop and eventually dry cooling, and as I mentioned, it's not a cause for evolution. Technological advances in cooling techniques that not only reduce but also reduce the cost should be encouraged. Exploration of a more efficient generation and coupled with more efficient uses of electricity including demand-side reduction in the advent of the Smart Grid will help to reduce the strain on water supplies. Also a top-down approach such as watershed or basin-wide planning will allow planners to better allocate and anticipate the increased use of water due to thermoelectric generation. In the end, thermoelectric generation is here to stay for the foreseeable future and the other demands from water will remain as well. The challenge, if not a juggling act, will be how to adequately meet all those requests for water, so stay tuned. Thank you.
[Applause]

Howard Gruenspecht: That was great and again, I'm sure we have excess...I don't know if I'd call it...supply of question; I guess that's demand for answers, I'll call it. But I'll try to go through these and try to think out some representative ones. There were three questions that asked the issue, and I think the issue has been raised in some of the presentations, about withdrawals and use and again, as described in the last presentation, there are some technologies that withdraw less but use more, and how, from the perspective of water issues do you wait? I guess large withdrawals are bad and more use is bad, but when there's a tradeoff between withdrawals and use, what are you looking for? And let's have the entire panel if they wish to talk about it. Jeff?

Jeff Wright: It really depends on the water body. Large withdrawals, if you're looking at a once-through cooling system, means you want to put water back at a higher temperature, and the aquatic life whether plant or fish or other things that live in the water — this is unacceptable. And that's why the Clean Water Act, as I've portrayed, that part is saying you need to look for the next best technology to use. So the Clean Water Act, in a way, is pushing people away from the heavy withdrawals, but then they're pushing them towards something which would be an actual heavier use of water — water that will never come back into that stream except maybe it goes up there and it rains, but it could go somewhere else through evaporation. I think where the industry is probably getting pushed is towards the dry cooling or some other technological breakthrough, but right now, the trend is towards less heavy withdrawals at the risk of more use.

Howard Gruenspecht: Anybody else? Jim, do you have any thoughts or…?

Jim Richenderfer: Just one brief comment with respect to the Marcellus Gas play which is what I was asked to address this morning. It's not so much the total amount of withdrawal, it's the location of the withdrawal. Much of the play is going on in the headwater so what we're trying to do is encourage to move a little bit further down watershed so they're out of the more delicate portions of the watershed and hopefully that will have less impact on the ecosystem. So again, the Marcellus play, not so much the total quantity of water being withdrawn; it's the location of those withdrawals.

Howard Gruenspecht: I see that's even more complicated as it always is.

Jim Richenderfer: It is, it is.

Howard Gruenspecht: I guess that one question related to the Marcellus is question of the approval rate, talk about the permitting of the pads and I guess the question relates to the approval rate and is that process going to potentially to be a constraint on the development of shale activity. In other words, you talk about permits and requests, but our permit's being rejected. Or is there strength in that process as the number of requests increases?

Jim Richenderfer: Howard, may I call a friend?

Howard Gruenspecht: Call a friend, and split 50-50.

Jim Richenderfer: We have essentially two permits that we issue with respect to the shale play. One is the *consumptive use* permit. That's essentially the permit that allows the industry to discharge water down the hole, whether it's for drilling or for hydro-fracking. That's one issue. That's called the *consumptive use* permit we're talking about. That consumptive use … we have streamlined our regulation so that we can typically turn that around in 30 days. We have online applications so people can get online. The project's sponsor can get online, fill out the form, submit it electronically. And, typically within 30 days, they have an approval back. Rarely is an approval denied on the consumptive use side of things, because that's pretty straightforward and again, our rule is "you pump it down the well, it's gone." It's consumptively used, and that's the way it's tracked. With respect to the *surface water withdrawal* side of things, that takes longer. The reason it takes longer is that the staff does not have the authority to grant surface water withdrawals. Only our four commissioners can approve surface withdrawals. Our commissioners meet once a quarter so that is the dilemma. It's typically six to nine months to get a surface water withdrawal approved, and there's not a whole lot we can do about that because again, staff serves at the pleasure of the commissioners. The commissioners meet four times a year, so that delay is kind of built into this system. We are trying to move forward with online applications of surface water withdrawals, to increase the rate at which staff gets to: see these applications, process them, and get them to commissioners for their approval. Most of the applications are approved. Rarely is one denied. What we may do is throttle back the total amount of water that's requested. Someone may be requesting 3 million gallons per day. Because of our cumulative impact analysis, we may cut that back to 750,000 gallons per day, based upon what we believe the resource can withstand. So, we don't typically deny. We may modify.

Howard Gruenspecht: Thank you. There were two questions related to Mr. Chaudhry's comments about the water losses from hydropower. Two people seemed surprised that there were *any* water losses associated with hydropower, and that they were larger than the water losses (or uses, I guess, to use that terminology we talked about before) associated with other energy. Could you comment on that?

Shahid Chaudhry: Absolutely. Yeah, this is surprising but the fact of the matter is: as I've mentioned, you know, we never looked on the large scale reservoirs on Hydro-Temp from that perspective before. And this is an issue which came out of the limelight recently, based on the report that was published by NREL just a few years back, and that was their data. So there are benefits associated with large scale reservoirs. There's just no question about that. But when we use those reservoirs for generation, we need to look from a different perspective as well, that if we are building this just for hydrogenation, is it more economical? Does it make more sense from a sustainability standpoint that we should have large scale reservoirs in hot areas with a lot of our operation? Or should we have small scale reservoirs in these centralized places, which basically will not help reduce water losses, but also provide some reliability and sustainability on a local basis? So that's not really interesting, but nonetheless that's true.

Howard Gruenspecht: Mike, do you want to jump in here? So the issue is of operations from early behind the reservoir?

Mike Hightower: And I think the issue is the evaporation behind the reservoir, and the issue that we always run into when we look at this is most of these dams (especially in the western U.S. that have a large amount of evaporation) have recreational uses as well as irrigation uses. So how do you divide up that evaporation loss? Do you divide all of it to hydropower? Do you divide it up to irrigation? And that's always been the concern on how you correctly value how the evaporation goes. Some small reservoirs in the southwest can lose 100,000-acre feet a year (which is equivalent to 100,000 million gallons a day), but that's a lot of water that's lost through evaporation. And so, does that go to irrigation? Or does that go to hydropower? So you've got to play around with it.

Howard Gruenspecht: So we got the multiple uses coming into place.

Male: It does, it does.

Male: Here's another consideration that we see a lot: before you develop hydro, and you dam up and make these nice reservoirs, development occurs around it. And the people that can afford to buy around these are those people who can afford to pitch a fit politically when the level of those reservoirs go down and they want that water at a certain level all the time.

Mike Hightower: Got to float all the boats.

Shahid Chaudhry: One more comment. There's a study being done by the University of Arizona right now. They're allocating, for personal value, to all these different uses of such resource: about how much benefit is coming out of generation, how much is on recreation and how much is from medical purposes. So that's really an interesting study to watch as well, as to how this allocation can evolve.

Howard Gruenspecht: Here's one for everybody. It's a good, good economist policy analyst question. All these presentations imply existing or coming scarcity. Do water prices reflect this and how can prices/taxes be used to push us toward a more ideal condition? Anyone thought on water pricing issues with the demand and supply balance?

Mike Hightower: Sure. We've looked at that very closely for the last four or five years, and I think probably the price of water in the western U.S., which is easier to look at because of the water rights issues, was running anywhere from … I'll just give some examples … $100 to $500 an acre foot. In the last five to six years, we've seen across the west that the numbers are now running $5,000 to $10,000 an acre foot to buy, so in that 5 or 10-year period, we've seen water prices go up by a factor of 10, and a factor of 20 in different regions or in different western states. So I think what we're beginning to see is that the scarcity is leading to an increase in price, and people are valuing water a little bit better than they did 10 years ago. There's not as much information with the different water rights issues in the eastern U.S.. But at least in the western U.S., there's been a tremendous increase in water cost.

Howard Gruenspecht: Right, it makes energy price changes look modest. Maybe I should change areas of function *[laughter]*.

Mike Hightower: You're too old to change, Howard.

Howard Gruenspecht: I'm too old to change. Don't say that! No! Okay last question … there are so many of them here … how to overcome consumer resistance to reused water? It's interesting. In some of these presentations, the idea was (I think) that reused water would be devoted to particular uses, be it energy development or be it cooling water. But I think this question speaks more generally to the issue of reused treated water going back into more general circulation. Any thoughts on whether ultimately that will happen? Or will reused water be applied in certain issues only as suggested in some of the presentations?

Mike Hightower: I don't think you're going to see reused water go back into the water supply. It's going to be used, for instance, for thermoelectric plants and be re-circulated. And that's going to cause some problems in terms of the piping of the works of the closed-lid system that need to have blow-outs every once in a while, but I don't think that water is going to find its way back into the water supply unless it's heavily treated.

Shahid Chaudhry: I think, you know, this is not really a new concept at all. It's getting a new twist, though. But the fact of the matter is, even from old civilizations if you could remember, all these communities, they were on the upstream of a river. They would draw water from that stream, use it, and dump it to the downstream, right? And the community downstream will do the same thing, right? The only difference is that our lifestyles were not so complicated, and we were not discharging all those sophisticated chemicals into the waste water. Nature was able to take care of all these problems by itself, right? But now, with all these things and new changes coming into the picture, all that water cannot dig it up. And that's why we are treating waste water to the degree required, right? Again, this is more in our mindset. There are a lot of examples I can quote where waste water is being treated to a level which is even purer than drinking water quality. Singapore is doing this. I'm sure, you know, most of you will be familiar with their pilot tap approach. There's one country in South Africa that's doing exactly the same thing. On a partial basis, we have been doing it in California for a long time. We've been treating waste water and injecting it back to the government water reservoir, which is basically not only increasing water supply but also (as I mentioned in my talk) was protecting this from sea water being treated. This is why it is doing exactly the same thing. There are so many different examples. I think this is in our mindset; and as long as we do not start educating folks that this is not anything new, this issue will not go away. But with education, and I think with information, this can be resolved to a certain degree.

Howard Gruenspecht: So one skeptic and one optimist. We'll give Mike the last word on this.

Mike Hightower: I actually think that if it looks like it's wet, I think in the near future we'll be using it. But I don't think that what we're going to see is we're going to take water and treat it to drinking water standards and use it for industrial applications, and then treat it again to drinking water standards to use it for agriculture. I think what we're going to have to do is be smart in the way that we sequence through how we use the water. We may not use fresh water for irrigated agriculture. We may use treated effluent, or we may reuse water first for industrial applications. And that way you can minimize the amount of treatment that you need each time, because from an energy efficiency and a water use efficiency standpoint, that's a smart way to go. We don't really have anything set up in this country to go that route, but I think you'll see some of the waste water used for industrial applications because it doesn't have to be treated as well, and then some of the other applications where we can treat it a little bit and use it for drinking water, we will. Israel's recycling 70% of their waste water today; Singapore's recycling 50%. In a way, Singapore got around it — they now call it new water.

Howard Gruenspecht: New water.

Mike Hightower: And if people are saying, "I don't want regular tap water. I want new water," which is really recycled waste water. We have a lot of applications that we can use it. I don't think it's just a marketing ploy, but I think that if we're smart we're going to have to reuse water a number of different ways.

Howard Gruenspecht: These weren't the guys that came out with new coke.

Mike Hightower: Same stuff, exactly.

Howard Gruenspecht: Well, I think we've covered a lot of ground at a short period of time. Please join me in thanking the panelists for doing an excellent job. *[Applause]* I somehow suspect this is a topic we'll come back to. I guess this concludes the conference. Thank you all very much.

END OF RECORDING