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NUCLEAR REGULATORY COMMISSION

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TECHNICAL SESSION - TH21

ARE WE OBSERVING MORE EXTREME WEATHER EVENTS THAT AFFECT THE RISK OF NUCLEAR POWER PLANTS?

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THURSDAY,

MARCH 10, 2022

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The Technical Session met via Video-Teleconference, at 8:30 a.m. EST, Mehdi Reisi-Fard, Chief, Performance and Reliability Branch, Division of Risk Analysis, Office of Research, Nuclear Regulatory Commission, presiding.

PRESENT:

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LAI-YUNG LEUNG, Battelle Fellow, Pacific Northwest National Laboratory

RAJIV PRASAD, Earth Scientist, Energy & Environment Directorate, Pacific Northwest National Laboratory

P R O C E E D I N G S

8:30 a.m.

DR. REISI-FARD: Good morning and welcome to Technical Session TH21, part of the We Are Observing More Extreme Weather Events that Affect the Risk of Nuclear Power Plants.

My name is Mehdi Reisi-Fard. And I have the privilege of being the chair for this session today.

In the past two years we observed relatively important weather events that affected nuclear power plants. Although the risk of those events was mitigated because defense in depth and plant-wide safety margins were maintained, our observations prompted us to organize this forum to facilitate discussion on extreme weather events, if those events are affecting commissioned nuclear power plants, and if so, the potential risk implications of those events.

The presentations will explore what existing data are or are not telling us about how weather patterns are changing, and any observed effects on the operation of nuclear power plants.

Today we have distinguished experts and

speakers from international and domestic organizations with diverse backgrounds and perspectives.

Our first speaker is Dr. Paolo Contri from the International Atomic Energy Agency. And he will present on climate change impact on the safety of nuclear installations.

For our second presentation, Dr. Ruby Leung and Dr. Rajiv Prasad from Pacific Northwest Laboratory, will discuss a regional perspective on climate change impact based on the site performed for the NRC.

Our third speaker is Mr. Christopher Hunter from the Office of Nuclear Regulatory Research at the NRC. Chris will discuss recent insights from loss of offsite power, trends, and risk evaluations.

And finally, our last speaker, Dr. Fernando Ferrante, from the Electric Power Research Institute, will discuss observations on extreme weather and impacts on nuclear power plants.

Before we start with the presentations, I'd like to thank all of our speakers for supporting this session. And I'd like to acknowledge and thank our Session Coordinator, Mr. John Lane for all of his efforts to make this session possible.

Please feel free to submit your questions using the feature available in the platform. We will collect all questions and address as many as time allows at the end of the presentations.

With that, I'll start with our first -- we'll start with our first presentation, and I'll introduce our first speaker.

Dr. Paolo Contri has a PhD in Structural Mechanics from the University of Padova in 1994. After a long experience in engineering consultancy in an international company in Italy, he joined the IAEA Engineering Safety Section in 1998, where he served until 2005.

After four years at the European Commission Joint Research Center Institute for Energy in Petten, Netherlands, he joined ENEL in Rome where he served as the head of the Nuclear Safety Division in the Nuclear Engineering Department.

In 2020 he joined the IAEA as Section Head of the External Events Safety Section in the Department of Nuclear Safety.

Dr. Contri, the floor is yours.

DR. CONTRI: Thank you very much, Mehdi. Thank you very much indeed. I'd like to focus my

presentation today on the challenges that the climate change has on nuclear installation safety.

The -- I have to -- do I have to wait for the presentation? Is -- I cannot see the presentation on -- Mehdi, can you help me?

DR. REISI-FARD: The presentation is being streamed Dr. Contri.

DR. CONTRI: Oh, okay. Okay, it's fine. I will go ahead. So, I'd like to focus my presentation, as I said, on the climate change impact on the nuclear installations. Next slide, please.

Of course we will have to start from a discussion on the hazard first of all. But, actually our focus will be on the challenges both to the -- to safety of the plant. Next slide, please.

The hazard parameters, we all know that the climate is going to be, the climate change is going to affect mainly the areas in the world that are both in the extreme latitudes of the globe.

And this is something that is very well known. We have many studies available and so on. What is more interesting for us as nuclear safety experts, is to understand which parameters of the climate change hazard are more relevant to the safety

of the plants.

In particular, if everybody can understand that even magnitude there is a particular parameter. The hazard type is less spontaneous, is less obvious for example.

We have sites where some scenarios have been screened out at the time of the siting. While actually now they should be recovered, because they are shown to be -- to have a high probability of occurrence.

The permafrost melting is a typical scenario that was not considered in the mainly -- in many high latitude sites.

Combination of hazard, also the combination is becoming an issue. And because again, they can, many phenomena can happen in contemporaneous scenarios, while in the past were screened out.

There is an increase in frequency, of course. They are particularly affecting storminess and lightning, but also an increase of the speed of development. We have to think that the eye of the hurricane jumped from a category one to four in only one day recently in the Mexico Gulf.

So, just to say that hazard change is a

generic issue, but we have to concentrate on those specific parameters that make the -- that pose major, biggest challenges to our -- toward the safety of our plants. Next slide, please.

So, the -- I like to support my statements on the basis of the analysis that we carried out in the Agency on the documented basis of events that we collected.

That the DB IRS has been in operation since 1980 here. And actually, it enables a very interesting analysis of the most recurrent events.

This is interesting because the scenarios affected by climate change are the -- are the most common into the statistics. Meteorology, precipitation, and flooding are responsible for 30 over 60 reports in terms of generic events.

And biological phenomena as well, which means actually that the impact of external, of these types of scenarios are growing into the list of potential incidents over the past, of incidents which happen in our sites.

Which are the most affected, the components by all types of events, are electrical components, service water systems, primary system, and

structural protections.

This gives us a good background for the understanding of the impact on safety. Next slide, please.

Which are the major challenges that we recorded in our database as posed by the climate change effect? Well, this a long list, but we can go into more detail later.

Of course, flooding. Of course, high temperature damage to digital components in particular. Wild fires affecting site access and operation.

Sandstorms, salt sprays impact on filters, impairment of vehicle access onsite, damage to electrical station, water availability, and so on. This is -- these are a number of scenarios, of damage scenarios that we recorded on the -- in our database.

And that we have to keep in mind when we discuss on the potential, on the improvement, all the protection measures that we may have in our sites. Next slide, please.

Well, more in detail, we can see actually, I can show here a one very famous picture from the IPEEE program for example, that was published in 2001

in -- by the NRC, where we see that the contribution of these types of scenarios to the CDF over a very large number of plants in the U.S., has been very significant.

Which means actually, that if the contribution of climate change is going to affect significantly the hazard in terms of flood, wind, lighting, and other related scenarios, we are going to suffer very much in terms of contribution to the overall CDF of the plants.

And this is why actually most, as you see there, the ratio between the contribution of different events into the different reporting categories, we see that most of the impact of the external events has been going into the degradation of barriers. Next slide, please.

This is a -- even a more evident proof of what we are seeing. This is an interesting picture on the, based on the nuclear power disruptions.

So, the number of the business interruptions that we have recorded at NES, all over the world, in all of the population of the nuclear plants in the world, and we can easily see that in the last 20 years, the impact of -- in climate related

events have been growing very significantly.

In particular for river, for river sites, were for plants, I mean, based on river sites, and in particular we will see actually into the high latitude.

So, this is actually the best proof that something has to be developed in order to improve the hazard, to update the hazard, and to consider all the parameters that we discussed at the beginning. Next slide, please.

This is the geographic distribution that I promised to show you. As you can see, most, most of the events have been recorded in Russia, Finland, and Canada, which actually are showing disproportionately affects by climate changes as compared to the other sites, and particularly in the last years.

So, this is a fact that there are some scenarios which are affecting our sites, particularly in the high latitude in a specific way, affecting the defense-in-depth. Next slide, please.

Which are the lessons learned at this point, and which are the proposals for protection upgrade? For sure there is a need for an improved approach to scenario screening.

Screening has been one of the major reasons why many scenarios have been scaled out from the detailed hazard assessment. And therefore, they are not into the design, considered into the design bases of many plants as they should be nowadays.

We should have an improved hazard evaluation approach, of course. Particularly with uncertainty control, and of course, with the simulation of climate change and load combination.

The periodic hazard review that the Agency recommends, is something that should receive a major emphasis now than before.

The periodic hazard review that is, that should be carried out during the periodic safety review of the -- of any plant in the world, is now becoming extremely urgent because of the reasons that we said before.

The risk analysis for the assessment of the beyond design basis margin and cliff-edge effect, is more -- is more and more important. This is a major lesson learned, and we learned particularly after Fukushima.

But, now it's becoming absolutely a requirement even in the Agency safety guides. So, the

analysis of the beyond design basis and the calculation of the margins, how big it has to be this margin beyond design basis.

What is important is that there is also, there should be an improvement of the monitoring. At the plant and in the region in relation to an event in order to support appropriate operational actions at the sites.

This is something that has been pretty much overlooked in many sites in the world that we recorded that in many review missions. We believe that actually this issue should be really emphasized now.

Why I'm saying also regional, because only by regional monitoring we can predict the potential impact of a major scenario into a site. And therefore, the plant can be prepared for such a type of impact.

Of course then at the site that we could have -- we could deploy some specific measures like movable onsite safety emergency systems, or movable protection devices.

We could also have and improve the component qualification methods. But this, I will

say, is just on the side of the mitigation. We believe that we should work a lot also on the side of the prevention and the hazard evacuation.

Well, in addition and provocation is that one at the end of my slide, when I referred to the system resilience approach. Next slide, please.

This, I believe, is an important concept that has been underlined recently by even the International Energy Agency by also by EPRI. And so, we realize that nuclear safety objective is not enough probably to face the challenge posed by climate changes.

We also have to address the system resilience in general. So, the overall energy supply system has to be able to withstand a challenge posed by climate change.

And in particular, we have to address the climate resilience, okay, the recovery time, because these are the issues that are affecting the population.

We realize that nuclear safety up to now has been addressing only the safe shutdown of a plant in case of a major challenge. We believe that nowadays we also have to address the resilience of the

old system.

We realize that because a business interruption could create major troubles to populations who are affected by those effects.

We realize that the components of the overall energy supply system may be managed by different type of administrations, that's clear. They may have been designed according to different design basis.

But, this is probably a new challenge that we have to add to what, to what we listed out in the previous slides.

So, I'd like to end here my presentation, opening for questions if needed. And I will give it back to you Mehdi.

DR. REISI-FARD: Thank you very much Paolo, for a very insightful presentation. We'll address questions after, after all the presentations.

So, moving to the second presentation, our -- we have two speakers for our next presentation. Dr. Ruby Leung is a Battelle Fellow at Pacific Northwest National Laboratory. Her research broadly cuts across multiple areas in modeling and analysis of climates and water cycle.

Ruby is the Chief Scientist of the U.S. Department of Energy's Energy Exascale Earth System Model. She's an elected member of the National Academy of Engineering and Washington State Academy of Sciences.

She's also a Fellow of American Meteorological Society, AMS, American Association for the Advancement of Science, and American Geophysical Union.

She's a recipient of the AGU Global Environmental Change Bert Bolin Award and Lecture in 2019, the AGU Atmospheric Science, Jacob Bjerknes Lecture in 2020, and the AMS Hydrologic Sciences Medal in 2022. She was awarded the DOE Distinguished Scientist Fellow in 2021.

She received a Bachelor of Science in Physics and Statistics from Chinese University of Hong Kong, and a Master's and PhD in Atmospheric Sciences from Texas A&M University. She has published over 400 peer review journal papers.

Our second speaker for this presentation is Dr. Rajiv Prasad. Dr. Prasad is an Earth Scientist in the Earth System Predictability and Resiliency Group within the Energy and Environment Directorate at

Pacific Northwest National Laboratory.

He has a PhD in Civil and Environmental Engineering from Utah State University. Since 2004, he has led hydrology related safety reviews and environmental analysis for supporting licensing the U.S. nuclear power plants.

He has contributed to the development of technical basis for flood hazard assessments, including local scout flooding, riverine flooding, and tsunamis.

He is currently developing probabilistic flood hazard assessment frameworks for local flooding at nuclear power plants.

With Dr. Leung he coauthored a series of reports that described how hydro-meteorological hazards in nuclear power plants can be affected by climate change.

With that, I turn it over to you Ruby and Rajiv.

DR. LEUNG: Thank you very much for the introduction. So, in this presentation, I am going to co-present with my colleague, Rajiv.

And we are going to talk about extreme weather hazards to nuclear power plants, particularly

providing a regional perspective, focusing on the United States. Next, please.

So, this presentation is based on the PNNL Climate Change Impact Study that we performed for NRC during 2014 and 2019. We reviewed climate change literature very broadly and produced four different reports.

The first one focusing on a national scope, and then subsequently the three other reports focusing on particular regions of the United States, including the southeastern U.S., midwestern U.S., and also the northeastern U.S.

So, as you can see in this figure, we focused on extreme weather events. And there are many different types. Some are common across different regions.

But, some regions also experience a particular type of extreme event. And we focus on reviewing those, how they have changed in the past, and how they will project -- how they are projected to change in the future. Next, please.

So, the reason why we've been focusing on the three regions, I think, should be obvious, because most of the nuclear power plants in the United States

are located east of the Rocky Mountains. And therefore we focus on the midwestern U.S., the southeastern U.S., and also the northeastern U.S.

And the definition of these regions we use, essentially come from the National Climate Science Report. Next, please.

So, climate change projections are produced by climate models following different scenarios of anthropogenic emissions of greenhouse gases, aerosols, and land use/land cover change.

These scenarios are named by their radiated forcing, meaning the imbalance of the energy in the atmosphere.

And for example, in the high emission scenario, the radiated forcing, or the energy imbalance towards the end of the century is 8.5 warps per meter square. And this usually is called business as usual scenario.

In another scenario that includes climate mitigation, greenhouse gas emission is lower as a result towards the end of the century. The radiated forcing is only 4.5 warps per meter square.

So, these are the two most commonly used scenarios that are used in climate models to project

future changes. And we will be focusing on these particular scenarios. Next, please.

In the first report, as I mentioned, we have a national scope and region that introduced the general ideas about how climate change has, and also will change, different phenomena and different weather systems particularly.

So, here for example, looking at extreme high temperature, the projection for the future, towards the end of this century, compared to the last, the end of the last century in the high emission scenario showed that the temperature of extreme hot days will increase during both winter on the left, and also during summer on the right.

But, you can see that the projection shows larger warming for these extreme hot days for the summer time compared to the winter time. And this is partly because during summertime there's also drying, particularly of the soil moisture.

And as a result, the reduced evaporative cooling can cause additional warming into the future. Next, please.

Now, looking at extreme precipitation, climate models all project changes, and particularly

increase in the future. And this is largely because with warmer temperatures, the atmosphere can hold more moisture.

And this is following a rule, basically called the Clausius-Clapeyron Relationship, showing that for each degree of warming, the atmosphere can hold 7 percent more moisture. And as a result, extreme precipitation is also projected to increase across all latitudes.

For example, if you look at the figure, the green curve shows the main changes in the future. Across, a little from latitude, you can see roughly an increase of about 6 percent per degree of warming.

But, there is also quite a bit of uncertainty, particularly over the tropical area where models, some can project a really large increase of up to like a 30 percent increase per degree of warming, and some project the smaller increases. Next, please.

We are also, of course, very concerned about sea level rise. So, sea level rise is because partly of the thermal expansion of the ocean as the earth warms.

But, it is also because of melting of the Greenland ice sheet, and also the Antarctic ice sheet.

So, projecting into the future, along the coastlines of different continents, you can see largely increases in the sea level.

In the upper panel, for example, when you particularly look at the sea level rise along the coastlines of the United States, there are larger increases in sea level, particularly in the gulf coast, but also increase in the east coast, along the eastern seaboard as well.

The lower panel show the uncertainty in the projection of sea level rise, showing the increase between 17 percent and 83 percent range level.

So, in terms of uncertainty, there are larger uncertainties in projecting sea level rise over the northeastern United States, and this is partly because of uncertainty in projecting how ocean circulation is going to change in the future. Next, please.

Now, assuming in the United States, before we particularly dive into the different regions, let's take a look at across the U.S., the observed change that has happened in the past.

So, the three figures here show the observed change in the annual temperature on the upper

left, and the annual precipitation on the lower left, as well as the change in the five-year extreme precipitation on the right.

So, these are results based on comparison of roughly the last 30 years compared with the first half of the last century.

So, you can see annual temperature has increased almost everywhere in the United States, except for the southeastern United States, where there is some actually cooling.

And this is what has been called the warming hole. And this warming hole has been studied a lot, and partly related to AMOC (Atlantic Meridional Overturning Circulation) variability that has happened in the last 30 years.

When we look at annual precipitation, the changes are smaller. There are both increases and decreases. And the changes are not very significant.

However, when you look at changes in extreme precipitation observed in the past, you can see increases everywhere in the United States, particularly on the eastern part where you see increases of several percent up to the northeastern United States, you see an increase of 17 percent.

Next, please.

Now, projecting into the future across the United States, looking at changes in precipitation. Let's particularly focus on the right-hand panel, where we are showing the projected change in the extreme precipitation, particularly the annual precipitation exceeding the 90 percentile.

Comparing the -- towards the end of this century with the end of the last century, we are showing the -- for the lower emission scenario on the left, and then for the higher emission scenario on the right.

And you can see that as emission increases in the higher scenario, we'll see increases, larger increases in the extreme precipitation projected for the future.

But generally, you see a larger change, especially for the western United States, as well as the eastern United States, the regions where mostly affected by storms coming from the ocean. Next, please.

Now we go into a particular region, for example the southeastern United States. A big concern in that region is sea level rise and that can result

in these sunny day floods, or what we call nuisance tidal floods.

On the left panel, you can see that in the last 20 years or so there has been accelerated increases in the rate of sea level rise. And you can see that particularly along the gulf coast as far as the eastern seaboard.

As a result, as I mentioned, there would be, there are increases in the nuisance tidal floods. And this is particularly happening over the southeastern United States in states such as Florida, and also South Carolina.

Over the years, you can see an increase of many days per year in these nuisance floods. Next, please.

Now, projecting into the future, on the left panel, as I mentioned before, the projection for sea level rise, there would be a larger increase in the gulf coast as well as the northeastern United States.

And you can also see this very clearly. But, also highlighting in the lower right panel, are the projections for the tidal flood. The orange bars over there are for the present day.

But, you can also see the projection into the future, suggesting that towards the end of the century, there will be almost by a tidal flood every day in the year. So, it's like over 300 days per year. Next, please.

Now I pass it to Rajiv to talk about the hydrological changes.

DR. PRASAD: Thank you Ruby. So, here would appear several studies that use predicted climate information that Ruby has been talking about, the estimated hydrological changes.

Usually what happens in these studies is that they're focused on mean annual or seasonal stream flow characteristics. But, they're not particularly focused on extreme floods such as design basis floods that Dr. Contri was mentioning.

These studies do provide information that is relevant and unique about plant operations. So, this study actually looked at the ability you see in between, looked at the impacts of climate change on 28 southeastern U.S. watersheds using what we call sea med pre scenarios and four sea med prime scenarios.

And they generated daily future climate scenarios using synthetic weather generators. And

then they used hydrologic models, which were created by these daily hydrology to estimate the future streamflows.

The study found that similar streamflows decreased for all watersheds under signature trace scenarios. And that can have implications on nuclear power plants that need to use water from those watersheds, the rivers and streams.

Sea med prime scenarios on the other hand only showed an increase in summer stream flow. So, that was in contrast to sea med three scenarios.

So, these were those points too somewhat increased on certain things, and it took climate scenarios to actually predicting future stream flow, even for mean conditions. Next slide, please.

Okay, this slide is a little bit, let's skip this one. It is only showing results from some climate change and organization scenarios.

What these studies usually found was increasing organization resulted in slightly higher stream flow, because of input business increasing. But, the long term decrease in stream flow still persisted. Next slide, please. Ruby?

DR. LEUNG: All right. So, now let's move

onto the midwestern United States. So, here we particularly looked at projected changes in extreme precipitation in the midwestern United States.

So, you see two panels over here, one showing the changes during the summertime, and the other one on the right showing the changes in wintertime.

So, we are comparing on the Y axis the future change in the peak precipitation versus the historical peak precipitation on the X axis.

So, what we are seeing is that during summertime most of the climate models project that in the future the peak precipitation will actually decrease. And therefore you see the red box falling below the diagonal line.

But, for wintertime, most of the climate models project significant increases in the peak precipitation as shown by all these dots that are above the diagonal line. Next, please.

We also look at midwestern United States in terms of changes in what we call the Mesoscale Convective Systems. So, these MCSs are the largest type of thunderstorms and they happen quite a lot during the warm season in the midwestern United

States.

So, these studies show that based on observation in the last 35 years, these Mesoscale Convective Systems have already been producing more precipitation shown by the blue patches of area in the middle panel, showing the positive trend, as well as the increase in the extreme precipitation produced by these Mesoscale Convective Systems shown by the lower right panel for all these different stations that we looked at. Next, please.

And this study also particularly looked at MCSs. But based on the climate model projections, particularly climate projections produced by very, very high resolution climate models of the order of like four kilometer resolution compared to typical climate models that are one at roughly 100 kilometer resolution.

So, for these very high resolution climate models, one can actually look at individual storms simulated by the model, and then they can composite the storms together.

And what we show over here, the composited storm precipitation for the current climate on the lefthand side, and for the future climate on the

right-hand side.

So, what you can see clearly is that in the future, the climate models project that the storms will become larger. So you see a larger increase in the area, as well as the color showing an increase in the intensity as well. Next, please.

Now, I pass it back to Rajiv.

DR. PRASAD: Thank you, Ruby. So, here we are showing results from two studies that analyze the annual maximum absorbed daily discharge from over 700 USGS streamflow gauges in the midwest.

And they found that increases in observed flood magnitude tend to be clustered. So, if you look at the left figure, you will see that those -- there are those blue dots, and there are those red dots that tend to cluster together.

On the other hand, the frequency of floods that is showed on the right-hand panel, is showing an increasing trend over much of the midwest. So, this one of the findings that the study shows in the observed records. Next, please.

So, based on that finding, the Army Corps in a 2015 study, looked at what would be the effect of climate change on flood frequency curves?

So, probabilistically looking at extreme floods, how could that flood frequency curve change? And they looked at variables at north at Fargo, North Dakota.

And at first it was the downscale climate predictions that generate 90 flow data sets that were used in turn to drive hydrologic models. And then in -- from the model predictions, flood frequency distributions were estimated.

And the Army Corps concluded that the peak flow discharge increased for all future time periods. So, up on the panel there you see a dotted line at the bottom. That is the historical.

And everything on top of it, are future conditions. And they all show increases all throughout the flood frequency range.

And the greatest increase they found to happen during the first half of the 21st century, which is really interesting. Advance, please.

So, this table, actually it's pretty hard to read. But, I will give you the gist of it. The largest increase was up to 35 percent in the annual flood. And it was associated with a 1 in 200 chance flood event. Next slide.

So, as part of the midwestern study, we also looked at Great Lakes water levels. And a lot of work has been done to understand what levels in the Great Lakes both by the U.S. Agencies and the State Agencies.

The Great Lakes Environmental Research Lab develops and maintains projection relation models for the whole watershed, which is pretty big.

And some of these models performed reasonably well, as you see in those figures there. A large portion of Great Lakes water is still ungauged, leading to uncertainty in the hydrologic model prediction.

A large part of that uncertainty actually comes from difficulty in categorizing various components of the water project. So, how much you are integrating from the precipitation, how much is getting lost through that extrapolation and things like that.

And this uncertainty actually leads to predictions in future water levels in the Great Lakes that show it range from the Slide B, which leads to a slight increase. Next, please.

Ruby?

DR. LEUNG: Yes, so now let's move onto the northeastern United States. Can you go back to the -- next, please. Yes, there, thank you.

So, now let's move onto the northeastern United States. So, in this region, they -- this region experiences a lot of extratropical cyclones in both wintertime and summertime.

So, this particular study looked at the changes in extratropical cyclones affecting the northeastern United States. And let's focus on just the upper panel, as well as the lowest panel.

The upper panel, there are three panels show the frequency of extratropical cyclones projected for the future, and then for the present day as well as the change, which is shown on the right-hand side.

And we see that if we consider all the extratropical cyclones together, the current models project a reduced frequency of extratropical cyclones shown by the blue color on the upper right panel.

But, if we looked at only the stronger, or more intense extratropical cyclones, which are shown in the lower three panels, we see that the projection suggests an increase in the more intense extratropical cyclones, even though the total number of

extratropical cycles is projected to be reduced in the future. Next, please.

And here again, the northeastern United States, of course the concern is sea level rise. So, I'm not going to repeat this.

This is again showing that in the last 20 years, sea level changes have accelerated in terms of rate. And this is projected to continue into the future. Next, please.

And this figure, let's take a look mainly on the left hand side. This is showing the projection for New York City in terms of the tide gauge.

And on the X axis you see the flood height in terms of the mean higher high water. And then the Y axis is the projected fraction of years that experience the different foot height.

So, the blueish color shows the mid-century. And then towards the end of the century is shown in the red curve.

So, you can see projection of increases essentially for all different foot height, particularly towards the end of the century. Next, please.

And this study also looked at projected

storm surge and flood levels, particularly looking at changes in tropical cyclones and the strong winds can induce a storm surge.

Mainly what you're seeing in terms of the blue color, is the change for the -- according to the present day. And then the projection into the future is shown by the reddish color.

So, essentially what you are seeing is the projection of increases in the storm high return levels, particularly for New York City, that are shown over here, suggesting an increase in all levels of different, of flood return levels into the future. Next, please.

Now I pass it back to Rajiv.

DR. PRASAD: Yes. So, here we are showing a few climate projections for the watersheds in the northeast. And recall that Dr. Contri was talking about this issue also.

And behind that issue, he was saying that therefore the green flooding hazards need to be reassessed, because they are changing rapidly.

This study actually shows why. Beginning of latitude, the freezing pressure in many of these northeastern or high latitude watersheds is ringed in

trees across the freezing threshold, giving various decades of the 21st Century.

And some of these are already happening. So, that is what you see in the top panel. So, the temperature, you know, increased.

And those vertical lines are actually showing you different decades in the 21st Century, and the horizontal line is the freezing pressure.

So, once this happens for what the watersheds start experiencing, is decreased snowfall and increased precipitation. Plus, because of increased temperatures, you have more rapid snow melt.

So, as the 21st Century progresses, particularly for the business as usual stand, it will turn out to be to comprise that will be much talked about.

The flood hazards in these terrain conditions can increase quite rapidly. Next slide, please.

Ruby?

DR. LEUNG: All right. So, let's summarize what we have been showing you for the different regions of the U.S.

Essentially, we have highlighted several

points. The first is that there have been changes in sea level that would affect the coastal nuclear power plants.

Changes have been observed in the past. And then changes are also projected for the future. Combining the increase in the sea level together with changes in tropical and extratropical storms, so that could potentially have significant impact on nuclear power plants.

Secondly, we also looked at changes in air temperature, although the changes are variable across different regions of the United States.

But, more importantly, the increase in the extreme high temperature is basically seen almost everywhere. And so that could also have impacts on nuclear power plant operation, related type of impacts.

And then we also looked at Mesoscale conductive systems. As I mentioned the largest type of thunderstorms that produce a lot of flooding events, particularly in the midwestern United States.

We are seeing based on observational records, already see increases in MCS precipitation, but also projected into the future. That could result

in increased risk, particularly for the midwestern Untied States.

And then we also looked at the Great Lakes, changes in the Great Lakes level, even though more uncertain. And then also changes in the seasonality of snow melt and springtime runoff in northern states that could result in changes to both flood magnitude and timing.

And so this current state of the information from climate science can be used to inform nuclear power plant operations, related type of uses.

Most of the present, the content we presented, based on the national climate assessment report, called the Fourth Climate Assessment Report, and scientists are now currently working on the next climate assessment report that will be available by the middle of next year.

So, all of this information could be updated by then. Thank you very much.

DR. REISI-FARD: Thank you very much Ruby and Rajiv for insightful presentation. Our next presentation, our next speaker is Mr. Christopher Hunter.

Chris Hunter joined the NRC in 2002 as a

member of the Accident Sequence Producer, or the ASP Program. He is the current ASP Program Manager and Senior Analyst.

He has performed dozens of precursor analyses under the screening analysis, and has offered several annual ASP Reports.

Chris has a Bachelors in Chemical Engineering from the State University of New York at Buffalo, and was an enlisted nuclear operator in the U.S. Navy for six years.

Chris, I turn it over to you.

MR. HUNTER: Thanks Mehdi. Good morning everyone. I think we're falling just a little bit behind, so I'm going to try to catch us up. And so we'll just move forward. Next slide, please.

Just kind of a brief overview to kind of just to frame this presentation. We believe the evaluations of recent events caused by severe weather conditions have provided important risk insights.

As part of that, severe weather events, they are very likely to lead to losses of offsite power.

And so therefore, we believe a review of the current loss of offsite power data and trends can

be used to evaluate whether the more extreme events affect, how they are affecting nuclear power plants. And so those trends are kind of indicators of how severe weather is affecting our current fleet.

And some of the kind of key questions we're kind of asking ourselves, not necessarily that we'll be able to answer them using the existing data, but, are the frequency and duration of weather related LOOPs changing?

And also, what do the results and insights from recent weather related LOOPs tell us? So, next slide, please.

The first part of our presentation we'll be talking about the LOOP data and trends. And just for your information, this information is also provided in the LOOP study completed by Idaho National Lab as part of our contract with the NRC.

That LOOP study and past LOOP studies are on the reactor operating experience results and database web page on the NRC public site. Next slide.

First point I want to talk about is LOOP frequencies, initiated event frequencies. And just for clarification, when I'm talking about the LOOP trends, we're talking about different date periods for

these, some of these insights.

So, they're listed here. But, just to prevent any confusion. So, the overall frequency of all LOOPs is decreasing over the past 15 years.

This kind of decreasing trend is largely influenced by the decreasing trend of switch yard related LOOPs. There is no statistically significant trend for weather related LOOPs during the past decade.

So, but I'll -- next slide, and I'll show you a figure here on weather related LOOPs. So, this is the weather related LOOPs that we typically do not, you know, typically do not get a lot of weather related LOOPs, however, one to two.

You can see here, based on the P value of .052 that this is a nearly statistically significant trend that's largely influenced by the trend starting at -- in 2011 when we had five weather related LOOPs, which is the highest we've had in, you know, at least in decades. So, next slide.

This table is just showing you the weather related LOOPs for the past 15 years. Just know that in the previous -- in the frequency and trend data, we do not include losses of offsite power that occurred

during shutdown.

So, this is just a mixture of all weather related LOOPs, whether they were -- occurred at power or during shutdown, along with their durations, and/or cause.

And you'll see, there's a variety of causes, from hurricanes, snow and wind and ice impacts, high winds, tornados, lightening, et cetera. Next slide.

LOOP duration. So, we looked at the LOOP durations for -- since 1997 through 2020. The duration of all LOOPs showed an increasing trend during that period.

This increasing trend is largely influenced by the increasing duration of switchyard LOOPs. Again, Switchyard LOOPs are happening in higher frequencies, so they are definitely having a stronger influence on the overall LOOP trends.

There is no statistically significant trend for the duration of weather related LOOPs during this same period. However, in the past couple of years will show us that we've had a couple of severe weather related LOOPs recently.

Most notably the Duane Arnold Derecho

event in 2020. And even though it's not part of this data set, we had a loss of offsite power at Waterford during Hurricane Ida that was a -- that was a pretty long duration LOOP. So, next slide.

And this figure is a little bit busy, but this is the -- is showing all the different durations of LOOPs since 1996.

The weather related events are noted in the dash marks.

And I think in the future we'll be looking at maybe making the data periods consistent where we're looking at frequencies and trends and even the duration.

And so that could have an influence on future -- future durations of the weather related LOOPs. And on the next slide we have the table of -- next slide, please.

Here we show the durations by LOOP type. We have the plant center, the switchyard center, grid, and weather related LOOPs.

Again, these --(audio offline from 9:24 a.m. until 9:25 a.m.)

Higher duration of events in this area. So, we're not sure exactly what those are showing us,

and we're going to kind of have to relook at this the way we're doing this in future studies. Next slide.

This next part I'm going to talk about recent events. And this will be -- let us analyze this part of the Accident Sequence Precursor, ASP Program. Next slide.

This is another one that came out about the Brunswick LOOP during Hurricane Isaias. There was a storm generated debris that resulted in a LOOP to Unit One in August 2020.

Unit Two actually remained at 100 percent power. And so this is a -- kind of a rare event in the sense of most of our severe weather events result in the loss of offsite power at all units at the site.

So, this is one of the few in, I would say, at least the last decade or two, that actually only resulted in a single unit LOOP.

The LOOP lasted approximately 14 hours. Although there was some potential that operators could have restored power earlier.

Sometimes the grid is showing some instabilities. But, if they needed to, they could have potentially aligned the safety-related BUS to offsite power to them.

The mean conditional core damage probability or CCDP was $2x10^{-5}$. Now, and as part of that, the LOOP transient scenarios dominated risk and station blackout or SBO risk, was minimal.

Normally a station blackout risk is the dominant contributor when we're referring to loss of offsite power.

However Brunswick being a multi-unit plant, they have access to no -- Unit One had access to no other two diesels, but also shared two diesels with Unit Two.

And also, there was an SBO diesel that could be shared between units. So, that largely mitigated the risk of this event. Next slide.

Duane Arnold. As I mentioned earlier, severe winds, approximately 100 to 130 miles per hour during a Derecho resulted in the loss of offsite power in August 2020.

This storm caused severe damage to non-safety related cooling towers, basically totally demolished them. And also minor damage to some other buildings, the reactor building, their FLEX storage building, et cetera.

The high winds also resulted in increased

debris loading to the essential service water system, and resulted in a clogged strainer. The operators were able to bypass that strainer and maintain the diesel generators, the cooling temp diesel generators.

The LOOP lasted approximately 25 hours. The mean CCDP was $8x10^{-4}$, so significantly higher than the Brunswick event.

And the station blackout scenarios were dominant risk contributors because of Duane Arnold being a two diesel generator plant. And it being a single unit, it had no other resources there to share between units. Next slide.

Waterford LOOP during Hurricane Ida. So, as it wasn't part of a LOOP trend, but we wanted to mention this LOOP, because it was a severe LOOP.

Heavy rain -- high winds, heavy rain, and localized flooding resulted in damage to both sources of offsite power. The supplemental diesel generator experienced a failed battery due to rapid discharge after the LOOP occurred.

However, there was definitely potential that that, if it started early in the event, that supplemental diesel generator could have powered one of the safety-related buses.

However, both diesel generators actually worked during the event. So, there was no demand on that.

The LOOP lasted approximately 53 hours, which is the longest duration LOOP since actually Hurricane Katrina in 2005, I believe, with the cause of LOOP at Waterford.

The preliminary ASP analysis indicates a mean CCDP in the mid $1x10^{-4}$ to low $1x10^{-3}$. That analysis is still in progress. The licensee is reviewing that analysis and providing comments on that.

And again, the SBO scenarios were dominant risk contributors as well. And the single unit LOOP however, the supplemental diesel generator mitigates the fact that they only have two safety-related diesel generators.

So, it wasn't -- the risk might not be as high as the Duane Arnold event. Next slide.

So, I just wanted to go over some kind of general risk insights. Some of these I've already kind of pointed out.

So, the SBO risk is dominant for two emergency diesel generator plants for long duration

LOOPs. And so, that's again, not earth shattering, not a surprise at all.

Multi-unit sites with shared diesel generators typically have much lower risk. Kind of another point is having an EDG not included in the same common-cause component group as the other safety related diesel generators can be a significant benefit.

So, having kind of a diverse -- a diverse, differently designed diesel generators can help in that because the common-cause failure impact can be an environment contributor.

Also, just modeling of common-cause failures across the units introduces significant uncertainties because the data do not support this modeling.

So, just kind of a mention on that, that the NRC's failure models include common-cause failure across certain systems, most notably diesel generators and also service water pumps, et cetera.

The common-cause failure data is not collected in a manner that necessarily supports this modeling, because it is collected on a single unit basis.

However, you know, these equipment do share common-cause failure coupling factors. So, it's just something that we need to look at in the future.

LOOP duration has a significant impact on plants that have dominant SBO risk. So, the more recent events at Duane Arnold and at Waterford this year, this past year, these longer duration events do cause a significant impact.

Whereas, looking at Brunswick, due to the diesel generators and what they had is the offsite common recovery time had a minimal impact on risk.

FLEX credit can have a significant impact on the results. Again, not a real big surprise. However, some of the FLEX data that we have is showing pretty -- relatively high failure to run, failure probabilities given the 24 initial time.

And also there -- the NRC's spot models currently where now in the modeling is kind of a generic structure that has to be modified significantly by analysts. And so this kind of introduced uncertainties along with the data as well.

I think that's it on my presentation. Thanks.

DR. REISI-FARD: Thank you very much

Chris, for your presentation. Our final speaker is Dr. Fernando Ferrante.

Fernando is the principal Program Manager for the Risk and Safety Management Group in the Nuclear Sector of the Electric Power Research Institute.

In his role, he is responsible for multiple areas related to risk informed decision making applications, development of research and guidance of probabilistic risk assessment modeling, and wider EPRI efforts on climate change and plant resilience.

Prior to joining EPRI, Dr. Ferrante held positions associated with risk assessment for large commercial nuclear reactors at the U.S. NRC, and for the Department of Energy facilities at the Defense Nuclear Facilities Safety Board.

He also performed research and licensing activities at Southwest Research Institute related to a potential high level nuclear waste repository.

Fernando is a member of the Joint Committee on Nuclear Risk Management. And has supported international efforts in risk assessment, he held collaborations with EPRI members, as well as the

International Atomic Energy Agency and the Nuclear Energy Agency.

He had -- he received a Bachelor of Science Degree in Mechanical Engineering from University College in London. A Master's Degree in Civil Engineering from the University of Virginia, and a PhD in Civil Engineering from Johns Hopkins University.

Fernando, please proceed. You're muted Fernando. Well, you're muted now.

Zoom shows that you are muted. So, you are unmuted now, but you can still hear. You just muted yourself.

Can you call via phone? It seems like you're unmuted, but we can't hear you. Thank you.

So, Fernando will call again. It may take a minute or two. In the interest of time, I'm just going to mention a couple of items that I was monitoring the questions.

And there's some items that were sent for me. I'm just going to address them until Fernando calls back in.

So, there was a comment on making presentations available to all RIC attendees. It's my

understanding that all presentations will be available. But, I'll confirm that with the conference organizers.

There was a comment on, it seems like in one of the slides in Chris' presentation the -- it was stated that Duane Arnold was caused by hurricane. If that's the case, it was a typo. It should have been a Derecho.

We have Fernando back. Fernando, can you?

DR. FERRANTE: Yeah, can you hear me?

DR. REISI-FARD: Yeah. We can hear you now.

DR. FERRANTE: All right. Okay. So, we've shown resiliency in the face of adversity. So, I hope this a good sign.

DR. REISI-FARD: So there, please. The floor is yours.

DR. FERRANTE: All right. Thank you so much. And so, let me start and go quickly to the next slide. Hopefully we'll -- we can still end in time.

But, I'm going to talk about a number of EPRI activities that have been overtaken in this area. And so, one of the things I want to do is, highlight a couple of really key items.

I think the prior speakers have done a great job, at already highlighting some of those things that are aligned with the research we've been doing.

And so, the first thing to say on this first slide is, we are looking at the impacts on nuclear in a more global scale.

And so actually EPRI works in many areas, not just nuclear generation. And so we're looking at the issue of climate change on the energy system as a whole. Not just the generation assets, but as well as the determination of distribution assets.

One of the things about -- that makes nuclear particularly special in this area is, nuclear already had a long history in trying to make sure it has sufficient robustness and a significant understanding of some of this strength phenomena that can be associated with climate change.

And so, one of the things that I'm highlighting in this slide is, resiliency has been a topic that EPRI has been pursuing as a whole, not just in the nuclear sector.

Within the nuclear sector, a lot of activities that can impact climate change have been

already covered as well, in the sense that the terrain is not necessarily new, but the understanding of how some of this information gets coupled with climate change and the particular impacts that that can do, is something that we are adapting and moving forward on.

And so, seasonal events, the change in seasonality of some areas, the identification of that strong wind hazards for specific sites, given all the differences in regional impact, as well as how to optimize the operation of certain impacts that can come with the different emphasis and the different areas with climate change, such as biofouling. It's something that has definitely been on -- on work that EPRI has been doing in the past.

What has been changing and is new, is looking at the site specific hazard information. The prior presenters made a great job of talking about the global impacts.

Of course, for different assets in different locations, and different regional effects, you have to understand how that information relates back to your site. Since no site is going to have a single or unique homogeneous impact with climate change.

The other aspect is this broadening of the activity that we're undertaking at EPRI to fully integrate the understanding of nuclear, the resiliency that nuclear power plants already have, and then get notation that is needed. Not just within the nuclear plant, but syncing that with, and the overall reliability of the energy system. So, next slide.

So, in the next slide, you're going to see that one of the things I've sprinkled in this effort has been highlighted in presentations is, collecting information appropriate.

And so, within the nuclear power plant framework, internationally and domestic of different countries, there have already been significant changes in terms of the expectations to collective appropriate information.

And so not just looking at many of the events in the data basis such as the ones that were discussed in the previous presentations, but as well considering the information in light of the overall performance of the plants.

Is this changing significantly, as Chris Hunter and the NRC presentation discussed, if there are changes, even if they are not as significant,

where are they, and what's going on?

I think one of the staples that we are pursuing, and I think it's in line with a lot of other activities, is making sure the information is collected in real time, understood, and then cataloged so that sensitive understanding of, is something changing, what type of information is coming down in terms of developments in the state of our -- in the state of practice, and how does that impact ultimately nuclear power plants and then the entire energy system?

Some of the efforts that we've been undertaking are in line with expectations after the Fukushima event that the NRC and other regulatory agencies have done. And we're also following the Institute of Nuclear Power Operation guidance in terms of making sure that information is collected.

And so, this understanding of what's going on in the area, and what are we observing about the events, and how this is linked with the analysis, is at the outset. Next slide.

So, what's new going on in this already existing ongoing effort by EPRI in the nuclear sector has undertaken to look at information?

So, we have been performing an external hazard's information compilation analysis. Again, it's a fairly broad and structured approach to look at not just operational events, but also developments in the sciences, development you know, such as the ones shown by the Pacific Northwest colleagues, development in studies, and the overall understanding of the global climate change analysis, as well as regional impacts.

And so, we have been doing this for many years now, in the last five years actually. And we have collected and observed some of the same events that have been mentioned in the past, so I won't repeat those.

But, we collect more than just that. We collect changes in information, changes in risk, risk analysis that's being performed.

And we observe that for the most part, plants have maintained in origins already existing in their design basis.

And so a lot of the events such as a stray winds Derecho event that Chris mentioned, were identified as interesting items from a climate change perspective, as well as from general external events

perspective, and the margins up to still over, well over 100 miles per hour exist in many of those events.

And so again, this is not to take the information as black and white, does this mean something has changed or not? It doesn't mean that we can ignore or use information in a directly actionable way.

It's not the overall intent of this. The intent is to understand what that information mean, how to put it in context. And then ultimately understanding if the margin is significantly reduced or not.

At this point now we haven't seen the margins be significantly exceeded. But again, it doesn't mean that climate change, you know, is not happening, or that we believe that this isn't something that adaptation shouldn't be considered for. So, next slide.

So, we also did a white paper that was published recently, which focuses on the resiliency of nuclear power plants. And again, this is the beginnings of developing of the understanding of global climate change impacts as well as the margins of plants reality to be operational insights that

we've been getting.

And so, one of the things that is very important to distinguish here is, a lot of times when we look at data, we do see that the plants have to power down or have to shut down, do a safe shut down in advance of an event, or a potential impact so that may cause, or maybe causing in the beginning of a hazard.

And of course, there's two aspects of this. One is operational safety. Of the events that we have seen that can be impacted by climate change, we've seen that plants can respond and have sufficient resiliency and robustness at this point in time, as Chris indicated with his data and some of his discussion of the operating materials.

Now again, we were trying to understand not just what we are seeing, but what we might see in the future. And connect that to the climate projections that we have gathered and continue to be gathered by large organizations such as the RPPC.

And so, and then for the direction in terms of the framework that this needs to pursue to make sure that the adaption of the resiliency continues to understand new information, including if

future information may change some of the insights that we're having.

And so, this effort also was strong in looking at not just the operational safety, but also the operational impacts that this can have in terms of lost electricity production.

And so those two can be different. I mean, the plant can work, you know, operate safely though extreme events, but loss of generation is still something that can be a concern in terms of understanding what the risk is.

So, it's still risk analysis, and it's still understanding what the overall risk currently and potentially in the future is.

But, it's understanding that there is a two-pronged aspect to the issue, not just, you know, whether a nuclear power plant can withstand some of the most extreme events that we may see in the future on a global change in a regionalized way.

But, also trying to understand whether the operational side of, you know, the expectations that ultimately these assets are expected to provide safe and reliable electricity sources in terms of how that gets impacted in the overall picture of the energy

system as a whole.

And so, in the next slide, we show a little bit of the insights that are contained in the documents I mentioned in the previous slide.

And so we look at some of the same data overall that Chris Hunter discussed in the U.S. We looked at it in a global level, as well as looked at it in terms of lost generation.

And so, not to take too much time here, ultimately we see what, for example we saw in an NIAA report in 2019, adapting the energy sector of climate change, which is the events ultimately, the extreme events that we may associate with climate change moving forward, are very small in the overall picture.

And so, the vast majority of events we see at nuclear power plants are not extreme events, number one.

Number two, even those events that we've seen where there was some impact, sometimes the impact is really lost generation in terms of grid instability, that causes the grid operator who has to plan to dump power.

Or potentially anticipatory shutdowns to make sure the plant can be secure and stay safe during

an event. Which again, doesn't really speak too much to impacts to their safety overall at this point in time.

But, it also speaks to electricity power generation is ultimately an important aspect of what needs to be considered.

So, we did look at the events and calculated a fairly high level, but insightful study in terms of how many hours, how many megawatt hours per year were lost.

And again, considering that plants, nuclear power plants and their overall energy system as generation assets provide, already have a very high capacity factor.

So, even where those plant shutdowns for refueling outages and so forth, the plants are already observing 95 percent capacity factors.

And some of the plant shutdowns that we have to observe, even those that are not necessarily related to weather events, the reduction goes down to 92.5 percent.

And so, the plants are still operating significantly. And that's a good thing, because our means of power generation is also, you know, already

significantly robust, but it's something to continue to look at.

You know, overall the nuclear power plants are producing, you know, through even more extreme events, the power that is needed, particularly in say a snowstorm. Homes and other facilities still need electricity to be able to operate through those events.

And they're operating safely. And so far we haven't seen a significant impact in the loss of margin.

Again, the purpose of this discussion is not to say this doesn't mean, you know, that climate change is not important. It's to understand the current margin, understand whether it might be changing, and as we collect information, continue to be informed as to what needs to be done if adaptation is needed. So, next slide, please.

So, some of, you know, the prior presentations already kind of touched on the different impacts that climate change can have.

And so clearly, for climate change some phenomena that the plants can be protected against, you know, are covered.

Some are not necessarily impactful to climate change. Loss of power can happen from a number of issues. Some of them are not related to weather.

And that's something as Chris Hunter highlighted in the NRC presentation, can be looked at in some ways into the risk models that we have for nuclear power plants, and in some cases has to be adopted to be able to understand that better.

The white paper and some of the studies that we've done in the past cover in detail changes in air temperature, extreme storm events.

Already the design basis and from a probabilistic hazard point of view, sea level rise and clean water impacts we understand, storm surge can be impacted from weather events.

We understand systems are interfacing with large bodies of water can be impacted by changes in temperature, by extreme phenomenon.

And so part of the question here is not just to say, well we see a change in some of the natural phenomenon coming, but how can that impact the plant?

And then not just how can it impact the

plant in terms of well, a loss of offsite power can lead to a significant event, but how can the particular phenomena be considered both in terms of the impacts to the site, as well as if it is air temperature, the side impact thermal limits that are imposed for a number of reasons on the amount of heat that is projected to the environment.

And does that impact the operational aspect and to the electricity generation as well from a perspective of the asset of the grid, the energy system, and the global impact of climate change. So, next slide, please.

So, one of the things that we're trying to do is provide a fairly structured process to cover information and to cover what we think is the best approach to go about this.

Again, without going into all the details and the time we have remaining, the thinking here is, overall is, there is a lot of good information already into the development of the science on the global climate aspects.

What hasn't been as well developed, and probably needs more information is, saying that there is climate change coming is not really the end of the

story from a proper way to deal with this complex issue.

What is important is to gather information, continue to develop the science. There is a lot of uncertainty in some of the estimates and overall in dealing with extreme events, and trying to understand whether there is a significant change.

Whether that covers something that has already showed us the margin, and then highlight the vulnerabilities that may lead to develop a plan.

And so, if something is going to be impacted, what is that? Is that the most important thing that can reduce the risk?

And how can the nuclear asset within the grid, within the energy system continue to perform its key functions and provide safety electricity, and provide potential climate change impacts. So, next slide.

So, in the time we have available, I won't cover everything that we're planning to do, but there's a big activity I'll cover in a little bit more detail next that is very large.

And it, I think our colleagues at the Pacific Northwest already did a great job in

discussing some of this.

We are planning workshops. We are planning collecting a lot of the community such as colleagues from the nation labs, the NRC, international organizations, NGOs, to come together and look at this information as a whole, and bring it together within the framework that can be used.

In terms of connecting the data to develop vulnerability assessments that truly understand the risk, impact this phenomenon can produce in the future, and ultimately develop a plan that those responsible for the asset can implement in an efficient and most appropriate manner. Next slide.

And so the initiative I'm discussing is called READi. It stands for EPRI Climate Resilience and Adaptation Initiative.

And it is divided essentially in workstreams that will capture a lot of the concept information. Looking at the data, understanding the data, continuing to develop the science and support the aspects of the analysis.

We look into a vulnerability assessment, not just well, is climate changing, and can that impact power plants, but how can it impact?

To what level, and what does the analysis of the risk, which ultimately needs to include both the hazard potentially changing as well as the existing margin and what can be done to improve, if anything, the resilience of the asset into one place.

And then ultimately the workstream 3, it just highlights the idea that there are many aspects just, not just beyond looking at the global climate change data, but analyzing the vulnerabilities and then providing the framework that can both communicate to those that need to address potential challenges or questions about the capacity of dealing with these issues.

Manage that information, continue to monitor and continue to consider what it does. And then look at the options that are in front of them in terms of what can be enhanced, what can be made more robust, and how can operations continue to run efficiently while ensuring that they are covered for climatic changes. So, next slide.

So, key takeaways I want to share with you here. The main one is that, you know, the robustness of the nuclear power plants is -- exists.

It has been enhanced in the last ten

years. It will continue to be enhanced. And understanding climate change is part of the continuing improvement of the activities that nuclear power plants have performed in the many decades of operations.

So, that doesn't mean that, you know, there isn't a need to continue to work on this issue. I think there is a need to make sure that it is informed. That ultimately the high reliability that nuclear power plants operate, is considered within this context.

And that adaptation is part of a risk informed approach that considers what can be done to provide the best improvements for risk, as well as make sure that improvement in risk, reduction of risk, is justified under a science base and a technical engineering approach that looks at the best pathways to make sure that the assets continue to provide electricity in a managed system, a globalized approach.

And so, that's the end of my presentation. And I'll take questions.

DR. REISI-FARD: Thank you Fernando and all the speakers. We are almost out of time, and we

have received many questions.

So, I'll just start asking them, and I don't know how far we can go. But, I'd ask the first question from Paolo.

How do you reconcile the increase in interruptions with improved capacity factors and energy production by domestic nuclear facilities over this same time frame?

DR. CONTRI: Well, I will say -- I will say that this, of course the picture that I presented is related to the worldwide population of plants, so not only the U.S. So, this is clear.

In any case, my answer has to be related to what other speakers clearly stated. That the business interruption related to same weather events, they have usually a very short recovery time.

And this is why actually the capacity factor doesn't go down too much. Even if we can count an increasing number of business interruption events.

This is a very -- this is a very simple question, answer I would say.

DR. REISI-FARD: Thank you very much. Perhaps there's time for one more question. So, the question is for Ruby.

How does the extreme precipitation increase in all regions comport with those U.S. regions that are observing severe drought?

In the view of the questioner, that doesn't seem -- that doesn't seem to be consistent. Are we observing severe droughts and severe precipitation in the same area? If so, is there a reason for some severe gauge for drought?

DR. LEUNG: Yeah. I think this is a very good question. Yeah, often asked like why do we expect like the two extremes might be happening at the same time?

And in fact, it is possible that in the same regions in the future, it could experience increase in drought as well as increase in extreme precipitation.

And that's because a drought is mainly caused by the heat, an increase in the evaporation. But, the land surface is not able to provide enough of the moisture. And therefore there is this increase in the aridity and drought.

But, at the same time, there could be weather systems that happen where the moisture is transported from the ocean overland. And because of

the warmer temperature, there is more moisture in the air.

And so in the right condition, the storm can produce more extreme precipitation because of the increased moisture. So, this is actually projected to happen in some regions, both extreme dry and extreme precipitation.

DR. REISI-FARD: Thank you very much. And unfortunately we're out of time. And we don't have time to go over many of the questions that we received.

I'd like to thank everyone who attended this meeting. I'd like to ask, to thank you for all the questions that you've sent.

And I'd like to especially thank our panelists for their time, informative presentations, and their valuable insights.

You can see on the last slide, if it's up, on the last slide that we have, you can see our contact information. If there are any questions, feel free to reach out to us.

And with that our session is closed. Thank you very much.

(Whereupon, the above-entitled matter went off the record at 10:00 a.m.)