COMMISSIONER: We convene this morning and I welcome back. We are moving back to topic 4, Low Carbon Energy Generation Options and this morning we will be hearing from Mr Mike McGough from NuScale and also from Westinghouse on the AP1000. Mr Jacobi.

MR JACOBI: Mr Michael McGough is the chief commercial officer of NuScale, a company from the United States. In his role at NuScale, Michael McGough overseas worldwide business development communications for the company. He joined NuScale from UniStar Nuclear where he was senior vice president. He has 36 years of involvement in the nuclear industry, supporting the construction, operations, maintenance and decommissioning of nuclear plants worldwide. He has been involved in new plants with Westinghouse, UniStar, dry field storage as senior vice president in Ace International, low level waste management and decommissioning at Duratech and Energy Solutions. He was the senior vice president and then the president of PCI Energy Services where he spent 11 years working in mechanical projects such as steam-generated replacements and decommissioning and the Commission calls Mr Michael McGough of NuScale.

COMMISSIONER: Mr McGough thank you for joining us. We are going to go through the technology and where you are with development but I would like to start with a more general question. We have heard a lot about the inflexibility of large nuclear reactors and I was just interested to hear from you about the ability of the NuScale SMR to load follow?

MR MCGOUGH: Sure. Again, thank you for inviting me to participate in your sessions; I am very appreciative of the rigour that you are making to consider these important topics. So large nuclear plants are typically designed to be base load sources that do not easily vary their power output over given units of time. So they are normally fixed at eight or 900 or 1,000-megawatt output and they run at that level for one or two years before they are shut down. The reasons that they don’t typically load follow is some mechanical issues and some – just generally the way the plants are designed and they (indistinct) the operating peak that we have today was really designed for that purpose back in the sixties and seventies. So those designs were quite some time ago. With the advent of intermittent sources of generation, leading to electricity grids, things like wind and solar, it has become important that base load generating sources are able to accommodate the fluctuations of the electricity as it is provided to the grid. So the NuScale plant is specifically designed to accommodate those types of things in three different ways: first, since our plant has 12, 50 megawatt modules in one location, the generator gross output of 600 megawatts. Each module can be independently taken offline, so by taking one module offline, you would reduce the output of the plant by 8 per cent.

The effective way of our ability to load follow is that each module is able to vary its output, plus or minus 40 per cent, per hour. So you would effectively have 12 independent degrees of freedom, by modulating the output of each module, independent of the others.

With the third and final way that we’re able to accomplish load following is that the plant is designed so that the whole speed and output from each module, which normally is rotating a turbine to generate electricity, it can be switched to completely bypass the turbine. We have all this steam; normally that’s to deploy the turbine, and instead it bypasses the turbine and it’s re-condensed to liquid water, right into the condenser.

That last mechanism is not a good use of fuel, because of course, you’re using nuclear fuel to generate the steam, but you’re not using the steam to make any electricity.

So those are the three mechanisms that the NuScale power module has inherent to the design, to allow it to accommodate load following.

COMMISSIONER: Thank you very much. Mr Jacobi?

MR JACOBI: Perhaps if we can start at the physical design characteristics of the plant, and then begin to address some technical aspects, with respect to cooling and safety, and I think we’ve got a slide that might pick this up. And I think it’s slide number 2, and I’m just wondering - - -?

MR MCGOUGH: Yes.

MR JACOBI: - - - perhaps whether you could explain the nature of the NuScale power module that you’ve already referred to, the 50 megawatt individual components?

MR MCGOUGH: Certainly. So as you can see in slide number 2, the picture on the right, that is a single NuScale power module, and you see how it is installed in an operating bay. Those vertical, cylindrical blue things, they represent the pool of water, and the power modules are installed in those operating bays, and what you’re looking at is a cross section of the reactor dome. So you see in there, six of the operating bays are for NuScale power modules.

The reactor building itself and the pool with the operating modules is below grade, so it’s underground in this large pool of water that serves the purpose of the ultimate heat transfer. So in seeing the location where the operating bays are located, on the left side of those you see an area where there are two small components. That area is the area where each module is disassembled when it has to be refuelled.

So now the 11 other operating power modules remain in service, one module is taken out of service for a refuelling cycle, every 24 months.

MR JACOBI: Yes. Am I right in understanding that that distinguishes this plant from other plants, in the sense that essentially it does not need to be taken offline?

MR MCGOUGH: Very much so, yes. It was a large plant, a thousand megawatt plant, and you said you were going to be speaking to the AP1000 people so this will be a good comparison for you.

The AP1000 generates a thousand megawatts of electricity and when it shuts down from refuelling, it's, like, a 35 or 40 day period, it's not making any electricity at that point in time. And similarly, in the construction cycle when we build the NuScale plant, as soon as the first module is installed, it will be generating electricity while at the same time, the additional modules are being commissioned.

MR JACOBI: Right. Now, can I just come to the image on the right, and I'm just interested about whether you could describe - I realise there's a complexity about the overall module design, but there's a reference on the left; can you just identify where the turbine generator is? With other plants, we've seen (indistinct) turbine builders?

MR MCGOUGH: Yes, sure. So if you go to slide number 6, you will see the general facility layout of the plant.

MR JACOBI: Yes?

MR MCGOUGH: And in the centre you'll see the reactor building; that is the location where the power modules are being located.

MR JACOBI: Yes?

MR MCGOUGH: And then you can see that it is flanked by the turbine buildings, each of which contains six turbines. So each NuScale power module is mated to its own turbine generator, effectively providing an independent 50 megawatt generating unit that is independent of the other 11.

MR JACOBI: Right. Now, perhaps coming back to slide number 2?

MR MCGOUGH: Yes?

MR JACOBI: With respect to the module itself, I'm just wondering perhaps whether you could identify just the key aspects, in terms of the overall module, in terms of what the componentry is that we're looking at, on the right?

MR MCGOUGH: So the best way to do that is to look at slide number 4.

MR JACOBI: Yes?

MR MCGOUGH: So if you look at slide number 4, the blue area on the outside of the vessel is water, okay? So that's the water of the pool. The outermost vessel, that is the containment vessel. With a normal nuclear power plant, containment is a large dome shaped concrete structure that's about four feet thick, and reinforced with steel rebar about the size of my arm.

In a NuScale power module, our containment is a vessel. So that outermost vessel that you see contacting the blue water, that's the containment vessel. Inside the containment vessel, you see a second vessel. That inner vessel is the reactor vessel.

So the way this works, is the nuclear fuel is represented by the red area at the bottom of the pond. The fission reaction generates heat, and that nuclear core is surrounded by liquid water, but it's under pressure of a pressurised water reactor, and that pressure allows the liquid water to remain as a liquid, even at 550 degrees, that's far above its normal boiling point.

When the fission heats the water, water, like any fluid, rises when heated by natural convection and buoyancy. So that heated water, represented by those red arrows, rises up through that bronze coloured tube, which is called the riser tube. That riser tube is surrounded by coiled tubing called the helical coiled steam generator.

That coiled tubing that is around the bronze riser tube contains cooler water. That cooler water is heated by the hot water, as it flows over those tubes, by conduction. So the heated water in the inside of those tubes is not under pressure, and it becomes heated to boiling point, at which point it is directed outside of the power module, to rotate the turbine in the main steam lines.

Then the water, after it has given up its heat, to heat the water inside those tubes, that hot water becomes cooler. When it becomes cooler, it becomes more dense, and then is drawn by gravity to the bottom of the reactor vessel, where the natural circulation flow path continues, as long as there is a source of heat.

So in order for the final reactor to work, it requires three things: convection, conduction and gravity. And those three things work all the time, and they're very easy to maintain. We have eliminated from the nuclear plant, a number of significant major mechanical components that are normally required to use electricity, and to use large mechanical pumps on pressurisers and piping systems, to make the coolant flow and to generate electricity.

MR JACOBI: I think that’s - - -

MR MCGOUGH: If you looked at - - -

MR JACOBI: I think at that point - - -

MR MCGOUGH: --- - - - the picture on - sorry - on drawing number 3, you can sort of see a comparison. On slide number 3, all of those components that are shown inside of that domed concrete structure, that’s what you see inside of the normal pressurised water reactor.

We accomplish all of those things with our cylindrical NuScale power module, that is 70, 60 (indistinct) feet in diameter.

MR JACOBI: Yes. I think at that point it might be appropriate to pick up the concept of reactor coolant pumps. Could you just identify where they are on slide 3?

MR MCGOUGH: Of course. So in slide 3, the red item in the middle, that's the reactor vessel. The blue things, those are called steam generators. Those steam generators are about the size of a NuScale power module. The green things, those are the reactor coolant pumps, and then that purple thing in the back corner, that is a pressure (indistinct) and then you can see the grey piping that's connecting all of that. That is several thousand feet of piping that is about 30 inches in diameter and about three and a half inches thick. Through that piping 20 million gallons an hour or 500-plus degrees of highly radioactive coolant flows in a normal Westinghouse pressurised water reactor. All the stuff that I just described is contained, and those functions are all performed, inside that one NuScale power module (indistinct) operations previously.

MR JACOBI: I think perhaps at that point - there's actually a reference to it back on slide number 2, and that is - there's a statement in the first slide with respect to the large bore piping. Is that what you're referring to there? Is that what you described?

MR MCGOUGH: Yes, exactly right. Exactly right. So in nuclear speak, we lots of acronyms and there's one there that says LB-LOCA. LB means large bore. So large bore piping is defined as anything over 3 inches, and a LOCA is a loss of coolant accident. It is one of the most significant events that you have to design a reactor to be able to cope with in terms of your safety analysis.

We've eliminated the need to do any of that safety analysis work because we don’t have any large bore piping; thereby we're not able to have a large-break loss of coolant accident.

MR JACOBI: Now, coming back to the coolant pumps, I understand that with respect to a number of designs that there's significant redundancy built in with respect to reactor coolant pumps and the like. I'm just wondering whether you can contrast the position between NuScale and between other designs.

MR MCGOUGH: So that is one of the biggest differences between NuScale and other designs. All other designs have some sort of a reactor cooling problem that is providing the driving force to force the coolant across the core. Well, the name of the game is you always want to keep the core cool, and it's done by mechanical forces, reactor coolant pumps in other designs. In that case, we use natural physics.

MR JACOBI: Now, if we can come back to the plant layout which is shown, I think, in slide number 6.

MR MCGOUGH: Yes.

MR JACOBI: I'm just wondering about whether or not you can give me an idea of the overall sit area that's expected for a NuScale plant.

MR MCGOUGH: Sure. So the area that's referred to there as the protected area, that is a 40-acre footprint, and the furthest out vent is the (indistinct) controlled area and that is said to be two acres. So it's approximately a 70-acre site footprint once construction is completed and it's installed.

MR JACOBI: Are you able to offer any comparison between that and, say, a larger nuclear power plant?

MR MCGOUGH: I would say that a larger plant is probably in the order of 350 acres, something like that.

MR JACOBI: I'm just wondering if we can just briefly deal with the issue of cooling. You mentioned the water usage associated with a typical large nuclear power plant. I'm just interested to understand the sort of water requirements that are expected to be required for a NuScale plant and any differentiation - I understand many plants use seawater - what the requirements would be with respect to seawater and freshwater.

MR MCGOUGH: Sure. Yes. The cooling requirements for a NuScale plant are not dissimilar to the cooling requirements from any thermal power plant, whether it be natural gas or coal or other types of nuclear plant. So we still do require a significant source of cooling water, whether it be saltwater or river water, freshwater. It can be either of the above. And we are capable of operating the plant in a dry cooling scenario, which basically means in an arid condition you put large fans to provide the cooling. The downside of that is it has about a 7 per cent parasitic load that it consumes from the output of the plant in order to drive those cooling fans. So if you're in a location where you didn't have a (indistinct) source, you could go to a dry cooling thing, but it penalises the regular output of the plant by 7 per cent.

MR JACOBI: The data, I think, on slide number 2 picked up the idea that the plant had a nominated output of about 600 megawatts and used about 30 megawatts, I think, in terms of its overall internal plant use.

MR MCGOUGH: That's exactly right, yes. It's 600 megawatts gross, 570 net, because about 30 megawatts are used to run the plant.

MR JACOBI: And would we be looking at another 7 per cent off that 570 number, is that right, for air cooling?

MR MCGOUGH: Sorry, I didn't quite understand your question.

MR JACOBI: I'm sorry. To pick up your answer from before, in terms of the efficiency penalty associated with adopting a dry cooling technique, are we looking at about another 7 per cent off the 570 figure?

MR MCGOUGH: Yes, that is correct. So if you take .93 times 570 - I'll grab my calculator and I'll tell you - that would make the output about 530 megawatts under a dry cooling scenario.

MR JACOBI: Right. And I'm just interested, in terms of the designs for using an air cooling system, has there been much design work done in terms of adapting the cooling systems for a NuScale plant for those sorts of different conditions, so using a wet cooling scenario and a dry cooling scenario?

MR MCGOUGH: You ask have we contemplated that as a design? That was your question?

MR JACOBI: No. I'm just interested to the extent to which there's been testing or demonstration done with respect to a dry cooling technique as opposed to using the wet cooling method.

MR MCGOUGH: Yes. Dry cooling is commonly used in a number of applications. We have not tested the cooling of the condensate from the backside of a turbine in the condenser. We have not tested that part of it, but those types of cooling are very well known phenomena and how they act, very well known. So we don’t feel compelled to test that when we've done the testing around it. I have the nuclear (indistinct) that works.

MR JACOBI: I think we picked up some aspects of passive safety already in our discussion, and I'm just interested to understand - perhaps we can express it in this way - about whether or not a Fukushima-type accident can occur with the reactor design that you've developed.

MR MCGOUGH: Sure. So that's a really good question and that's one of our distinguishing characteristics that our inventor, Dr Jose Reyes, set out to accomplish when he designed this plant. But to be specific, in the case of a Fukushima-like event, which is referred to as a "station blackout", where the plant was deprived of all off-site power and all electricity to run the plant systems - so if you remember, a tsunami washed the emergency diesel generators out to sea and the backup battery systems ran for about 14 hours when they're designed to run for 12. At that point, there was no additional source of electricity (indistinct) the operators in the control room holding flashlights in their mouths, trying to reach strip chart recorders (indistinct) condition of the plant.

In the case of a NuScale plant, our plant will shut itself down and cool itself off forever with no operator action, with no additional source of water other than the common pool and with no AC or DC power. So it is designed to do that in a relatively simple fashion. If you refer back to the slide number 4, what happens is we have main steam lines that exit the containment vessel and those main steam lines have valves attached to them which are energised in the open positions. So the require electricity for them to be open. When the station blackout happens, those valves – they’ll shut and at that point the containment vessel is isolated from the rest of the world, and all that steam is now bottled up and not going anywhere. There are a second set of valves called the decay heat removal system valves that are energised in the shut position and on loss of power they will open which now allows the steam, instead of going to the turbine, goes through those valves and in to heat exchangers that are mounted on the outside of the containment vessel but inside the common pool (indistinct) So now that steam is going through those heat exchangers and it will continue in the same natural circulation flow path but it uses the heat dissipating capacity of the 7.3 million gallons of water in the common (indistinct) So that is an executive summary fashion, that is how our plant has what is referred to indefinite coping time in the case of a station blackout event, like what was experienced at Fukushima. And I should had that they have tested and demonstrated this with the Nuclear Regulatory Commission on our one-third scale prototype which has been operational now for 12 years.

MR JACOBI: I am just interested – this might be to ask something you have already answered but in terms of operator intervention that is required to achieve those outcomes, to what extent is operator intervention required?

MR MCGOUGH: To what extent is operator intervention required?

MR JACOBI: Required in the event of that station blackout?

MR MCGOUGH: None. In fact we don't want the operators to do anything. The control room allows the operators to monitor the plant doing what it is designed to do but there is no operator action required. The (indistinct) view in that room could be the controlling operators have a cup of coffee, watch the control room monitors indicate the components of the plant.

COMMISSIONER: Could I just interrupt there? When you are talking about people in the plant, can you contrast - - -

MR MCGOUGH: Yes.

COMMISSIONER: - - - a large nuclear reactor footprint in terms of people and what you would expect to run your reactor?

MR MCGOUGH: Certainly. The typical large nuclear plant will have probably seven or 800 employees and will require something upwards of 5,000 people at peak construction time. We need to look at the (indistinct) for global nuclear plant construction efforts that are going on at the southeastern United States and get a really good feel for that. In a NuScale plant, the peak construction workforce will be about 1,100 workers and in normal operation with 12 operating NuScale plants who have 360 employees that are working at the plant. The one thing that is very important to understand is that in a normal large nuclear plant the refuelling is – takes place every 18 to 24 months depending on the plant cycle and when that happens they bring in about 1,000 workers to run that outage and to do all of those specific activities. When the outage is over those people leave. With a NuScale plant, we do the refuelling work with indigenous house personnel, who do nothing but refuelling and since we have 12 reactors and they run on a 24-month cycle, you could quickly understand that every other month, we will have a refuelling outage. Those activities will be performed by people who are very good at it because that will be all their function is, is to do the refuelling. So comparing it to larger plants, you have to consider the work load that takes place during refuelling that we have accommodated with our 360 people that run the plant.

COMMISSIONER: Could you just explain for us dummies what reviewing is?

MR MCGOUGH: Sure, so the core – nuclear core is comprised of fuel assembly and fuel – in our case we have 37 fuel assemblies. A fuel assembly is an array of (indistinct) symbols of zirconium tubing and inside of that zirconium tubing are uranium oxide pellets that are about the size of this joint on my little finger. So you have these large – these stacks of the uranium oxide pellets that are in this – the zirconium clad material, held inside of the core. After a period of time, typically in our plants, two years, you take about one third of those fuel assemblies and remove them from the core and replace them with new fuel assemblies. That is what the refuelling cycle is. So the fuel is a physical solid material. If you look at drawing number 5, you will see there the fuel pool is located to the left of the operating bays. That fuel pool is where the used nuclear fuel is stored for some number of years while it thermally and radioactively decays. Does that answer your question, sir?

COMMISSIONER: You did indeed, thank you.

MR JACOBI: Can I just - - -

MR MCGOUGH: You’re welcome.

MR JACOBI: Can I just come back to just very quickly, the issue of passive cooling and we have heard, certainly in some of the submissions that we have received, that because gravity is relied upon and natural systems are relied upon for the movement of coolants, that there might be a potential - - -

MR MCGOUGH: Yes.

MR JACOBI: - - - for blockages. And I am just interested to understand the extent to which that has been addressed in design.

MR MCGOUGH: Sure. So the audio is a little bit fuzzy there, I couldn’t quite understand your question. Sorry.

MR JACOBI: I am sorry, I will repeat it. We have heard in submissions that with respect to passive cooling, that you need to take account of the potential for blockages and I am just interested to understand the extent to which blockages have been taken account for in the design?

MR MCGOUGH: Yes. So if you (indistinct) some blockages, I am not exactly sure what that could be referring to. There is an issue that can happen in a large nuclear plant (indistinct) to have a loss of coolant accident that resulted in steam exiting the reactor vessel and becoming (indistinct) inside of the containment building. The reactor vessel has on a normal operating nuclear plant, reactor vessel has insulation on its outside and that insulation can break down and cause blockage in the sump where the steam is recirculated from. That is referred to as the sump strainer blockage issue. I am not familiar with other incidences where the primary coolant system, that large grey piping I showed you on that drawing before where blockage occurs in there. In my experience I haven't seen that. In our design, as you can tell, everything is contained within the containment vessel, so we don't have the potential for such a blockage event because there isn't any pipe to the block.

MR JACOBI: Again, picking up just on a different topic, which is this issue of site size and do you have a view about the difference in site sizes, likely to affect the buffer zone that would be required around a NuScale plant as compared to the buffer zones that are required around other nuclear power plants?

MR MCGOUGH: Again, I apologise, I'm having a little bit of a hard time picking up some of the audio, it sounded like you were asking for comparison of the site size?

MR JACOBI: No. We understand that nuclear plants typically have an exclusion zone or a buffer zone around them and - - -

MR MCGOUGH: Yes.

MR JACOBI: - - - I just wondered whether there is a difference between the buffer zone that would be expected around a NuScale plant - - -

MR MCGOUGH: Yes.

MR JACOBI: - - - as compared to a larger conventional plant?

MR MCGOUGH: Sure. Certainly. Sorry, I understand the question now. That is referred to as the emergency planning zone. So the EPZ by regulation in the United States is 10 miles. So it's a 10 mile diameter from the centre of the plant is this – considered the emergency planning zone and that requires the owner of the plant to behave in certain fashions in that emergency planning zone. The emergency planning zone is determined as a function of a couple of things. One, the probability of an event that results in damage to the core and that in nuclear speak is called core damage frequency. For existing nuclear plants in the United States by rule, the core damage frequency must be less than 10 to the minus fifth in reactor operating years. So what 10 to the minus fifth is that the one with five zeros after it, so that means it is one in a 100,000 operating reactor years of experience would be the predicted frequency of a core damage event. In a NuScale plant our core damage frequency is 10 to the minus eight. So it is (indistinct) of magnitude less likely to experience a core damage event than in conventional plants.

MR JACOBI: Sorry, can I just - - -

MR MCGOUGH: (indistinct) our - - -

MR JACOBI: I am sorry to interrupt you there, I was actually going to come to this, so I am happy – I am glad that you have raised it but I am just interested to understand the basis for the calculation of the core damage frequencies and how you have arrived at that particular figure? How it is derived?

MR MCGOUGH: Sure. Yes, it is a very complicated calculus and basically what we do is we calculate the likelihood of different events that can happen in the plant. So it is actually a living calculation as the plant design is completed because certainly when you go through the mathematical modelling of different occurrences, they have multiplicative effect on each other. So it is – if you think of basically every possible thing that you can think of that could go wrong, you have to calculate what the probability of those events happening and then you sum them up and the results – and come to a core damage frequency calculation that as part of your design certification application submit to the regulatory (indistinct) so there is a separate part of that emergency planning zone that I want to connect the dots for you. Once you have done the core damage frequency calculations, the second thing you have to look at is, what are the barriers between the nuclear fuel, which is the hazard and the outside world. In a conventional nuclear plant there is three barriers, the first is that zirconium-clad tubing that I described that houses the fuel pellets. The second is the reactor vessel and the third is the concrete (indistinct) containment building; that is your three barriers.

In the case of a NuScale plant, we have seven barriers. We have four additional barriers besides the three that exist in the normal nuclear plant. We have the (indistinct) cladding, we have the reactor vessel, we have the containment vessel, we have the water in the pool, we have the liner of the pool, we have a barrier over the top, a biological shield barrier over the top of the pool and then we have the reactor building itself. So we have a lower probability of a core damage event and we have greater protection between the core and the outside world. That allows the NuScale plant to justify by calculation the emergency planning zone to be the site boundary. And we have submitted this to the Nuclear Regulatory Commission, the US Nuclear Regulatory Commission and those commissioners have agreed to consider the right sizing the emergency planning zone for our plant based on our unique safety features.

MR JACOBI: Now I am just interested to understand - - -

MR MCGOUGH: So have a lower emergency - - -

MR JACOBI: Sorry. No, go on.

MR MCGOUGH: I was going to point out one other thing that having a lower emergency planning zone, (indistinct) to site one of our plants at a location here in the United States where coal plants are being retired.

MR JACOBI: I will come to licensing in more detail in a minute but I am just interested - - -

MR MCGOUGH: (indistinct)

MR JACOBI: - - - just to pick up on one aspect of the issue with respect to fuel loading and I am just interested – I think we have read in the literature that there is a stated capacity factor for the NuScale plant in the order of about 90 per cent and I am just interested to understand the basis on which that has been arrived at?

MR MCGOUGH: I am sorry, I heard you say 90 per cent but I could not understand the other part of the question.

MR JACOBI: I am just interested to understand your view as to what the likely capacity factor is to be for the NuScale plant?

MR MCGOUGH: Yes.

MR JACOBI: And then to understand - - -

MR MCGOUGH: Right.

MR JACOBI: - - - what the basis is for the statement of that figure?

MR MCGOUGH: Right. So the capacity factor at the plant will be 96 per cent and that capacity factor is driven by the operating cycle of 24 months with a 10 day refuelling outage. So in a 24-month period, any given module will be out of service for 10 days. So the capacity factor is calculated based on that fact.

MR JACOBI: We have heard there is – we have heard in the submissions some controversy about the capacity factors for nuclear plants and we have heard some evidence that plants in the United States are now operating at about – around about the 90 per cent level and I am just interested - - -

MR MCGOUGH: Yes, that’s correct.

MR JACOBI: - - - your view as to how it is that this plant can achieve 96 per cent, as against some operational experience that has been at some point in the eighties and as I understand now in the – around the 90 mark.

MR MCGOUGH: Sure. Yes, that's a really good question. The main reason that our plant will operate – and there are plants in the United States now that operate in the high nineties capacity factor, some actually operate over 100 per cent. But the main reason that our capacity factor would be higher is because of the things that you have to do in your shut down. So how long the – how often do you have to shut down and you shut down for refuelling, what are the work activities that have to be performed. If you look at slide number 7, you will see a list of safety systems that are necessary to protect the core of a typical light water reactor. That was the 26 systems – the eight systems that are in dark black letters, those are the only systems that we have in a NuScale plant, so we have eliminated many of the items that require inspection, maintenance, repair and replacement during normal outage. We just don't have them. So that is why our refuelling outages are much shorter and why we are able to keep the plant online for much longer periods of time.

COMMISSIONER: Mr McGough could I just go back to some evidence you just gave to indicate that some plants are operating at 100 per cent. How is that - - -

MR MCGOUGH: Yes.

COMMISSIONER: How is that so?

MR MCGOUGH: It is as a function of a unit of time. So you can be (indistinct) for 100 per cent for a year and in some cases, I think the longest continuous run of a nuclear plant in the United States is over 700 days, so if you just consider that on an annual basis and that plant ran that entire 12 month period, it would be operating at 100 per cent capacity factor. That is not uncommon.

COMMISSIONER: Okay, thanks.

MR JACOBI: Could I just come – I am interested to understand, I think we have had some discussion already about the third scale version of the plant. I am interested to understand the extent to which the performance of the components in the NuScale plant have been demonstrated or tested in operation and then come to their testing and demonstration for the purposes of the development of the project?

MR MCGOUGH: Sure. So the plant – we have what we call the NuScale integrated system S facility and that is located in Corvallis, Oregon and if you look at slide number 12, the pictures on the left, the kind of – the left group of pictures, of those – the one in the upper right where you will see a logo that says NIST, that is the one third scale NuScale integrated system test facility.

That facility has been operation since 2003 and we recently completely overhauled it to add additional instrumentation. It has about 750 instruments in the test facility which allow us to measure temperature, pressures and flow rates and changes in those conditions in the plant during normal operating conditions, as well as during accident condition scenarios, which we run.

So what we've done is, we've tested the individual components of the plants, by themselves, and then once each of the individual key components were tested, like the helical coiled steam generator, like the fuel design, like the condenser, then all of those components were put together and integrated into one integrated system test facility.

That test facility allows us to demonstrate the plant's performance, and verify that the mathematical modelling and the engineering calculations that we have performed, that said (indistinct) how this plant will perform. This physical facility allows us to verify that our map is correct, so when you go into the licensing phase with the US Nuclear Regulatory Commission, they ask you to provide the description of your design, and they ask you to provide test data that demonstrates that the design performed in the fashion that you've described in your design details.

So the testing that we're performing right now is to validate those mathematical models, and to document it in the license application that we are preparing to submit to the NRC about 12 months from now.

MR JACOBI: I'm interested to understand the extent to which the technology that's used in the NuScale modules has otherwise been demonstrated in practical operation in nuclear reactors, and the extent to which it might depend upon what I might describe as "novel concepts"?

MR MCGOUGH: Yes. Yes, that's a really, really good question, and it's an important distinction about our plant design, in that we are using pressurised water reactor technology, and we are using proven nuclear fuel design.

We wanted to keep some of the predictable and known parts of nuclear technology, and use them in a different way. So we are not using, you know, unproven fuel sources, we're not, you know, trying to do nuclear fusion or other types of fuel. That sort of locks down one variable as, you know, well known and proven for 50 years of nuclear fission. So I hope that answered your question.

MR JACOBI: Can I just come to the question of licensing? You talked about the idea of making a submission to the NRC within about 12 months, but we've already had some discussion about it, and some earlier dealings with the NRC with respect to, I think, to the exclusion zones and with respect to some of the safety systems. And I'm just interested to understand where you are, perhaps as of today, in terms of the licensing process, and then what you expect the program to be?

MR MCGOUGH: Sure. So we prepare - if you want to design a nuclear plant, and you want to put it into commission in the United States, you have to have the Nuclear Regulatory Commission certify the design, that it is safe and it will protect the American public from the hazards associated with ionising radiation. That's the mission of the Nuclear Regulatory Commission.

So in order to do that, there is a very prescriptive series of proofs that you have to provide. We initially engaged with the NRC in April of 2008, to begin to prepare them to receive our application. That application will be 75 per cent complete in six days from now. When it's 100 per cent complete, it will be a 12,000 page document that is mostly charts and graphs, and numbers.

It will have cost us several hundred million dollars to develop that document, and when we submit it to the NRC, they will review it over a 40 month period and bill us $258 an hour for every hour they spend reading it. So far, project life to date, we have spent over 16,000 of those NRC reviewing hours, as they prepare to receive our design certification application.

Along the way, we prepare what's referred to as "topical" reports. A topical report is a specific subset of the design certification application, that allows us to sort of provide an early look for the NRC on key aspects of the design. We are in the process of submitting 17 of those topical reports; I think we've submitted four so far. That will help expedite and help ensure that that 40 month design and review cycle proceeds in an expeditious fashion, such that our plant can be ready for our customers.

MR JACOBI: Do you have a view about when the application will be lodged, that you refer to?

MR MCGOUGH: Yes. The early submittal date is Halloween of next year, so October 31st of 2016; the late submittal date is December 31st. So some time in that 60 day window, one year from now, our application will go in.

MR JACOBI: Yes. And I think it's about 40 months, in terms of the assessment process - - -

MR MCGOUGH: Correct.

MR JACOBI: - - - so three and a third years?

MR MCGOUGH: That's correct.

MR JACOBI: I'm just trying to understand, what's the basis for you having some confidence that that's the time period for a licensing authority to analyse your application?

MR MCGOUGH: Yes. We interact with the NRC every day, virtually every day. And we have worked with them to develop what the review cycle will look like, and we have worked with them to develop what's called "the design specific review standard."

The design specific review standard is tantamount to a handshake between us and the NRC, about what their expectations are of us, in the design certification application. They recently said, "Okay, these are the rules in the design specific review standard, and if you submit your design cert application in accordance with how we've designed it in the design specific review standards, then we will be able to accept the application and review it on a schedule of 40 months."

So that's been a long series of discussions over the past seven years, but we're quite confident that it's an achievable schedule, because of the amount of pre-application work that we've done, to ensure that it will go.

MR JACOBI: In terms of, we've also heard about, in the course of the Commission's process, the COLA licence by the NRC - - -?

MR MCGOUGH: Yes.

MR JACOBI: - - - and I'm just interested to understand the extent to which - whether you think that a COLA will ultimately be lodged with the NRC, with respect to an actual construction project, with respect to NuScale?

MR MCGOUGH: Sure. So it might be helpful to turn to slide 23, which shows the overall project schedule for our first plant. That acronym at the top is for the Utah Associated Municipal Power Systems Carbon Repower Project.

That picture there, if you look at them, there are five "swimlanes" I like to refer to them as, and the middle swimlane lead, where it says "licensing" you can see the top line, that is the progress schedule for the design certification application. The middle and review; that shows receiving the design certification in early 2020.

Parallel to that line, below it, is the COLA schedule. So the COLA stands for the Combined Operating License Application. A COLA is project specific, so everyone in the United States who wants to build a NuScale plant has to apply to the NRC for a project specific construction operating licence. And that (indistinct) NRC, “We would like permission to build the NuScale certified design.”

That COLA will be submitted by (indistinct) between the fourth quarter of 2017 and the first quarter of 2018. And once it’s submitted, it will be a similar 40 month review cycle to the design certification application process. We expect that that will result in receipt of their COL, their Combined Operating Licence in early 2021, and that permit them to begin the safety related portion of the project construction.

MR JACOBI: Perhaps if I could just step away from that. We're going to come back to some issues associated with construction in markets in due course, but perhaps if we can just step by the question of costs, and I'm just interested to understand whether you have a view about what you think the construction cost will be of your first-of-a-kind NuScale plant.

MR MCGOUGH: Yes, we do. We have a very good view of what the costs will be for the first of a kind and for the subsequent plants. The first-of-a-kind plant will cost about US$2.9 billion, which equates to just slightly over $5,000 per kilowatt in what's referred to as the overnight capital cost of the plant. The subsequent plants will be approximately US$2.6 billion, which equates to about $4300 per kilowatt hour overnight capital cost. The reason that we are confident in these numbers is because we spent an awful lot of money and man hours determining that.

We are owned by the Fluor Corporation, which is the largest publicly traded engineer procure construct firm in the United States, and they are very good at estimating construction costs. So we commissioned them to perform an analysis of what it will take to build the plant, and it is, I think, something like a 14,000 line item estimate that includes specific take offs on weldments, on mechanical material, quotes from vendors for major components. So we're quite confident in those numbers, and those are the basis of our discussions with our customers for what they're expecting to pay for the plant.

COMMISSIONER: I'm assuming that your customers are US.

MR MCGOUGH: Sorry, I heard the part about you assuming our customers are US.

COMMISSIONER: Do you have overseas customers, and would you expect those prices to significantly change?

MR MCGOUGH: So we have customers in the US and we have customers outside the US. There are at least four other countries outside the US, probably five, that we are having significant discussions with. I would not expect the pricing to be significantly different for other locales. As you can imagine, with the NuScale power module being manufactured in a factory, it can be shipped to other countries from a US manufacturing location. We envision over a long period having multiple manufacturing locations on different continents, but we do have international customers as well as our US domestic clients.

COMMISSIONER: So can I just follow - you've currently got plant that could build this, or do you need to build the plant first?

MR MCGOUGH: No. So we have plans to build it - I think, if understood your question correctly, you know, the first customer will be the US Carbon Free Power Project. They are in the process of doing site correction as we speak to determine the exact physical location where the plant will be built. They have made the commitment to the Nuclear Regulatory Commission with respect to (indistinct) of their COLA, their construction operating licencing application. They are our first customer, and there are other - and actually, we inquired about what does it mean to be a customer.

A project like this, there is a sequence of commitments that get made from a financial standpoint that become greater and greater over time. They have a mean date for this plant to be in operation in the mid 2024 type (indistinct) to help offset some planned carbon generating assets that would be retired. So that’s what your project schedule is, but they have not made the major financial commitments on a $2.8 billion project. The big commitments will be when we start ordering the NuScale power modules and that won't happen for a couple more years. In those cases, they were talking about, you know, hundreds of millions of dollars of financial commitments, as opposed to the tens of millions of dollars that are being committed and spent today.

MR JACOBI: That might be an appropriate point. I think you mentioned, in terms of the development of the licencing application you made to the NRC, I'm just interested to understand whether you can give a broad range of what NuScale's costs are through the development of this particular reactor.

MR MCGOUGH: Sure. So as of right now, we are about $370 million into this, and it will cost us a little bit over $1 billion to complete the design and have manufacturing and construction ready drawings and to have the completed design certification through the NRC process. The amount of money that we've laid out now really comes from two places. I mentioned that we're owned Fluor. We were also the recipient of an award from the US Department of Energy. The US Department of Energy had a competition for a small modular reactor design to help their development. We were the sole awardee on 12 December of 2013. We received the award of $217 million in matching funds. What I mean by matching funds is the DoE provides $217 million to support the design and the licencing work, and Fluor provides the match to the 217.

So if you take it to the point where we first began receiving DoE money, at that time I think we were probably $320 million or so into it. So that 320, plus 217 from the DoE and 217 from Fluor, that gives 534, plus, you know, 300 or so (indistinct) about three-quarters of $1 billion, which is still not the full $1 billion we need to complete the project. We'll be using additional sources of capital as we get into the later years of the design and the design certification.

MR JACOBI: Can I just come back to the overnight capital costs that we're talking about, and that is that in the submissions the Commission has received with respect to SMRs, and in fact, I think also with respect to NuScale, we've seen ranges of figures for overnight capital costs that range from the sorts of numbers that you've talked about to numbers that are much higher. I'm just interested in your view as to your confidence with respect to that number, and your view about what the relevant ranges are.

MR MCGOUGH: Yes. I'm not familiar with ranges of numbers. I would suggest that if you want to know how much something is going to cost, you probably should ask the person who might sell it to you. So I've seen estimates of automobile costs all over the place. Until you go to the dealership and ask the guy how much do you have to write a cheque for, you really don't know. So in the case of NuScale, we would sign a contract today to sell these plants at these prices. So I'm quite confident that these numbers are accurate. If there are figures that have been generated by others, unless they're getting their figures from me, they're probably not right.

MR JACOBI: I'm just interested to understand what your own accuracy range is with respect to that number.

MR MCGOUGH: Sure. In America there's the American Association of Cost Engineers, and this is considered a class 4 estimate, which means about plus ten - it's plus 35 per cent minus 10 per cent after (indistinct)

MR JACOBI: And I think picking up on a question that was asked by the Commissioner a moment ago, in terms of the assumptions that are built into this modelling, what are the site assumptions, labour rate assumptions, that are built into the overnight capital costs that are stated here?

MR MCGOUGH: Yes. It's based on a populated project in the Southeastern United States at the South Eastern United States labour rates. I can't tell you exactly what they are in terms of dollars per hour, but that’s what it's based on.

MR JACOBI: And in terms of the time to construct, what's the assumption with respect to that?

MR MCGOUGH: Sure. So the construction time from the start of safety-related construction, which - that's what happens as soon as the COL is granted by the NRC. That safety-related construction sequence is 28.5 months from start of safety-related construction until mechanical completion. Mechanical completion means that the plant is now able to receive the first NuScale power module to be installed and put into operation. So before the safety-related construction starts, there will be several years, probably two years, of early site work done, so clearing, grubbing, grading, excavating, roadwork, things like that, but you cannot begin to place safety-related concrete until you receive the (indistinct) from the 28.5-month safety-related construction sequence, it will take about 12 months to install and commission the 12 NuScale power modules.

MR JACOBI: That period of time is a period of time that's much shorter than we've seen with respect to even recent projects that have in fact been implemented both in United States and in Europe, and I'm just interested in your view as to why you have confidence that you could do it in 28 months against a background where current projects in the United States certainly have taken much longer.

MR MCGOUGH: Sure. The easiest way to understand that is, I think, if you go back to that drawing that was - the slide that showed a picture of the large containment dome and the NuScale power module next to it. I think it was slide number 3. See, I'm looking at the wrong deck here.

MR JACOBI: Yes.

MR MCGOUGH: So if you look at that slide, you'll see that we have a lot less stuff to make in the field. That large concrete dome, that is formed out of liner rings that are welded together. You can look at the actual construction videos of what's going on in South Carolina and Georgia. You'll see why it takes 5 or 6 thousand people on the site. We don’t do that. We do that work in a factory location and it's sort of like just-in-time nuclear. You can manufacture the NuScale power module and ship it to the site when the site is ready to receive is, as opposed to in larger construction projects they have all of these structures that must be built in the field at the location of the site. So we can be manufacturing our reactor vessel and our containment vessel in one location, while at the same time the site preparation work and civil work is going on at the physical site.

MR JACOBI: Perhaps we can quickly come to the levelised cost of energy. Do you have a quote for what you expect the level of costs to be?

MR MCGOUGH: Yes, we do. The levelised cost of electricity is that for conventional financing plant. So by conventional financing I mean 55 per cent debt at a contemplated 5 and a half per cent interest rate, and then 45 per cent equity at 10 per cent. That levelised cost of electricity will be around $100 per megawatt hour, and with municipal financing - I'm not sure what your financing structures may be in Australia, but for municipal financing, like our first customer is able to obtain, their LCOE, including owner's costs, will be about $77 per megawatt.

MR JACOBI: Just so that we're clear about the municipal financing, am I right in understanding that that's a reference to a government authority being able to obtain finance at a lower rate?

MR MCGOUGH: That is correct.

MR JACOBI: Now, just to come to the question of customers, and I'm just interested - you referred to the fact that you had a first customer. Are there other potential projects in the United States for a NuScale plant?

MR MCGOUGH: Yes, there are. So the first project is part of something that is referred to as the Western Initiative for Nuclear (indistinct) Initiative for Nuclear started out of a - there's a group called the Western Governors' Association. There are 19 western states that comprise the Western Governors' Association. One of those governors, the governor of the state of Idaho, is a very strong proponent of nuclear energy and he has the home of the Idaho National Laboratory, which is the US national laboratory focused on nuclear energy. So Governor Otter created a Leadership in Nuclear Energy Commission and built into the initiatives of the western governors a program to further the development of small modular reactor technology.

In the ten years WGA Energy (indistinct) has a specific objective to develop small modular reactors in the west. In the west there are six states that have active engagements with us, contemplating possible new nuclear plants. In the state of New Mexico, the state of New Mexico issue their state energy plan at the end of September and it includes a specific objective to perform a feasibility study for siting small modular reactors in New Mexico. I'm working very closely with the governor and her team to help them contemplating that in New Mexico.

Arizona has planned coal plant retirements that are likely to be replace with nuclear technology, and we believe they will be ours. There are (indistinct) contemplated in the state of Wyoming. In Washington State the owners of the Columbia generating station have signed an agreement with (indistinct) to be the operator of the US Carbon Free Power Project and that entity is known as Energy Northwest. They expect to be an eventual owner of a NuScale plant in the state of Washington, and the state legislature in Washington and the governor have put together specific roles to promote the development of SMR technology in those states. There are other states and other locations in the country, some of which I can't discuss because of confidentiality; those projects have not yet been publicly announced. And then of course we have the international projects.

MR JACOBI: In the submissions that the Commission received, we heard that there was some optimism about the building of new nuclear plants in the period after about 2005, and there's been some contention that that didn't material other than the projects that I think we've already mentioned, and I'm just interested to understand why you have a view that they will materialise; why the position is going to be different coming out from 2015.

MR MCGOUGH: So back in 2005 (indistinct) there were, I think, 17 projects that were proposed to go through the combined operating licence process and those were all large plants, and the large plants at prices of, you know, $8 billion a plant. Those are very heavy lifts and they can become a (indistinct) company proposition for a large utility. You can't project finance anything that large, so you really have to put the balance sheet of the owner's company at risk. On a project the size of ours in the 2 and a half to 3 billion dollar range, that is project financeable and because it can be developed over a shorter time frame, the capital is at risk for much less time and the financing costs are much lower than for a bigger plant.

The main thing that has changed in the landscape in the last ten years here in the United States is the amount of pressure that is being placed on carbon-generating sources of base load electricity. The US Environmental Protection Agency has recently issued the Clean Power Plan and it makes it pretty much impossible to develop a new coal-fired power plant in the United States and is forcing many coal-fired plants to go out of business. What that creates is it creates a vacuum of base load electricity that is carbon free that has to get filled by something and there are really aren't very many choices.

So that's how we believe that nuclear will be successful, particularly our plant, because it's a price point that is much more palatable and it can be deployed in a fashion allows the output of the plant to be scaled by adding 50-megawatt modules as your load grows. You can start with installing only two or three modules and then adding additional modules in later years.

COMMISSIONER: Mike, thank you very much for your evidence this morning. That was very useful.

MR MCGOUGH: The pleasure was mine.

COMMISSIONER: Thank you. We'll now adjourn until 9.30, when we'll have Westinghouse.

ADJOURNED **[9.20 am]**