May 13, 2021
Nuclear Waste Technical Review Board

>>Paul Turinsky: -- [Welcome to] the second day of the Nuclear Waste Technical Review Board meeting. Hello and welcome back to the U.S. Nuclear Waste Technical Review Board spring meeting. I am Paul Turinsky, deputy Chair of the Board. Yesterday I described the Board's mission and introduced the other Board members, rather than taking time to repeat that, I will direct you to our website, www.nwtrb.gov for information on our mission and our members as well as Board correspondence, reports, testimony and meeting materials, including webcasts of its public meetings.
This slide show is yesterday's agenda; we heard about DOE Office of Nuclear Fuel Cycle Supply Chain support of R&D for accident tolerant fuel. This was followed by a description of the accident tolerant fuels and the commercialization path. A presentation by Lightbridge on metallic fuel design and development and Nuclear Regulatory Commission presentations on the Project Plan and the U.S. regulatory perspective on the impact of accident tolerant fuels for the storage and transportation of spent nuclear fuel. Yesterday's meeting ended with a presentation by the DOE Office of Spent Fuel and Waste Disposition and Sandia National Laboratories about their evaluation of advanced nuclear fuels, including accident tolerant fuels and their implications for spent nuclear fuels storage and transportation.
Today we will turn the spotlight on work in Switzerland, Sweden and the United Kingdom to develop advanced nuclear fuel designs and plan for the management and disposal of the resulting spent nuclear fuel. So we're in contrast to yesterday, which was U.S.-focused, today we're more international in specific European-focused. Each presenter will describe the advanced nuclear fuels, including accident tolerant fuels being considered for their countries. They will also discuss the processes in place for concerning the implications that the new fuel designs may have on spent nuclear fuel management and disposal prior to approval of the new fuels for use in existing reactors.

>>Stefano Caruso: Thank you Paul, can I start? I assume. Hello everybody. So I'm Stefano Caruso with Goesgen Power Plant and my talk will be about our plan on advanced nuclear fuel with the back end of the fuel cycle in Switzerland and the focus will be of course on the Goesgen strategy.
These will go to the following topic starting with the Goesgen Power Plant and describing the spent fuel cycles and the disposal concept. Then I will move on to cladding and the fuel integrity issue, which is very important for the back-end and I will illustrate some part of the license application for new fuel in Switzerland, going through the Advanced Nuclear Fuel and Accident Tolerant Fuel and give you some new light about our strategy

and research on advanced fuel, particularly the accident tolerant fuel and role and implication to the back-end.
Starting with the power plant, Goesgen is a Siemens design. It was started in 1979 as one gigawatt plant and with a peculiarity with the three loops. We burn fuel up to almost a 5% enrichment. With the AREVA design and Framatome today, 15X15 ..and the work has been important around the facility with the burned fuel up to 70 gigawatt per day/per ton on average, average burned. And we also power, [indiscernible] the power of 525 W/cm.
The fuel cycle in Switzerland is quite complex because we started reprocessing. We were reprocessing fuel and sending our fuels... spent fuel to La Hague and Sellafield. We had to [indiscernible] canister, we would vitrify and compact the [indiscernible]. But we had to stop this because of the moratorium, so..a popular decision, a political decision to stop this. So this means we have not any more a closed cycle; we have an open cycle with different problems and on the top here you can see, which is the part of the waste that enters an interim storage facility. We assume that we will have an encapsulation facility and we will have a repository for high level waste and spent fuel. We have also, of course, other waste from the commissioning, from other institutes and this will be intermediate, lower-level waste, which goes to the interim storage and these will go to a repository as well which is a repository for lower level. At this stage, we cannot assume there will be two different repositories; it can be a combined as one. It is still to be decided.
If we could focus just on the spent fuel now, this picture want to discuss a bit, what is the meaning of the new fuel in our cycle. We have a reactor, we have the spent fuel pool, we have an interim storage [indiscernible]. We have the cask transportation. We have encapsulation facility to encapsulate the fuel canister to be ready to be in place. So this means that we will [indiscernible], according to the type of operation at [indiscernible]. We have operational safety issues that are related to the reactor, we have aging management completion. We have safety assessment for with respect to cask fuel and transportation. We have safety expected that ability to hold the pre-disposal operation of the facility and we have long-term safety aspect. This mean that many times we can say many of these are overlapping, but in some computations of safety, long-term safety is a completely different aspect to be considered. And now that we would like to buy or we want to use new fuel, we don't think only to the front-end. We need to see the back-end implication and this is maybe the change of this days. You have to keep in account the full cycle of the fuel.
To go into specifically in just the illustration about our, as we have seen, interim dry storage facility, ZWILAG. It is a centralized storage located in Wurenlingen, close to Paul Scherrer Institute. The facility is not only just a

storage facility, it also a special hot cell where we can unload fuel from cask, and reload another cask. It is a very unique, this facility. We have 200 transport position plates for transport cask. From different vendors, from Orano, from GNI, from GNS. And this is important part from the other concept.
The last part, of course, is related to this will be disposal of the fuel in a repository, a geological repository. The plan is to construct in 2050 and operation should start in 2060 with emplacement until 2075 and actually the general license application will be submitted in a couple of years by the NAGRA. But this disposal concept... Because our disposal concept is based on a multi-barrier system where the barriers are the steel canister, the buffer around it is bentonite and the host rock.. actually, the cladding is not considered to be a barrier of these. We don't take credit on the long-term. We take credit on the cladding only on the pre-disposal phase. We will go back also at the end for some discussion.
So now, considering the pre-disposal operation and the long-term safety disposal. Also with aspect related to the surface facility, also related to the perception from the population, the authority is different because we have here a radioprotection issue and to be avoid and fuel has to have integrity, the integrity, the consequence of release this as also [indiscernible]. The aspect related to storage and transportation, actually analyze it very well. For the long-term safety disposal, we have a range, totally different range of time from one million years.. the radiological impact on the near field and biosphere. We can, we can consider that we would like the long-term release of radionuclides, where we assume the radionuclides will diffuse, but different speeds because we have cladding materials, from these we assume the release to be faster than the fuel matrix which is the "slow" component -- but we assume that showing this will be the second point partially... Then, there are two aspects which are very important to preserve engineer barrier which is the criticality safety. We will try to demonstrate safety with burnup credit for [indiscernible]. This is important, but comes on other criteria that is, that is determining also, the layout, the loading strategies and the optimizations, because these are direct impact on barriers; we have a limitation of 1.5 [KW/canister]. In this arrange we preserve the multi-barriers. Now moving into the principle parts focus being on the cladding integrity. One of the common issue that we are dealing in nowadays is to how to solve this, the hydride reorientation, the problematic action of hydrogen that goes into solution when the fuel is operated in the reactor, because of corrosion… the oxidation, corrosion of the cladding. Then, the hydrogen precipitates when the fuel is cooled down because the solubility limit is reached. Because the concentration is high enough and the temperature is low enough, we can have this precipitation, and this will form a balanced system .. these hydrides which orient normally in axial-

circumferential orientation, which is not too bad, it's fine but under a critical stress, which is radial tensile stress, these orient radially and these may affect the properties of the cladding… because also demonstrated the properties of the fuel, cladding. and pellet together. As entire fuel homogenous system…[indiscernible] But then, talking about influencing factors: temperature during storage, internal rod pressure, hydrogen concentration. Therefore, burnup, for instance,… it's one of the criteria ..we want to increase the burnup. We know increasing burnup will increase also the possibility of more hydrogen in the cladding and temperature, you know. So what we can control, however, is the oxidation of the cladding. These, we cannot reduce, which is high burnup. And that's why here, interesting also the topic of the –fuel. Now, the jump on the administrative part, which are the steps to license new fuels, which are the main actors of this. Of course if we want to irradiate new fuels we need to deal with a competent authority which is ENSI. I will describe in a few slides. So we need the approval and we have also the Nuclear Energy Ordinance, the safety aspect are related not only to fuel design but also the core. There they define the criteria to, to define "safety limits." Concerning, ..the licensing program, the safety aspects consider reactor, storage and transport, pre-disposal and disposal all together in different steps. But have to consider to get the license have to put evidence of all these safety, …of all these steps of the fuel. And..our typical approach at Goesgen is to test the fuel; so we're going to irradiate the fuel; we're going to have an inspection; we inspect the fuel; we're going to have some evaluation, post irradiation examination from the lab. Then we ask for approval or we get the further requirements. And this is a special peculiarity of Goesgen, is that we can inspect the fuel, we can repair the fuel, we can make a ..we can extract a rod.. and this gives a lot of freedom for to test different fuel. Considering which are the main actors or we consider the authority from one side and the interlopers. So, the authority we consider first is… the Federal Assembly of the Swiss Confederation, which produced the law, the new Nuclear Energy Act. ..The Federal Council, the Nuclear Energy Ordinance, the Department of Environment, Transport, Energy and Communications, with the Swiss Federal Office of Energy and then there is the Swiss Federal Nuclear Safety Inspectorate that is the regulator. On other hand there are the power plants, the utilities, we have ZWILAG, the centralized dry storage facility which is a "daughter" of the power plant, as well as Nagra, which is the company responsible for the disposal of the fuel.. but however, have to consider the spent fuel remain under responsibility of the power plant until final emplacement in the repository.. have to consider..[indiscernible]. Now relevant documentation for the licensing process, as I said the Nuclear Energy Act, the Nuclear Energy Ordinance, the Regulation for Protection Against Incidents in Nuclear Installations,

and together, we get all the guidelines from those and these are spread on the different ENSI ..which are on regards to changes to fuel assemblies and control rods, changes to safety criteria, and changes to validation methods, and disposability of spent fuel is considered. And then, A03, which is more a little bit on operational experience and focus on periodic safety checks. …Given the G20 which is more widely validation and qualification of program codes and also related to the new fuel ..[inaudible].. And then G03, which regards the geologic repository itself. Then today we also have aging management guide also written by ENSI on dry storage. Now specific to Goesgen, which is our strategy. Our strategy is to get some sample of the new fuel, the new material, we irradiate these we perform some pool inspection, we send these to the hot lab for instance and then we require the approval of, for the next phase, which is the irradiation of the Lead Test Rod and again this process, pool inspection, plus post irradiation examination of the, for the approval for the next phase that will be, Lead Test Assembly. But to be clear, the first two steps, two phases are not really a requirement for this. It is just a strategy to perform the steps. More easily to this level, the environment, the Lead Test Assembly and the two other in the investigation, to the authority to have a core loading. Now after remarks, our operational safety is not really affected by availability of advanced fuel, they are performing really well. The Duplex cladding, we are quite satisfied with this. We don't get benefit in the current stage because we don't need to improve our safety criteria; we are good but of course we can always improve.. we can always be on line with the state of the art, it is wise to follow.. new technology. So, why we're talking about accident tolerant fuel? because it's actually the main objective is more related to reactor operation especially on the beyond-design basis accidents that to improve the oxidation, the high temperature oxidation. So this was coming exactly from Fukushima, the first target is to have fuel that ..increases efficiency in the case of accident --. This is clear...it may be a benefit on the back-end and this has to be considered as a secondary effect. To be specific why to this benefit, of course, if we can reduce corrosion, oxidation, these could be practically some beneficial for the integrity of the cladding, because if we use reduce oxidation we will have better heat conductivity on the cladding. It means we have less fission gas release… This is an argument. Of course, if we have less oxidation, then we have..we pickup less hydrogen and the mechanism like hydride reorientation can be reduced..Now talking about accident tolerant fuel.. I was just mentioning three kind of approach, this is not, this is general slide not specific to this, but also not, all the kind of advances and just to generalize a bit.. that cladding coating and consider to be a short-term solution because will deposit coating, chrome on the zircaloy, and these apply to existing cladding. So there are also alternative cladding

development of the alternative like ceramics, and also we have new fuel they are using dopant fuel with different kind of doping, like microcell or pellet. This is to be more general. So this is, now to jump the Goesgen-Framatome, we can be more specific about the what we are doing, so we are considering EATF and talking about two solutions: near-term evolutionary solution, which is actually the chrome-coating on M5, which is not properly defined as the best solution. And then the doping of the oxygen chrome in the fuel with again with M5 and/or even duplex. This is considered the first, the first step. Then we have long-term revolutionary solution, which silicon carbide composite cladding. At least Framatome is following this direction and we are helping them to develop, to test this fuel. The chrome coating is applied to the cladding, by physical vapor deposition and the properties are to reduce high temperature oxidation, reduce corrosion and improve wear resistance. And there are two main projects that we are having together with Framatome, one is say a Phase 1, a R&D program IMAGO, since 2016 and will be finishing in a couple of years. In the meantime, Phase 2, where the GOCHROM, follow up of IMAGO, and this is started in 2019 will end in 2026. When we go into details, showing some …results about these programs, preliminary.. is it important when we say irradiation examination what it means. As I said we have, visual inspection, annual pool inspection at Goesgen is standard, not only for these material, for the assembly or a part of them. Then the framework of this and we follow the strategy to instruct road after the first cycle, the third cycle and the fifth cycle and for us the cycle means 11 months, which is enough to reach high burnup for the first cycle, which is [--] GWD/ton and then we do the test again with visual inspection and the gamma scanning standard and metallography, and the hydrogen measurement is the standard package. Specific to the IMAGO program, IMAGO is the Irradiation of Materials for accident tolerant fuels in the Goesgen reactor, and this was the first irradiation of chrome coating in a commercial power plant, PWR. The objectives were to verify the behavior of the fuel concept in a commercial power plant, PWR conditions to assess the coating irradiation, observe the corrosion behavior under irradiation, to study the microstructural evolution under irradiation and some mechanical properties when possible. And the material tested in this program is just cladding, just cladding, just chrome-coated zirconium alloy, the SiC composite cladding. The irradiation phases were interesting because we had samples inserted in some, in a couple of assembly and then up to 7 irradiation cycles. The samples have been investigated… I will show you some of the results we got. In this picture on the left we see that we cannot sample the layer of chrome sample, the sample of just one cycle. And the metallography showed that particularly the layer is quite homogeneous, so we can see there is not inhomogeneity, and is quite, quite confident of this results that shows that,

that coating works properly. On the other hand, on the right-hand side, with the sample where was partially damaged with extracting or removing the chrome-layer, on the on the left side there is -- integer and then on the right side where the chrome is removed can observe, there is already corrosion. So this is already a confirmation of the good stability of the coating and low corrosion... This is another result on the cycles after two cycles just an inspection with a high definition camera but it is possible to compare after two cycles to see the activity of the samples are changed but still this [audio cut out] is excellent -- and found not really to affect the degradation of this chrome-coated. So, it is promising results. That's why we decide to go to the GOCHROM program which is not any more simple but really, …lead test rod..these are inserted 20 chrome-coated M5 lengths with in two different assemblies with fuel UO2 and doped fuel. We completed now two cycles and also important that [audio cut out]… as expected of course. So most of the study, the operating behavior of this fuel and again target lower oxidation rate during accidents and this hard protective layer which may be very useful to minimize debris fretting. Here just examination on this, is a picture, you can see the rod, the chrome-coated rod is brilliant compared to the other in the two pictures. So bright metallic appearance is nice to see, so as we said there is not an indication of our corrosion in this, this is sort of confirmation of the old, of the IMAGO results -- not to repeat but we can observe maybe that the layer of the coating is quite homogenous.. no porosity and lower corrosion. And yes this …tube that did not result in any flaking of the chrome coating, this is actually scanning from not from this program but from parallel work.. qualification by Framatome. So we are going, we want to share the results also in international Congress and partners and but also activity that not only referring to, using, that's why just to mention that we are working together with, for this program but also with mechanical test and we are also very interested we are taking part in the SCIP program, the Studsvik cladding integrity project because there are many task that are interesting…. The long-term storage and, the …testing of materials and we are participating to work in an indirect way with ENSI, program that we are testing with Nagra is structural components, guide tubes, and trying to simulate the aging process during dry storage. And we are also observers in the “Spent Fuel Characterization and Evolution, among the other.. just to mention something.”. Now back to the, so we can consider that cladding integrity and improving the cladding integrity concept is important in the predisposal operation. The disposals including transportation. That's why it is a safety criterion but for the cladding integrity is not specific criteria after emplacement. Not at all. But consider the case of the criticality, for repository for long-term for a million years. We assume this fuel has to cope with some failure mode, so we have to demonstrate that actually we cannot demonstrate that the fuel will be

intact for one million years, we have to assume the canister will collapse, the fuel will lost the geometry, the position, the rods will be closer together, there will be some corrosion and this makes more complex evolution. And performing the burnup credit approach.. this possible benefit, is that they better corrosion resistance and we can of course extend the range of the, of this cladding and reducing the, some requirements especially for probabilistic approach could be interesting. But there is just a possibility not more than this, because here is quite complex. So then I want to thank you from -- especially my colleagues Girardin, coordinator of the project Accident Tolerant Fuel and Dr. Elmar Schweitzer, coordinator in-pile testing. So thank you very much. For any question.

>>Paul Turinsky: Yeah, thank you Stefano. I'll open up the floor for questions now from Board members. Lee Peddicord?

>>Lee Peddicord: Thank you Paul. Stefano this is really, as always from Goesgen a fascinating presentation and congratulations on really first class work, being the first to irradiate the advanced fuels like this as well, too, and so on. A couple of questions come to mind. You talked about your capability at Goesgen for moving PIE, ..it was all that non-destructive and then the actual cutting of rods is done at the Paul Scherrer Institute? do you take it a step further at Goesgen?.

>>Stefano Caruso: Yes, I did. [audio cut out] we have actually, twice, two storage. One internal and one external and one, external one we can take out fuel from there. We can cut, we can shuffle, the shuffling the fuel bundle.. the that's why we put also reach 120 gigawatt-day of burnup on one rod, so we can play with this and of course capability are limited to [inaudible] and visual inspection or other in the main activity for.. destructive analysis. Because [inaudible[receive our fuel as well but not accident tolerant but other.

>>Lee Peddicord: Uh-huh. So you mentioned burn-ups, what is your current target burn-up for your standard fuel at Goesgen, and are you expecting those targets to change as you move to advanced fuels?

>>Stefano Caruso: The question is good. Actually, I with 70, we're quite satisfied; I think with five cycles we reached 70 and I don't think plans to change it, of course when the fuel will be licensed and then the discussion can change. This is step by step approach. At the moment we don't want to increase the burn-up because really quite, quite high.

>>Lee Peddicord: Yeah. …also I think it was slide 24 or 25 where .. you are showing those photos of the fuel and let's see there, so you are noting, you know, the chrome-coated is more brilliant, which I guess is true in a lot of ways, isn't it? But at any rate, in the picture, is that due to, is the difference due to corrosion of the standard clad that is making it not show up as brilliantly in these photos?

>>Stefano Caruso: I don't think so, I mean I think the color of the rod, which is brilliant ..this is also in not irradiated stages of, show are visible. So this is not really proof

of one [audio cut out] better or …not. But what is interesting is to skip this brilliant even after one cycle and is indirect way to see there is not so much corrosion, or oxidation.

>>Lee Peddicord: Uh-huh, finally one last question you are noting that essentially the industry response in Switzerland is to the point where the fuel is then emplaced in the repository. But so, but that does not mean until the repository is closed. It is simply until in emplacement that is the repository can still be open for a number of years afterwards, did I understand correctly?

>>Stefano Caruso: Yes, you are right. Because there is a concept to retrieve the fuel and actually according to this point I will correct myself, I will not say after emplacement, but will say after the …the repository. I think is not clear that how many years will be still, but let's say once is really shield then it should, the question is also -- because we don't know how many utility will be -- in principle could be also politically or strategically changed the situation in the sense that Nagra could be the whole organization in charge.

>>Lee Peddicord: Uh-huh, I see. It sounds like an interesting question. You also made I think the very interesting point that with this better corrosion resistance it may ultimately be possible, at least in best estimate type of analysis to take credit for the clad over at least some period of time during storage and final disposition and that sounds like a very interesting topic to explore.

>>Stefano Caruso: Yes, but of course is, is a chance [indiscernible] demonstration of these are not so easy. But if we assume the canister…, will last more than a normal steel canister so we can take credit from the cladding. That's why we assume these. Maybe we will reduce the probability of criticality event, with the problemistic approach because also, the problem I would like to solve is really deterministically the solution. But I cannot, we need also problemistic approach in there I think we can take benefit from this long-life of the cladding, the fuel.

>>Lee Peddicord: Yep, we're good. Thank you I appreciate it. Very nice presentation.

>>Stefano Caruso: Thanks a lot.

>>Paul Turinsky: Tissa?

>>Tissa Illangsekare: Yeah, can you hear me? Yeah, this is very general question on your slide number 9 where you talk about ..slide number 9 talk about the safety assessment – yeah, that one. In this one you had a number two, long-term safety during disposal, then you have the first bullet, six years then you have the long-term then you look at fuel matrix and cladding…my question is when you say “fast” component, accident you are looking at that time frame and then my question is that when you are looking at 10 to the 6 years, what is the relevance of two in the context of that long time period. Because it may be more short even, my question will have to do is, are we worried about some sort of mixture behavior?

>>Stefano Caruso: Actually the safety case, there is an assumption: this material will be released. And in the assumption, we assume the cladding will be .. first. That's why we need to calculate the activation, also the migration of the spaces like cesium, separating from the fuel because in time if you see the plot which is quite interesting of the, the dose rate in the biosphere, that is there is this component that is negligible of course compared to the fuel, but is not negligible if this is moving along in the time, in the time frame which is different from the fuel. At first release, and you have to assume this release, in the biosphere and then you have the second release from the fuel. And in this first component you have also some bad nuclide like carbon-14 and this is a long lived nuclide, so that's why there is this, in the safety case.

>>Tissa Illangsekare: Yeah so, the reason I ask the same question yesterday where I was asking whether you are looking at how this system, your system you are looking at affect a larger system, but they said they are looking into that. But in your program, you are looking at the biosphere and the possibility of cladding material releasing into a much larger system between the biosphere and water and everything else. Is that correct?

>>Stefano Caruso: Yes, yes. That's why I can tell you as, as Gosgen now, we are not taking care of this aspect because I mean the back-end is quite wide. As Nagra employer I that was dealing with this, I was dealing with this aspect of the long-term release. That's why it is clear now component to the, you have to consider.

>>Tissa Illangsekare: Yeah, that answers my question. Thank you very much.

>>Stefano Caruso: You're welcome. Paul, I cannot hear you.

>>Paul Turinsky: What level of technical detail do you have to provide to the regulator and also to the people who are going to dispose of the fuel, regarding the back-end stages of storage, transportation, and disposal?

>>Stefano Caruso: Quite, quite a lot. Now, dealing with the problem of [inaudible], we are dealing with say frustration of the limit, the safety limit really okay I would say the [audio cut out] safety limit, so we are these are affected the they must works with evidence that, they want to have evidence..[audio cut out] not an issue and during [audio cut out] normally, so point not -- really perform, the performance, so it is a cross between.

>>Paul Turinsky: A second question is you mentioned on a slide that you had a joint program, I think maybe it was with Framatome some other parties on aging in dry storage. Could you say a little bit more about what the issues are that you are looking at?

>>Stefano Caruso: This one, yes. Actually this is important for the back-end, for Nagra, not the repository but the predisposal activity, so the encapsulation facility. What means that, when we open a cask, we will open and extract the fuel. The main issue is the fuel has to be intact and end-able. This means the guide tubes are taking the weight and that's why we want to test.. if there is a phenomena, some aging, can accelerate the aging process is

to see if this is an issue. I cannot really tell you too much on this because it is, there are other…, we but quite promising, it is quite promising it think will be very useful in the future.

>>Paul Turinsky: Will the results be publicly available, will there be papers and reports published?

>>Stefano Caruso: I cannot tell you because it is a copyright problem. So we are, we are providing the material but [audio cut out] Nagra has to decide when and how to release the data. I assume that this is, because interesting results and we will use it probably also for the license.. general license and application the general application of the repository. Could be but is up to them.

>>Paul Turinsky: Okay. Are there any further questions from Board members? Tissa, I see your hand up again. Did you forget to take it down?

>>Tissa Illangsekare: Sorry, I need to take it down.

>>Paul Turinsky: Okay. Okay. Turn it to the staff now. Dan Ogg?

>>Dan Ogg: Hi, thank you, Stefano, very interesting, thanks for your presentation. My question goes back to slides, I think 12 and 13 and I know you touched on this but I think I would like to have a little better explanation of the approval process by Nagra of these new fuels before they are used in a reactor. So what is their role and how do either you interact with Nagra or does the fuel vendor integrate with Nagra so make approval.

>>Stefano Caruso: Is a good question, actually the process for the licensing is not generally touching directly Nagra. But since now we are checking the back end more closely, for instance when we have a new material, new cladding, we ask Nagra to perform some characterization on this given cladding. To see if these particularly the release, faster term that is the cladding that release as of the first source of irradiation is in line with the other already used claddings. This will also go to the regulator, so we ask Nagra to perform this analysis. So Nagra is the one who also has to take a position on the disposability of the fuel.. It's not the certifying of Nagra because Nagra is not the only that will apply also. For the very end of the process.

>>Dan Ogg: So, then, does ENSI have a role as a regulator in approving this fuel considering some of the back-end implications?

>>Stefano Caruso: Yes, yes, yes. The last word is they see some problem. yes.

>>Dan Ogg: Ok, this is where they're applying maybe some of these ENSI guidelines [multiple people speaking].

>>Stefano Caruso: Yes the G3 and the, no the A04, for spent fuel disposability. What is important to, not really defined what exactly you have to do. But you have to guarantee fuel will not be a problem from the back end. So this is more specific, sometimes it is more, it's still not clear for instance the criticality safety, which is the most important is not so clear defined [indiscernible] to other norms, Germany, I think this is [indiscernible] --

>>Dan Ogg: This helps clarify for me how they get involved. Appreciate that, thank you.

>>Stefano Caruso: Welcome.

>>Paul Turinsky: Any other questions for Stefano from either Board members or staff? Okay. Andy has a question.

>>Hundal Jung: Hello this is Andy from the Board staff. On slide 26, you show a cross section of the chrome coated surfaces. Just one simple question have you checked the hydrogen content in the zirconium alloy side, morphologies?

>>Stefano Caruso: This is (microphone feedback) part of the [indiscernible] but I don't but this will be done, will be done. But still like not tell you because I don't have the results, but --

>>Hundal Jung: Okay. That's a plan. Thank you.

>>Paul Turinsky: Thank you for your presentation.

>>Stefano Caruso: Thank you very much.

>>Paul Turinsky: Before we move on to the next speaker you probably noticed I had some network problems during the introduction stage. My wife and I were both connecting to the network at the same time for video conferencing. I now know we know we both can't do that. I do want to repeat something, which apparently didn't come through during the introduction. It's with regard to public, making public comments. So let me, let me read what I was trying to say and didn't come through. An online link for submitting comments can be found on public meeting website which in turn can be found on the Board's website, www.nwtrb.gov, under the "Latest News" heading. Comments received before the end of today's break period will be read online in the order received by the board staff member, Bret Leslie. Time for each comment may be limited depending on the number of comments we receive, but the entirety of the submitted comments will be included as part of the meeting record. And we do encourage comments.

Let me now introduce our next speaker, our next speaker is Anders Sjoland from SKB Sweden, who is anxiously waiting for their license at this point I gather. And he will be talking about program in Sweden. Anders?

>>Anders Sjoland: Yes, good afternoon can you hear me?

>>Paul Turinsky: Yes.

>>Anders Sjoland: Okay very good, thank you. And thank you for inviting me to this exceptionally interesting meeting which I've been looking forward to for some time, because I think it's very timely to address the issues of ATFs and particularly in connection with back-end, nuclear fuel cycle.

And next one please. Thank you. So just I begin here we have some slides about my organization, SKB, Swedish Nuclear Fuel and Waste Management organization. And, so we are financed by a tax on the nuclear electricity produced in Sweden. I'll come back to that later. It's quite a big tax at this point.

Next one please. And, we are owned, we are a private company owned by the owners of the nuclear power plants in Sweden. We belong to the Vattenfall Group.
Next please. Yeah just an image of the different bodies that have some role in the Swedish system, the government, Swedish Radiation Safety Authority, SSM. We have a nuclear waste council which is appointed by the government. It's a little bit like this review board that we are having this meeting with today. We have the land and environmental court, we have the municipalities, we have financing on the of the Act, Financing Act, we have Nuclear Activities Act, Environmental Code, Radiation Protection Act and Planning and Building Act among others to relate to.
Next one please. So our mission is to take care of actually all nuclear waste of all types in Sweden, also from hospitals and research and things like that. So, well, regardless of the future of nuclear power, which is always under debate in Sweden. Nuclear waste exists of course and this waste must be taken care of to protect people and the environment and the task is so extensive that it's regarded as one of Sweden's most important environmental protection projects. Yeah and then we have different systems for different type of waste. We have spent fuel system, we come back to that a bit later and then operational commissioning waste where we have the final repository.
Next one please. Yeah, the Swedish system as I said, we take care of everything, nuclear waste produced in Sweden. We have also transport system consisting of at least by our own ship, the ship Seagate. All our Nuclear Power Plants Studsvik also, this is situated along the coast so the majority of all transports of fresh and used fuel can be done by ship in Sweden. We also have access to transport casks, et cetera, et cetera, that can go both on ships and on, on tracks.
Next one please. Yeah so one of the central place in our system is then the Central Interim Storage Facility for Spent Nuclear Fuel, that we call the Clab which is situated very close to the Nuclear Power Plant in Oskarshamn in the southern part of Sweden. And it is, I think it is only wet intermediate storage system that is below ground, 50 meters below ground approximately in Swedish bedrock.
Next one please. And as I said, wet storage and it has been in operation since 1985 and there's a lot to say about that, I would come back a little bit to the system later but it is in contrast to many other countries that have dry storage, of course.
Next one please. We have final a repository for short-lived radioactive waste, SFR, situated in Forsmark, north of Stockholm, a little further north. I don't go into that, in this talk.
Next one please. And as I said we have our ship, actually our second ship called Seagrid. That goes along the coast and also sometimes to foreign countries for some operations and some missions.

Next one please. And then we have a number of planned facilities and the chairman alluded to our, our license application process which I won't go into much in this talk, but just say that what we have been applying for now are canister factory and the where the canisters for the disposal system will be produced, encapsulation plant, where the fuel will be encapsulated and spent fuel repository where we will finally dispose of the spent fuel.
Next one please. And the application, the spent fuel repository will also be placed in Forsmark, North of Stockholm close to the other final repository, SFR.
Next one please. And the reason for choosing Forsmark was that the rock in Forsmark was very good, there were two candidates at that time, Forsmark, Oskarshamn, but the rock was considered better in Forsmark and then also it's very suitable because it can be, it is adjacent to the Nuclear Power Plant in Forsmark and can be connected to the already existing infrastructure.
Next one please. Yeah so it will look a little bit like this, the spent fuel repository, about 420 meters below ground will be the depth of the repository.
And next one please. And then it will be the SKB method which is called KBS3 which has been copied by Finland which loudly consists of a copper canister where Spent Nuclear Fuel is placed in a cast iron insert. This will then be placed as I said for 500 meters below ground in the Swedish bedrock, this very special type of clay called bentonite clay. And then, as I said, in the Swedish bedrock, granite, granitic bedrock. And it will be completely back filled and closed and until it's closed, there was a question about responsibility after closure before, I can say now finally determined by in addition to the existing law in Sweden that after closure, the responsibility goes to the Swedish State.
Next one please. Yeah and then encapsulation plant will be an extension of the existing Clab facility, intermediate storage facility. So it will be in, so there will be in Oskarshamn so it will be an extension.
And next one please. Yeah and then we also have another long-term [indiscernible], the other types of low, intermediate level waste will be replaced possibly for instance control rods or some things like that. It has some bearing on what we are discussing now actually. That we haven't began designing yet.
Next one please. Yeah yes to make clear to everybody because I think the Swedish back end is a bit different, is particularly quite different from the American system. So after leaving the reactor, the fuel goes through the following steps in the Swedish back-end system, at the nuclear power plant, it's then cooled for a few years in the wet pools. And then it's transported to Clab, the intermediate storage facility. It's first dried and

then it’s transported and beginning really transportation the responsibility of SKB takes over. So after that, it is SKB's responsibility.
Next one please. And then it goes to our interim storage facility, Clab where it is off loaded from dry to wet, moved to service pools, then to storage pools, all wet around 20 to 30 degrees Celsius and then placed in it’s these storage pools for decades until we encapsulate it for final storage. So encapsulation then consists of moving the fuel to a dry hot cell in Clink, where it is dried at a particular temperature which is not finally decided yet, probably be somewhere around 100 degrees or so depending on the drying method and then it is put into these copper canisters in a dry state and then the lid of the copper canister is welded on.
Next one please. And then it is transported to geological final repository and then by ship, so it is taken from Oskarshamn to Forsmark by our own ship [indiscernible]. And then it is taken down into geological final repository where it is disposed of in the KBS-3 multi-barrier system where it is supposed to sit for literally eternity.
Next one please. Yeah and then, just to show the things we like to know about the fuel before we take it into the back-end and then in the back-end system all the way until the final repository. So decay heat is very important because have to fulfill the temperature on canister, bentonite and rock and fuel, for instance. Criticality must stay subcritical, multiplicity to assure that criticality does not occur. Radiation doses, both gamma and neutrons for safety. Nuclide inventory, I say nuclide inventory, not radio nuclide inventory because there are also nuclides produced that are no radioactive but are toxic for instance. These also have to go into the safety assessment. And then the properties for safeguard verification, fuel pins, missing pins, contents of the fuels, amount of the fissile material, burn-up, initial enrichment, cooling time, weight, et cetera. And then fuel integrity and mechanical properties and I think a lot of this has already been copied by the excellent presentation by the last – yesterday and Stefano’s before me. But just to give an indication of what kind of things are important.
Next one. Yeah and another thing that is certainly important to, not least our owners is economy and optimization now 25% of production cost more than 25% of production cost of electricity in Sweden is for the back-end for the activity of SKB, actually, which is enormously much more than it was only 10 or 15 years ago, maybe ten times more or something like that in percentage. And according to both the new nuclear act and the environmental act, economy must considered when designing nuclear systems. Therefore, optimization is very important thing in the back-end in Sweden. Perhaps, the most important way is thermal optimization for the back-end, and particularly the final repository system. Decay power determination, accuracy, materials, thermal modeling et cetera are

paramount in this process. But it also has some bearing on these new fuels.
Next one please. Yeah I was particularly asked to speak about the Swedish nuclear fuel approval process. And so I've tried to as simply as I can spell them out here in a few slides. So all fuel to be used in a Swedish Nuclear Power Plant has to be approved in advance by SKB. And the reason is that the fuel must be possible to handle and appropriate in the back-end of the, in the Swedish Nuclear Fuel Cycle. So the fuel is analyzed in the various parts of SKB that is relevant for the back-end, transportation, immediate wet storage, encapsulation and of course not least, final disposal.
Next one please. Yeah so what happens is then that the power plant that wants to purchase fuel indicates intention, its intention as early as possible far in advance of actual fuel purchase negotiation is really starting for the power plant. And sometimes indicative decision is suggested, new ATF types. We've had those or had the opportunity to explain the principles for accepting a new type of fuel in the Swedish system. And then meetings are set up to guide this process, beginning with an introductory meeting. All parts have to sign off their approval of the new fuel and in the end, the formal decision is made by the designated division head at the formal approval decision meeting. And time, average about nine months for this process now, this could be done faster depending on when the decision is necessary for the fuel purchase process. But we usually get these requests so early that these nine month or about year or so is appropriate. The fuel people at the power plants know about this in advance.
Next one please. Yeah so what is then approved so to speak. We have acceptance criteria for what can be accepted in the Swedish back-end system. So all fuel accepted must fulfill certain criteria such as dimensions, weight, et cetera. So it fits the components of the system such as casks and canisters. Criticality in the various parts of the system, or more I should actually use the word sub-criticality levels used yesterday, indicates of course what you want to demonstrate is that there is no criticality. Radiation levels, initial enrichment, fuel mechanical integrity now and projected into the future based on the, on existing knowledge. And very important then for these ATF fuels that the uranium matrix must consist of uranium dioxide. We don't accept any other, any other fuel matrix in the [indiscernible] system. The fuel must be shown to have low dissolution rate in water and this is one of the major tests that has to be done demonstrated for each fuel type because it's almost like a 4th barrier in the KBS system that the solution rate when exposed to water very long future time is very low. So and the then variations such as dopants must be verified experimentally. All the information must be available for the fuel such as all nuclide content of the fuel, including

cladding and other components. If fuel does not fulfill these criteria, special analysis can be made, for instance what can be done to remedy the situation and not least the cost for this. Of course, coming back to the cost analysis before, everything can be done, almost. But everything also has a cost. And the nuclear system, at least in Sweden is already pressed for cost, so it is to show that it doesn't, this new fuel doesn't mean new hefty cost for the system is of paramount importance. And then there are additional acceptance criteria when the fuel has been used in a reactor, such as burn-up, cooling time, et cetera. It is not really, it's another type of acceptance criteria, you could say but it's also a type of acceptance criteria. But, I will add that because Sweden is supposed to be quite the advanced in final repository area planning, hoping to get the final repository operating fairly soon. We also have had, then, to make a lot of investigations of the as I said and these, not least these solution rate investigations are quite expensive. And that's just say not too happy about taking all that cost for looking at new fuels. I think we do think that these costs should be shared by the international community to much larger extent than they are done at the moment.

Next one please. Yeah and then, yeah, the accidental tolerant fuels, as I said, all fuels must be accepted must fulfill certain criteria beginning to be considered by the, by the power plants, doped fuels already in the system and has been approved. Chromium doped fuel are already operating in Swedish reactors. And they have been investigated for this dissolution behavior, that's considered to be acceptable. Some of that has been international European Union product called DISCO, has been some cost sharing for this actually and as I said Uranium dioxide fuels are generally considered to be acceptable, although has to be verified. I can also add that we are actually taking many types of ATFs in the Swedish system, but very little amounts because lot of those fuels that are tested or has been tested in Halden has been taken to Studsvik and investigated and then there is a special Swedish government decision that allows Studsvik to take some small amounts of Uranium that then changes title to Swedish fuel. And that then SKB has to finally dispose of. So we have an agreement and a special contract with Studsvik where we specify which ATFs we can accept, as I said this is a very small amounts. All of those that are not Uranium dioxide has to be transformed into Uranium dioxide. And of course that can be generally done, but of course this process is quite expensive if you're having to do it for large amount of fuels. I can also say that in Sweden we have some old metallic fuel from the 60's, discontinued operation of a Nuclear Power Plant at that time called Agesta, which is sitting in Clab at the moment. We don't -- haven't finally decided how these should be treated but we know we have methods to treat them if necessary. So that's kind of ongoing activity to think about how these should be taken care of in the Swedish system. I should tell

you, also say that processing, it’s not done in Sweden and it is, but no law against it. It's for purely economic reasons. It was decided in the 80’s, not in the economic way to deal with the back-end so that was never right. There was some fuel repossessed in the 70’s in other countries for Sweden, that was quite small amounts, that was unchanged since title exchange with other fuels. But so not allowed, it is not disallowed but it is not nothing that is considered acceptable to do in Sweden. So of course also for other reasons then commonly. So and that's of course one of the reasons why it’s so important to state from the beginning what, what kind of fuels you can accept because if you have access to possessing some of these may be different. I would like to, if you allow me to make a general personal remark here, that I think surprising that after 70 years, more nuclear power is not natural in the development of new fuels that there is a back-end and that is must be better to optimize the Nuclear Fuel Cycles from the outset beginning with the development of these new fuels. Just a general comment that I think it would be optimal for the entire Nuclear Fuel Cycle to have this from the beginning of the development of the fuels.

Next one please. Yeah.. I also would like to state some recommendations from IAEA. The IAEA working group for Nuclear Fuel Cycle, where I sit myself. So we have made these recommendations here. I will just read them to you. “While there has been significant amount of research development and analysis regarding the performance of these fuels in reactors, very little work has been done to date to investigate these advanced fuels within the back-end of Nuclear Fuel Cycles. Only recently has work began to investigate the impacts of chromium coated zircaloy clad accident tolerant fuels within the broader fuel cycle. Organizations responsible for back-end in some countries, like Sweden, already have been requested to provide opinions for possible new accident tolerant fuel purchases by nuclear power plants operators, but been unable to do so due to lack of information about properties impacting long-term safety of final disposal. “

Next one please. And “the IAEA, in its international leadership position, is well poised to begin addressing this issue for the benefit of member states. As such the nuclear fuel in this working group for Nuclear Fuel Cycle recommends that the IAEA undertake an activity in biennium 2022/2320 to consider the impacts of advanced Nuclear Fuel within the broader Nuclear Fuel Cycle, including storage, transportation, reprocessing and disposal. The working group believes that the IAEA could, one, identify different options for managing spent advanced nuclear fuels. Two, establish a process for identifying and evaluating these impacts. Three, identifying the data and information needed for these evaluations and four, demonstrate it in an evaluation of the potential fuel cycle impacts of advanced fuel forms that could be deployed

in the next decade, including accident tolerant fuels that could be expected to be deployed in the very near term. Future evaluations could include other fuel forms as they mature towards deployment."
So I have a few more slides, but I think all that has been covered already. Most of them from the next speaker, David Hambley, so I don't think I have to go through those. So this concludes my talk. Thank you very much. I'm open for questions.

>>Paul Turinsky: Thank you Anders for your presentation. So I'll open the floor now for questions from Board members. Tissa?

>>Tissa Illangsekare: Yes can you hear me?

>>Paul Turinsky: Yes.

>>Tissa Illangsekare: Thank you so again I'm not an expert on nuclear technologies but my question has to do with the environmental issues, so in slide number 26 you saw spent some time talking about the difficulties in the solubility testing, so my question is that when you are looking at these systems, the geochemistry of the water you are dealing with as an impact on that fundamental process. You are not looking at solubility in, water so my question is how do you deal with the new define solubility on this fairly complex conditions which can exist in the size and also the time frame.

>>Anders Sjoland: Yeah these, what is done is that these different fuel types are exposed or rather, the pellets are exposed to typical water for particularly geologic repository situation, such as now the Forsmark in Sweden. And as you indicate it is not, not clean waters of course lot of components and some, not so much but a little bit. So that's how they are tested, generally. With kind of a typical let's say the hardest, most difficult water in some sense for the fuel to be exposed to. And the time frame is very long future because in the Swedish system we are, as the Swiss are, we are analyzing in detail, one million years the regulation is for, is for 100,000 years and then we make an analysis, detailed analysis for one million years including eight consecutive ice ages and so and under all these circumstances we think we can show that the copper canister can sustain, that will survive one million years. But if something would happen then that would break the canister and make, and exposing the fuel to water then that's where the dissolution rate comes in and that's why it's, why it is done.

>>Tissa Illangsekare: Yeah so recently for technical detail when you discuss solubility, on the dissolution rate assumption is this when is not, this is not equilibrium, because that would be move some dynamics of the water moving, so do you factor those dynamics can vary depending on the external drivers. So how do you allow for all those uncertainty associated with almost like a laboratory determining number was behavior for real system.

>>Anders Sjoland: Yeah and then as I said what is used in some kind of work that is supposed to be difficult one for the fuel. I'm not an expert in this myself, but so and with this ice age, you could say for a long time we actually

have, we will get a cleaner water because of the ice. So it is, to say it is a very complex moving situation and I would think that David Hambley that comes after here would know more about exactly these kinds of details that you are speaking of.

>>Tissa Illangsekare: Thank you very much. Thank you.

>>Anders Sjoland: Thank you.

>>Paul Turinsky: Lee?

>>Lee Peddicord: Just really, as always very interesting. Couple of questions it is very impressive, you know, at this stage, SKB gets involved in looking at the new fuels, the purchases and so on and you have really a very detailed list of acceptance criteria as well all to the good, so one of the questions would be of course the regulator, SSM, they must be interested in a whole host of questions associated with this fuel their lists might be a bit different than yours as well too. Do they get involved at such an early stage as well or only upon submission of an application by the utilities to load new fuel or purchase new fuel.

>>Anders Sjoland: Yeah, no, we delegate the responsibility SKB to take these back-end considerations into account. So the --

>>Lee Peddicord: Operational aspects as well too prior to the back-end, issues as well.

>>Anders Sjoland: Yeah, yeah, of course are interesting. Not making a formal decision based on the back-end in these detail fashion that I have declared. That's the responsibility of SKB.

>>Lee Peddicord: How about the land in environmental court. I guess you are waiting for them or something --

>>Anders Sjoland: [LAUGHTER] We are not waiting for them, they have given their verdict and …that's the consequence of that verdict is what we are waiting for in the decision by the Swedish government. So we haven't got a decision yet and actually the, this KB3 programs in the SKB has been paused waiting for a decision by the government. But, but the environmental court wouldn't have any say. I mean you are not applying for every fuel type or anything like that, environmental gave a verdict on KBS system as a whole based on the application presented and submitted by SKC and of course, the fuels and the planned fuels -- but I don't think we had much about ATF in that application in, dare I say it, 2011, more than 20 years ago. Of course, it was there but I don't think we have much about ATFs in that application.

>>Lee Peddicord: You mention the issue of the disillusion, I think you dealt with some things on copper corrosion as well over a period of time. So does SKB, do you have your own research facilities or do you use other organizations to carry out the kind of research you need to answer your questions?

>>Anders Sjoland: With both actually. If I'm understanding your question correct, you ask generally, and generally we have our own research facility, we have one for instance a canister laboratory in Oskarshamn where canister research and development is done but not exclusively. And there are also many

others that say, external consultants, universities, et cetera in Sweden and outside that are employed. And we have an undergrad underground laboratory, the Aspo underground laboratory, also in Oskarshamn where we do the particularly full scale and also experiments on the rock and the environment in the rock. We do, the Clab facility, we actually do -- it is not a research facility and as a researcher myself I say unfortunately, of course it is a storage facility. But we are lucky enough to be able to use it for a considerable amount of experiments not least for, for radiation and decay power [indiscernible] for fuel assemblies, for instance. So, we have our own facilities and then also using a lot of other facilities of course in Sweden we have Studsvik which, of course, we use a lot. A lot of the disillusion experiments are done in Studsvik, also the mechanical experiments are, of course, done in Studsvik in the [indiscernible] there. We are participating in the SCIP program, now SCIP4, to mention a few. We're also taking part in, in lot of other projects, European projects Stefano already mentioned the spent fuel characterization project, project, 60 million US dollars or 70 million US dollars which is, European project and the spent fuel characterization of work package is about a tenth of that and that's actually headed by me. Stefano was taking very nice part in that.

>>Lee Peddicord: Finally you mentioned, you know, that Finland has adopted KBS3 as well. To what extent do you have interaction with Finland, what they use Clink for example for encapsulation or what do you foresee or will they have their own?

>>Anders Sjoland: We have a lot of collaboration, of course and we have this is a corporation agreement and kind of structure guiding this corporation. And they will have their own facilities, they have, they are building actually own encapsulation plant on top of the geological repository. I know it looks a little bit different in Finland they don't have any central storage facility but fuel is kept at the two sides for Nuclear Power Plants are situated and so they will have encapsulation plant. We are discussing things like a canister fabrication, not encapsulation but canister fabrication, production, et cetera. Some of that is still in the discussion phase, some will be natural to do independently. Some will be natural to do together.

>>Lee Peddicord: Thank you very much, very good, very impressive.

>>Anders Sjoland: Thank you.

>>Paul Turinsky: And Steve?

>>Steven Becker: Steven Becker, Board member, thank you Anders for a very interesting talk. During yesterday's presentations one of the speakers mentioned and actually emphasized the need to communicate early and often with the public. This is not always easy with highly technical topics, but it can be quite important. Could you tell us a bit more about what is being done in

Sweden to facilitate early and frequent communication, including with the public about the topic of accident tolerant fuels.

>>Anders Sjoland: Well that's an interesting question, of course SKB has a very, very extensive communication program since many decades and we have spent a lot of resources and energy on communicating with the publicly, locally, regionally, nationally and I think also internationally. And that has been very, very important not least locally to get people informed about what we are doing. We like to think that transparency has been a key guiding star for what we are doing. Now when it comes to actual fuels, I haven't noticed so much interest in the public. There's interest in the final repository, there is interest in the method, there is interest in this perhaps Clab, interim storage and things like that. There is actually very little interest in transportation, done all the time in Sweden but it is never, there's never a newspaper article about it. So which means that there is not a public issue related too. And I don't think I've seen any discussion on particular fuels or the ATFs, yet. But what has come to the fore is something we're not supposed to discuss at this meeting and that is, but which is related to ATFs, that is SMRs, small modular reactors which of course would probably use ATF fuels and that has come pretty quickly to the political arena in Sweden, being publicly debated and also the [indiscernible] has been out speaking about SMRs and we aren't discussing that here, but so but that's relationship to new fuels I think is, will be important. But the discussion hasn't got to that kind of detailed level and I wouldn't say that, what has been discussed publicly in Sweden related to SKB's activities is to very, very large extent this issue of copper corrosion. Which I think is quite known now and well the heated debate let's say.

>>Steven Becker: That was very informative, thank you.

>>Paul Turinsky: Anders, I have two questions. One is sort of a curiosity question. Most other countries have chosen dry storage for extended storage. Sweden has chosen wet storage. What was the logic behind that?

>>Anders Sjoland: Well, easiest answer is that I don't quite know, it was before my time and but I think, you know, it was planned in the 70's and then it was finished and began operating in 1985. And I think that at that time it was considered, at least in Sweden, at the best, most ambitious way without any compromise to do intermediate storage. And I must say that to many, particularly of the little bit older Swedes been involved in this, I think it is a surprised that its now in many [countries] regarded as that dry storage is let's say the safer option, particularly with passive cooling. My personal opinion is that both dry and wet are probably okay, are good. There are advance to both, of course with the dry the passive cooling is very attractive. With wet I would say that this possibility to continuously monitor the fuel is interesting. So you don't have to open a dry cast to look how does the fuel look like. That's very important. How can we handle the fuel,

for instance, at that the encapsulation plant. Will it be robust enough to lift, for instance and all these kind of issues. We can continuously monitor the fuel at Clab. That's a kind of advantage, I think there are pros and cons, I think an exact answer of your question is difficult, but I think it was that was considered the best. That was, at the time, Swedish nuclear system was extremely ambitious and cost was not an option at that time.

>>Paul Turinsky: Okay and my second question, I'm trying to understand responsibilities for different organizations and let me start by talking about responsibilities when the fuel is in the reactor. That responsibility eventually the utility shifts back to the fuel vendor to a great extent to justify why the fuel is acceptable to go and operate in a reactor. As we move to the back-end I should sense fuel vendor doesn't have the same level of responsibility but now that falls on SKB which is really part of the, you know, really part of the utilities ownership as part of the utilities to do it. So could you clarify exactly what responsibilities the fuel vendor has to support the R&D and answer those scientific questions for the back-end?

>>Anders Sjoland: Yeah at present not so much, they have the responsibility to provide information about their fuel even if there are some issues about that as well because there are some secrets fuel vendors like to keep. But so giving the specifications of the fuels and then of course what happens to them when they are operated in a nuclear reactor under normal circumstances but, not more than that. We are not relying more than to a small extent on the fuel vendors at present.

>>Paul Turinsky: Okay, that helps. Okay. Questions from the staff? Are there any questions from the staff? Any, okay. Nigel? went away here. I don't see any questions from the, okay. Here we go.

>>Nigel Mote: Thanks Paul and thank Anders for a very clear and interesting presentation. Another question about the acceptance criteria and the way they’re applied in the experience. So you outlined the system, can you make some comments about the experience of how that's been applied, for example I'm sensing no fuel designs have been rejected but at this point is that true, have any fuel designs been rejected on the basis of the implications for the back-end and whether or not that's true the next part of the question is has there been some impact on the design of new fuels that maybe has been adjusted, materials specs change or altered because of the application of the control SKB and the others involved in the back-end said have on the new fuel design sort of being considered by the --

>>Anders Sjoland: Thank you Nigel. Very interesting question I, there has not been a specific rejection but there has been some close ones. This would chromium doped one, there was quite a lot of discussion about what investigation had to be done in order to get them approved. But, of course, also have to know that the Swedish power plants know what SKB can accept. So that's what new the ATF fuels and before we go to request very early on

from one of the Nuclear Power Plants on the ATFs that made, to be able to clarify what types of ATFs we would be prepared to accept. The question if there has been any adjustments of the fuel, that's difficult to know. I think there might have been some at some point but I don't think that that's officially recognized. There has also been I don't think I can speak very explicitly about that but there was an issue X number of years ago with a certain nuclide that would not be problematic for a final disposal, but that could be problematic for the low and intermediate level repository SFR. SFR, you know as it takes care of for instance the filter materials from the power plant and things gone away from, from off diffuse. And there was, there was one example of a certain nuclide that hit the roof and actually in some analysis early analysis above the dose limits for SFR. But then actually there was a big discussion because it was quite close to the limit, but then there were more detailed analysis done and it was shown that it was okay, not really enormous volume but it was okay. So that purchase was done but still keeping an eye on that particular issue. I don't know if that answers your, but that's the reality anyway.

>>Nigel Mote: It does in fact that's interesting what you are saying is the acceptance criteria are not only looking at disposal, repository but other waste streams that may be generated by the nuclear power stations that are secondary to disposal of the fuel but they are important in terms of power station operation.

>>Anders Sjoland: Yeah, yeah.

>>Nigel Mote: Yeah, okay, all right. Yes, thank you that answers, thank you Anders.

>>Anders Sjoland: Thank you.

>>Paul Turinsky: Any other questions? Again thank you for your excellent presentation where I am personally envious of where Sweden is in their back-end of the fuel cycle at this point and let's hope that action is coming pretty soon on a positive sense on that. Again thank you very much.

>>Anders Sjoland: Thank you, thank you very much.

>>Paul Turinsky: Okay. At this point we're going to take a 20 minute break. Which means that we will be starting up again at 2:10. 2:10 Eastern Time.

[BREAK]

Paul Turinsky: Well, welcome back to the Nuclear Waste Technical Review Board public meeting. This afternoon we have one more presentation and then there will be a panel session followed by reading of the public comments. Our last presentation for this meeting is, are, is going to be given by Dave Goddard and David Hambley from the National Nuclear Laboratory in the UK. And I shall turn it over now to our speakers.

>>Dave Goddard: [Inaudible]

>>CART PROVIDER: It sounds like he is muted.

>>Paul Turinsky: We do not, we're not hearing you.

>>David Hambley: Can you hear me now?

>>Paul Turinsky: Certainly can.

>>David Hambley: Okay, sorry about that. My name is David Hambley, I'm the research fellow for spent fuel storage and disposal at the UK's National Nuclear Laboratory, I'll be doing the first half of this presentation. Dave do you want to introduce yourself?

>>Dave Goddard: Yeah, sure, for this presentation you get two Dave's for the price of one, I'm Dave Goddard, I'm also an NNL fellow, I'm looking after the fuels area so I'm advanced fuels fellow.

>>David Hambley: Right. So in overview we're going to talk initially about UK nuclear policy, how we manage spent fuel and storage disposal in the UK and how we implement changes to fuel and the decision making around implementation of changes to fuel. And then I'll hand off to Dave who will talk about current work on new fuels and accident tolerant fuels. So in the UK the government produced a new strategy for the UK nuclear sector as part of its overall net 0 carbon emission program. This included a significant investment into a range of nuclear technologies. Large nuclear covers implementation of current large scale reactors into the UK there is one twin station being built, the planned commitment here is to seek to get at least a second one in the coming years and implementation of accident tolerant fuels would be initially seen as into those reactors at the decision of the utility. In addition to that, there's a significant commitment to the development of advanced nuclear technologies, which could either be small modular reactors based on adaptations of current Light Water Reactors technology and advanced modular reactors which are alternative reactor systems such as molten salt, so high temperature gas reactor. Commitment there is to fund research and support the development of small modular reactors for deployment early next decade. There is a commitment to fusion and a commitment to supporting a hydrogen strategy and that includes an element to nuclear general area to the electricity, which most likely to evolve high temperature gas reactors in the development of ways to green hydrogen. So substantial investments in nuclear and innovative nuclear within the UK program. The national strategy for dealing with waste in the UK is that for high and I happened immediate waste and for any fuel that is declared as a waste, UK policies that will go into a geological disposable facility. We have an organization, Radioactive Waste Management Limited which will be the developer of the disposal facility and the government is conducting a citing process currently, which is based on voluntarism and partnership. The government has set out proposals for the implementation of a deep geological repository and process for site selection and development and we're in the stage where communities are being invited to express interest and discuss with [indiscernible] the government about whether they wish to go forward as a potential site for a deep repository. In terms of the time scales relevant to spent fuels the earliest anticipated date for

spent fuel disposal is some time around 2075 and that's principally because the current plans foresee a large volume of intermediate level waste being prioritized for disposal as this arises from um wastes and activities that were earlier in the nuclear history within the UK.
In terms of spent fuel, the government position is that it’s up to commercial judgment of the fuels owners to decide how they wish to manage their fuel subject to meeting necessary requirements. In the UK generally, we are transitioning from an open fuel cycle to, sorry to an open fuel cycle from one that has been largely based on reprocessing. But the option remains open for future transition to close the fuel cycle should anyone wish to pursue that. The decision to move to an open fuel cycle for the fuels coming from existing reactors was really made on the economic case and the specific requirements for upgrading UK facilities in the context of international market that was not very strong. The UK geological disposal facilities intended to receive all the spent fuel and vitrified waste from UK research and test reactors, from the closed Magnox reactors, current power reactors and up to 16GWe of new power reactors operating for a lifetime. That impacts significantly into the future of nuclear power within the UK. And strategic planning recognizes that if there were to be a very large scale deployment of new power reactors it’s more than likely that we would go back to a closed fuel cycle.
We look at the implementation of policy in relation to the storage and disposal of spent fuel. The legal framework is based on justification, legislation and regulation principally. So the justification is a very strategic level demonstration that would benefit the nuclear or regular enterprise outweigh the risks. The last one that was done for new build program justified on basis of open fuel cycle. But that doesn't preclude other options being implemented later. There is a wide range of legislation to support the regulation of safety environment transporting securities associated with management to spent fuel. There are regulators to insure the implementation. They issue license and permits as to common in all places and in relation to fuels and their implementation. Most likely for this to be considered within the UK is in relation to a modification of way the way plants are operated in the UK So it would be a modification to an existing license most likely for a short term ATF implementation.
One of the aspects that is considered within UK system, although not directly necessarily as part of the formal licensing process is that the disposability of fuels is considered by the regulators both the safety regulators, the office for nuclear regulation and the environment agencies that issue environmental permits. They place weight on the assessment of whether fuel is disposable when issuing licenses and permits. This is a confidence building measure and it's not part of the formal licensing process. But since the UK has a less prescriptive regulation, a more target setting regulation these often aren't taken into consideration. If we

look at the right-hand side flow diagram, disposability assessments are undertaken against conduct for potential geological repositories in the UK. Has defined what these are and the way they expect manage fuel into a range of potential host rocks and geologies. From this they produce a packaging specification for different types of waste and then early engagement by utilities allows the utilities to produce a proposal for packaging waste, which RWM [indiscernible] to see whether it complies, and if not in what ways further underpinning, technical or engineering might be required. That can be fed back into satisfactory degree of confidence can be established. And that degree of confidence will vary depending on the maturity of the licensees proposals. It is possible within the current system, where it's beneficial to the nation as a whole, for the geological proposal concepts to be modified to allow some change to the management to spent fuels. An example of that recently was for the PWR [excisal], request to consider disposal of spent fuel in MPC, large dry storage canisters, that was put through to RWN who conducted their assessment process and evaluation, although that ultimately led to a conclusion that the current UK disposal concepts could not be modified in a way that would allow MPCs to be used. And therefore, the utility concern has gone back and revised its strategy from the fuel in order to enable fuel to be loaded into a disposal system compatible canister.

A second, less formal process, that runs alongside the form regulatory process is the generic design assessment, which can be used for new reactor systems. This can include new conventional reactor designs, examples on the slide include AP1000, UK APR assessments undertaken in recent years. The general design assessment process is a way of providing vendors and utilities with confidence that a reactor design can be licensed to operate in the UK with a degree of certainty before formal application to construct a reactor on a particular site is made. Within that process, the management of fuel must be demonstrated including at a strategic level, cutting on site storage, transporting infrastructure and final disposition as well as developing design and operating safety case integrated waste management strategies. As would be expected for a new development, this process goes through a number of stages where the level of detail required from the utilities must be demonstrate increased as the plans progress. And that's about building confidence that the entire system will be licensable and permittable.

For novel reactor systems, the UK is government is funding a feasibility and development program for a number of advanced modular reactor systems many of which would use ATF-like fuels. From the initial phase of the funding, the tenders were required to address, amongst many other things, both the management strategy for spent fuel after discharge and also final disposition. Initially that was simply to demonstrate understanding of the potential challenges associated with back-end

strategy covering storage transport, recycle, if required, packaging and disposability. In the second phase, where there are a fewer potential candidates and the aim is to fund development, this stage at which those reactor systems commend to the generic design assessment, further detail is expected on all those topics to give confidence that any new reactor and novel reactor system will not lead to the generation of future liabilities that are unquantified.

I'll now talk a little bit about of changes to fuels in current reactors. At the center of this brief graphic is the utility which generates the fuel and has the responsibility for management of it. The in tract with [indiscernible] rely on regulators, vendors, disposal facility entity and the fuel management entity. They sit within a framework developed by governments in order to serve the public society. How those relationships between these parties develop is a matter of both national difference, but also the history of the national nuclear programs.

So I've got two examples of fuel types in the UK to look at the ways in which implementation of new fuels are managed. So the first of those are for the current reactor fleet, for the gas code reactor. Both the current AGRs and their previous reactors were developed and deployed by government organizations. The reactors were eventually prioritized into commercial companies, but took with them arrangement for the management of spent fuel that didn't derive from that historical context. So for AGR fuel, the utility is responsible for short-term storage at the reactor site and transport of fuel to a centralized facility at which point the red star responsibility for fuel changes to the nuclear decommissioning operate authority to operate the interim storage facilities and who will, in the future package and transport that fuel to the GDF. RWM currently is responsible for the approval of disposal plans and for the development of GDF and in the future for its operation and replacement of spent fuel. In relation to changes to fuel design, the utility may request changes from the fuel manufacturer and approve those changes. But before the fuel can be considered for transfer from the reactor site to the NDA, the NDA normally agrees to those changes prior to loading and that agreement, in essence provides the utility with the comfort that modified the fuel will be transferable to the NDA and the NDA will accept it under its current terms. Strictly it's not necessary to load fuel but that would lead the utility within a liability in the event that the NDA decided there was an additional risk associated with that fuel. Likewise through the disposability assessment process, RWM would expect to be requested to evaluate any significant changes to fuel that are likely to affect its disposability. Again, that process is about providing comfort, utility that fuel liabilities are not going to increase.

For current fuel and the fuel for new build reactors, this situation is different. New reactors are developed by commercial organization. The

fuel liabilities that derived entirely from this commercial context and in for the new reactors, the utility retains their responsibility for interim storage and for packaging and disposal for transport to the GDF. In this case, the utility retains liability for the fuel until it is delivered to RWM at the GDF in a package that's suitable for disposal. In terms of changes, the utility is free to request and approve changes to the its fuels of course the regulatory bodies will need to issue the relevant licenses. But the utility can only dispose to the repository, if RWM has agreed that the packaging of that fuel and behavior of that fuel is satisfactory. And, therefore is normally, would normally be included in the approval loop before the utility undertook a change to its operations that left it with a liability.
That covers my initial description of management of changes to fuel in the UK. I should say, finally, I have rather skipped over the important role of the regulatory bodies, naturally have to approve license any changes as they would in other places and they will require all the underpinning for the qualification of fuel for use in the, but the focus here was on other aspects that control the way in which changes in fuel are considered for the back-end. Now, I would like to hand over to Dave to talk about what currently going on.

>>Dave Goddard: Okay, thank you so much David and so yeah I'm going to talk a bit more about what we're doing on developing new fuels in the UK and UK energy policy is set by Department of Business, energy and industrial strategy which would be the equivalent of the US DOE. And in policy space the UK has legislated to meet that zero target by 2050 and it is looking for all sectors in the energy world to contribute to that target, including nuclear. And there's parts of that it has an energy innovation program and there is a fairly sizeable nuclear component to that called the Nuclear Innovation Program, which has been running now since 2016. So we just coming towards the end of first five year cycle and so plans are now being looked at towards what is going to become the Net Zero Innovation Program going forward. Now the program itself is split into a number of different areas, two of those areas are being led by National Nuclear Lab, one by future fuels and one in the recycling of fuels from future reactors and in the last part of the program we brought those two areas together into what we have called the advanced fuel cycle program. So it is quite an important change it ensures that when we're thinking about new fuels, we are also thinking about what we are going to do with the fuels after they come out of the reactor. So bring those two areas together under a single umbrella helps us ensure that we are making the right decisions.
And just to illustrate that a little bit further this sort of overview of the fuel cycle, if you like and the boxes and circles in green illustrate the areas that the innovation program, Advanced Fuel Cycle Program is concentrating on, as you can see we're looking at the fuels and particularly the recycle areas. The parts of the process, if you like, that

we're talking about today in terms of the storage and disposal, they're not directly part of the program and that's because responsibility for that lies with the nuclear decommissioning authority. So we don't want to sort of cross over into the territory to some extent. But certainly when we are developing new fuels and looking at recycling of them, the storage and spent fuel management and disposal is also part of our consideration.
This slide doesn't have much detail on it and it's something that we have been developing through the program concerning how we communicate really the outcomes of the program and it's really important and I think there was a previous question about it around public perception and how you communicate what you're doing and particularly the impact of the work that you are doing. So we spent quite a bit of time thinking about this and we have people that are dedicated to communication using all different channels to do that as well. So when we communicate we like to think in terms of how the programs link into industry, how it is benefiting in terms of building new infrastructure for sort of testing, et cetera. The benefits we bring to supply chain companies in the UK and also, as I'll talk about the ability to be influential internationally and to communicate with other international bodies. And actually through this program, the UK set up with the IAEA, the first step of fuel cycle collaboration center which is come out of this program.
So I'll get into a little bit more detail now about the fuels that we're looking at, I think I don't need to go through too much of this slide but the accident tolerant fuels have been something that is, has been of interest since Fukushima. What we've noticed and researchers have started to comment on now is that although the safety aspect of these new fuel types is important, it is equally important they are economically viable and so we are looking really at these knew new fuel types in terms of what they can deliver over and above in improved safety performance. And that means, improving the reliability of the fuel in the reactor and its performance in terms of being able to achieve higher burn-ups and longer cycle lengths. Or even high density materials where you can achieve an economic benefit because of either reduced volume of material that you have to manufacturer or reduced enrichment costs. But certainly when we look at these cost benefits that potentially come with these accident tolerant fuels, we need to consider the full life-cycle of the fuel and so actually understanding if there are any back end considerations for these new fuels it is really important when we do that cost analysis.
Just to highlight some of these cost reduction drivers, here's a couple of illustrations from previous reports. One thing that's very important to understand with nuclear in particular is that the capacity factor of the reactors depends very strongly, or reflects very strongly in the levelized cost of electricity, so small changes in capacity factor have a greater impact for nuclear than they would have for other energy generation

forms. And talking also about the fuel reliability, fuel vendors and operators of improved reliability of fuels consistently over the past decades, but there's still more improvements that can be made. So we look at what's at the major causes of fuel failures when they do occur in Light Water Reactors, therefore are the ATF solutions actually tackling these specific issues and therefore going to lead to better fuel performance.

We also do some sort of analysis looking at some of the aspects of different fuel and cladding options and this slide illustrates sort of the considerations in terms of the maturity of technologies, the economic benefits as well as the safety benefits and although I'm not going to talk in detail to this slide, these are the ways in which we look at different ATF concept and we decide which ones we should be supporting and developing.

So one of the first concepts that we have been looking at and obviously is the one that is probably closest to deployment now is coated zirconium alloyed cladding, we have already heard about the work being done in the Gosgen again reactor with irradiation testing under way. Been developing our own chromium-coated cladding and we have developed manufacturing processes now through to the ability for coating full length fuel tubes. And that's also an important aspect of the whole economic fuel cycle is the production costs for the fuels. And these are showing excellent performance in both normal operations as well accident conditions. The work we do is also quite international and we got a number of different collaborations through some of the fuel vendors, so we're working quite closely with Westinghouse and they have taken samples that we have provided to them and they have been irradiated in the MIT reactor recently. We're also looking supply coated tubing for an INCA fuel creep test which is to take place in the Czech Republic as part of NEA FIDES fuel and material testing program. We're also joining the QUENCH-ATF NEA joint program which is looking at bundle test and subjecting them to LOCA and severe accident conditions. And we've also been collaborating with Oak Ridge looking at simulating LOCA testing in burst tests. So there is a lot of international cooperation within this area and the UK is looking to play its part.

In terms of the performance of the coatings, as I said they do perform very well. The chromium, you see weight gains, reduction of weight gain of greater than 90% compared to stand-alone coated cladding and importantly, you see the weight gain is essentially proportional to the hydrogen pickup. And, what that means is that the chromium coating is acting as a very effective barrier for hydrogen in getting into the cladding. And we can see obviously that will have benefits in, into storage and disposal. The chromium itself is fairly robust and we don't expect dissolution, although this is something that perhaps still does need to be

fully tested particularly if you potentially form hexavalent type chromium and issues changing water chemistry.
We've also got some work going on looking at the longer term cladding option of silicon carbide composites. Clearly with this material there is quite a lot more development work required because of some of the technological issues in terms of manufacturer joining particularly and hermiticity as well the corrosion under the normal operating conditions. And it's a very different type of material and therefore the licensing of such a cladding is going to require a lot more consideration. But in terms of the long-term storage of these materials, we do not expect them to be particularly problematic because of the nature of the material.
I'll move on to just say a little bit about the fuels now and doped 202 fuels already heard a little bit about them this afternoon. We've got three UK participants in the DISCO project which is a Horizon 2020 project in Europe which is ongoing at the moment. And there are a number of tests being taken place in different water chemistries on a variety of oxide-based fuel materials in different forms: finally radiated a sort of simulated irradiated and irradiated fuels and the indications from this work is that the dopants are not likely to be detrimental. In some cases with iron presence it could actually be beneficial.
Other area we have been looking at is that of the higher density fuels and this is, as I said earlier, primarily associated with the potential economic advantages. And if you look at the options that you have of increasing density of fuel materials there are, with the exception of the metallic fuels, relatively few options but of those options, there are a number of benefits. So one is the improved thermal conductivity, which occurs across the temperature range as well. And this leads to a safety benefit because of that high thermal conductivity and therefore the power to melt ratio relative to UO2 is enhanced. So you've got a material if it was suitable for Light Water Reactors will give you both an economic and a safety benefit. But when you actually look at decision to change fuel material, we have to recognize that UO2 is a very good fuel material if you look at all the properties irradiation performance, how it behaves in water and steam and how easy it is to manufacturer, any alternative material has to, almost, meet these criteria and if you look at these alternatives you can see there is issues of particularly around the water reactivity and I'll just sort of illustrate that with the next slide.
This is some images taken from a paper from Andy Nelson when he was at Los Alamos National Lab showing what happens to these three different fuel materials after just two days in pressurized water conditions. And at the moment we are focusing on, you might be surprised, uranium nitride because of the higher fuel density improvement that you get with it. But clearly from these images, the uranium nitride is not a very tolerable of those water conditions.

So we don't give up necessarily just because of that fact so we are looking at different strategies to provide improvements in the water tolerance of uranium nitride. There are a number of different ways of doing this. One is to look at dopants and putting additives in the fuel which can have a beneficial effect. Another way is actually form composites of different materials so that you can provide another material providing a beneficial protective effect while not reducing the density of the fuel. Coatings could be applied to the fuel pullets themselves. This is already done in some conditions for available absorber fuels. And another option is to look at sort of microencapsulation of the fuel particles within another matrix. And there are a number of technologies available that can develop these sort of microencapsulated fuels.

The other thing we are doing with this is looking at spent fuel inventories. This is something not being thoroughly looked at yet, but we are looking to see okay after irradiation, what is the constituents of the efficient products and how to, what speciation, what form did they take within the fuel so we are getting some idea through modeling work to look at the inventories and the forms. And then looking in the next phase to start looking at manufacturing simulated irradiated fuel and then starting to test that in different, both storage and disposal conditions.

So just to summarize then, as David said, the UK regulatory process does require demonstration of full life-cycle management for any new reactor construction or changes in fuel designs. UK's doing a lot of work at the moment in wrapping up research into new fuels and we're engaging both with fuel vendors and also international bodies. Some of the near term ATF concepts such as the coated cladding are very promising and we don't think deployments of those are expect to be limited by any back-end considerations. For the longer term, advanced cladding and high density fuels still a lot more research that needs to be done and that includes in the area of spent fuel and disposal.

So, that brings me to the end of the talk and I'm sure David and I will be very happy to take any questions.

>>Paul Turinsky: Thank you very much David and Dave for your presentations. I'll now open up the questions for Board members. Tissa?

>>Tissa Illangsekare: Thank you for your presentation so I guess these are mostly clarification questions for me. The first one has to do with, I think David mention that the modified to meet for management. So what do you mean like we are deciding this system for long periods, so what you are saying is that the initial stages you are anticipating these different types and will end up with a position to modify the concept and if you say modify, can you give me a little bit of what modify means like, you know, it is same rock but then you are modifying the various systems. How do you modify?

>>David Hambley: We, because we are, we don't have a site, because we're still concept stage have identified its reference fuels and what it is designing the

repository to handle. So we have High Level Waste from processing and spent fuels in a reference disposal system very much based on the Swedish and KBS3. Having said that, for some of our research fuels, the concept know that spent fuel is necessarily optimum and there could be, there are significant economic benefits if we can devise some form of alternative volt and package combination that will provide sufficient containment for those materials. And it depends the characteristics of those materials as well because they tend to be low very long fuel, not like reactor fuels. So RWM and its process at the moment allows somebody to come forward and say I would like to do this with my fuel. It doesn't quite meet your repository concepts, can it be modified? And RWM will take the view on that, which it may accept or it may not and it might not because it is not engineeringly possibility, realistically to do that or that it is just going to be too expensive in which case will say no. But we are in that position at the moment where we have reasonable degree of confidence in what we think geology GDF engineering design and safety performances. But we still have some flexibility to introduce new concepts and new approaches.

>>Tissa Illangsekare: Thank you, next one is for Dave. You mention the types economically reliable and you also mention the full life-cycle. So when you say life-cycle these are design for 10 million years, 10 to the 6. So how do you define life-cycle in the context of economics because, yeah, that’s the question.

>>Dave Goddard: I think, perhaps the terminology these clarifying, we're also looking at economics of closing fuel cycles as well so I know it is not relevant necessarily for this conversation but, when we are doing a life-cycle analysis it would be looking at all of the factors that would potentially cover the reprocessing of the fuel as well the cost of putting it into, into storage and then eventual disposal. So I think it's more a case of is there anything in the new concepts we have that would make a difference to the current assumptions that are being made with regard to the fuel.

>>Tissa Illangsekare: The next one is you mention the stability, stability to water conditions and water tolerance. So when you look at that these sort of same question ask this morning that an example you mention that the steam and the steam the protection oxidizer creates a surface layer. But when these things go to different scenarios of including accidents then the processes can be quite complex because you can have steam, maybe water. Then the cyclic exposures or some other chemicals coming and some other material mixtures of chemicals. How do you in designing these things how do you factor those things if you are factoring, are there research going on these type of issues of failure of these scenarios?

>>Dave Goddard: I think the majority of testing I have to say on ATF is looking at in reactor scenarios. So a lot of it is well, and again it is sometimes through convenience is to look at the testing of as manufactured material. But

clearly accidents aren't going to necessarily happen the first point you put the field fuel into the reactor. Really a better test is to start doing some of these accident scenario testing on partially irradiated fuel or fuel that's had recently high burn-up so that you can really see the consequences of what accidents would take place. And I'm sure that this is part of the plans that the fuel vendors will have as part of their irradiation testing, just that at the start of the process you tend to investigate how the fuel as manufactured behaves it gives you an indication as to whether it is worth pursuing any further before you embark on those irradiation testing programs.

>>Tissa Illangsekare: So these related to your showing us pellets going to different chemical, upscaling problem moving from that scale to the how the whole system behaves. So that is within your research strategies or you are thinking?

>>Dave Goddard: In terms of the fuel materials there, that is very much looking at the behavior, as I say, in reactor. I think there is, there is a separate argument to say in addition to that we have to look at the storage and repository conditions because as you rightly point out, those conditions could be different for the fuel to behave in. There may be an assumption, whether it is true or not, if the fuel is good in reactor it ought to be able to survive a long time out of reactor. But that is an assumption and it needs to be underpinned with some data and at the moment we are lacking in data.

>>Tissa Illangsekare: The reason I ask -- the reason I this question I was in another board looking at the Fukushima data, so what happened in Fukushima is not something you anticipate in this condition that things went wrong and you know, so that's why my question, with the idea of thinking, my interest is like in my area of expertise is how the large environmental system responds to this type of thing so I think it is important to anticipate this type of possibilities in the future where this knowledge just, the real systems. Thank you.

>>Steven Becker: Steven Becker, Board member. I have a question for Dave Goddard, thank you for a nice talk, thank you also for following up on the earlier discussion during the meeting about communication and for discussing communication and stakeholder engagement in the UK context. From your experience either with accident tolerant fuels specifically or just more generally, what has been the biggest challenge in the communication and engagement efforts that have been undertaken in the UK? Tough question, but an interesting one, I think.

>>Dave Goddard: It is and I think one thing I would say in response to that is, I mean I'm a scientist and I like graphs and sometimes equations and things and --. The way I would communicate with the public possibly won't come across right because scientists aren't always the best communicators, sometimes there are good communicators in science, but sometimes we need to be filtered and one thing we've done on this program is we have employed someone who is a communication expert and who's done a

really great job of actually taking some of our stories and work and actually, I would say, try to translate it into a way that is more accessible for public. But I think it is a really important area in how we do this. We've tried a number of different things, videos, animations, that have been produced through the program, there's quite a lot of activity using social media as well so different forms of communication that have been used to get the message out about the program and the impacts of it. And so start a bit of a conversation with, with people who are, who are interested in the topic.

>>Steven Becker: Is that sort of collaboration between technical experts and communication specialists common in the UK program?

>>Dave Goddard: I wouldn't say generally common, I think it is something that we have learned through this program because it is a fairly well-funded program and we've had the ability to essentially employee somebody to help us with that part of the program. I wouldn't say it's generally done within the UK, but this is a, I like to think, you know a good example of how we are developing those sorts of communication strategies.

>>Steven Becker: So you found it to be a fruitful collaboration?

>>Dave Goddard: Absolutely, yeah.

>>Steven Becker: Thank you.

>>Paul Turinsky: This is for Dave. Has anyone done ballooning experiments at all? That's really the proof of the pudding. I mean we are talking about putting coatings on to protect against LOCA and during the ballooning event will probably be the challenge of the coating surviving at that point and even for unirradiated materials, you would think you would do that early on because that's what it is all about.

>>Dave Goddard: Yeah and that is the case, ballooning tests have been carried out, been fortunate we had some test on Oak Ridge to simulate LOCA and generally the response, the coating has an effect of increasing the burst temperature slightly and also slightly reducing the size of the burst opening. So there are some small benefits that occur from having what is relatively thin coating layer on the surface of the cladding tubes.

>>Paul Turinsky: Okay but you have water ingress into the tube once you get to a reflux stage.

>>Dave Goddard: Yes, yeah.

>>Paul Turinsky: Okay.

>>Dave Goddard: Coating the inside of the cladding tubes is more challenging.

>>Paul Turinsky: Yeah, yeah. And this is for David, can you give me a little feeling the depth of analysis that RWM does in making a decision whether the fuels acceptable or not? And what's the onus on fuel vendor supporting that?

>>David Hambley: It is the utility that has to provide the information to, what makes the proposal to for how they are going to do it. In my, my experience is largely based on oxide fuel, so mostly AGR and a little bit of LWR. I would say that for this established fuels the vendors probably have very little input

directly because most of the information will be held by the utility now because they have a wealth of irradiation data. In terms of depth, for middle stage of the assessment process goes into a recent amount of detail so they will look at what is the dissolution rate of this type of fuel. What's the evidence-base? Where does this fuel within it currently for instance there is a lot of evidence for LWR fuel but comparatively little for [indiscernible] reactor fuels, although it is the same type of material irradiated under very simple conditions. But RWM is undertaking work with do the leech tests on ATR fuel to demonstrate that. That behavior is similar to the LWR and similar enough that it can be considered part of that population. So they do get into a fair degree of detail in terms of understanding the performance of the parameters that effect the both the operational phase, transport and post-closure demonstration.

>>Paul Turinsky: Okay, do they, when they need help do they turn to you folks for doing that?

>>David Hambley: The, they will go to some of it we do, some of it other companies with experience in this type of work will do, sometimes been to over seas labs. The UK has not dopant disposability related research for fuel for about 30 years because we've been focused on, been focused on reprocessing more fuels but within the next week we expect to start our first set of leech trials on irradiated fuels looking at our own domestic fuels to begin with.

>>Paul Turinsky: Okay, thank you. I see Lee Peddicord has a question. I'm clicking on you Lee but it is not coming up.

>>Lee Peddicord: I'm technically challenged here. So couple of points I was really impressed with in your presentations. One is flexibility which I think is very, very good at the point you are at and the other is that you already have an awful lot on your plate to deal with for historical reasons and so on. You talked about the MAGNOX, the AGRs, but in a lot of ways you have incredible diversity, I think it is my impression in the UK, with your the history of your nuclear background. You know, it is geographic from Dounreay to Winfrith, the different kind of facilities you have had and so on. It kind of leads me to the notional impression that given all that you are going to be dealing with in terms of disposal now and the range of the things, the kinds of reactors you had, the kind of fuels, the kind of tests you carried out that ATFs might kind of just shrug your shoulders at that almost anything will come along now, you all probably have had to deal with something like it or even more bizarre. So my real question I guess is, given the history, given the technological diversity of the nuclear history in the UK, is that going to be helpful in informing the directions you might go in terms of the back-end in disposal now of what might be coming along, not only with ATF, you mentioned other advanced fuels and SMR, which in some ways are going to be, diverse as well.

>>David Hambley: Yes no doubt the experience helps. We've recently done some work um for advance modular reactor based on some fuel type that we have as experimental fuel so from the assessment to the disposability of the development and research fuel we've learned a certain amount. But the quantity of materials is very different from a research reactor, from a fleet program and that makes a material difference in the disposability assessment process. So for a small amount of material, you can dispose of it in ways that you could not conceive of doing for a large amount of material which is a significant proportion of the GDF. So I think, yes, we have learned a lot from, still learn a lot from the disposal of our experimental fuels but also coming to the understanding of the difference between experimental quantities and fleet quantities so that's, it is an interesting thing. And most of our experimental fuel was reprocessed so we only have relatively small amounts of bits and pieces around the country.

>>Lee Peddicord: Yeah, okay. Thank you.

>>Paul Turinsky: Any questions from staff at this time? Okay.
Thank you very much for your presentation David and Dave. I guess we will see you in a second on the panel at this point. So at this point I'm going to turnover my virtual podium to Jojo Lee who is going to be the moderator for the panel.

>>Jojo Lee: Hello everyone, I'm Jojo Lee, board staff. I want to thank all of our speakers again for their participation in our meeting these past two days, especially our speakers from Europe and the UK who are staying up late in their time zones to join us for the panel discussion.
Our panel discussion will focus on the potential impacts of advanced nuclear fuels, including ATFs on spent nuclear fuel, storage, transfer and disposal. Our panelists today are Stephen Caruso from KKG in Switzerland, Anders Sjoland from SKB in Sweden, David Hambley from the National Nuclear Laboratory in the UK, Aaron Totemeier from Lightbridge, John Wise from the US Nuclear Regulatory Commission, Dan Wachs from the Idaho National Laboratory and Sylvia Saltzstein from the Sandia National Laboratories. We will start the panel discussion some preplanned questions also printed on our agenda. Then we will go to the Board members for their questions and then there will also be an opportunity for the panelists to ask questions of one another. We ask that the panelists, if you are not speaking, please keep your mic muted using the mic button on the top left of your screen.
Now to start the panel discussion. I'm going to go in the order of the panelists just mentioned and ask each panelist to give a brief response to the following question. Please limit your response to two minutes.
Question: What do you believe are the maintaining-aways on the back-end implications of advanced nuclear fuels, including ATFs that were discussed in our two day meeting? Stefano?

>>Stefano Caruso: As I said main gain and main benefit on the back-end will be -- assistance and um integrity but always remembering that the accident, initially and still today as accident, so the second, the benefit of on the back end is byproduct and I hope we can achieve something that would be for sure benefit, as I said before in the transport, in the handling of the fuel, hopefully, also on the geological disposal issues, [inaudible] has to be proven.

>>Jojo Lee: Okay. Thank you. Next is Anders Sjoland?

>>Anders Sjoland: I tried to come up with a catch-phrase here, I heard catch-phrases are very popular in America so there is always a back-end to nuclear. That I think is really something for everybody to remember. And um and of course the background behind that is really that also the back-end has to be included in the complete analysis and not least cost analysis. And I think that in reality all countries is facing this issue that the back-end is very substantial part of the nuclear fuel cycle and also economically. So it makes great sense not to be surprised after eight years of running nuclear things that oh it is our back-end yes there is a back-end we know it very well, should be taken into account already from the beginning. There's always a back-end to nuclear. Thank you.

>>Jojo Lee: Thank you Anders. Next is David Hambley.

>>David Hambley: Yes I think for me what comes across is in the short-term the implications of the short-term ATFs are likely to be minimal in terms of mention to the back-end. We should be able to manage these with thought. I think we can now have the tools and the approaches that will allow us to say what is it about those fuels that we need to provide confidence in. We need to confirm our expectations and I think Sylvia's presentation in particular set out how we can go about doing that. I think there is an increasing awareness that fuel development needs to consider the back-end I think that's a timely thing. And I think the other thing that came across to me was that for countries that have less clarity on their disposition strategy and the practical implementation of it, that makes it harder to do that back-end work up front.

>>Jojo Lee: Thank you. Next is Aaron Totemeier.

>>Aaron Totemeier: Thank you Jojo. I would say a key take-away in regards to back-end is scope of the challenge before us with the number of different fuel designs being considered and the large amount of back-end R&D remaining to be performed identify and addressing right issues for the right fuels is a significant challenge that requires integrated approach and I think this meeting has done a good job at demonstrating that kind of whole of industry approach that's behind the current new term ATF fuels that were conceived in response to Fukushima. We've hear about the NRCs efforts to prepare for evaluating advance fuels, support for [inaudible] and of course variety of near term ATF technologies that are being tested by vendors and utilities both domestically and abroad today. I think

complicating that challenge of course is that it is impossible today to predict which of these fuel technologies will ultimately be deployed at commercial scale and it's a certainty that any fuels that are, initial versions of that will see modifications and optimizations as they are adopted more broadly across the industry. So it really makes a holistic and kind of technology inclusive approach to identifying and addressing these back-end issues to make sure we can adequately address management for whichever technologies the market decides have the biggest impact on the utilities bottom line.

>>Jojo Lee: Thank you for that. Next is John Wise.

>>John Wise: Good afternoon. I guess I would like to emphasize cooperation. We are really fortunate that we have so many people in the national and international community that are engaged and that we, you know, we have a good working relationship, so many of the people that we've heard about, heard from in the last day or two um we know each other because there is just been so much cooperation through all the activities through the IEAE activities that you heard us skip for activities come up a few times, the EPRI escape activities. All venues that allow everybody, you know, everybody to cooperate, share knowledge, give opportunities to get involved in research that's been key and it has been very positive development. You know, in my topic we emphasize the early engagement with our licensees to, you know, make sure we are prepared but you know, equally important, early engagement with all of the community including the international community because it's a, it is a big job and it's an expensive job and if we can share the load, all the better. So that's what I would like to emphasize.

>>Jojo Lee: Thank you for your response. Next is Dan Wachs.

>>Dan Wachs: There we go. Yeah I think the big take-away from a fuel developers point of view is that it's important to recognize that progress is moving very rapidly. We are largely through the development process and into the licensing phase for a lot of these technologies which means they are going to be in deployment before very long, in the next couple of years. So it is critical we prepare ourselves to respond to that and be ready. And also I think in the US where we are seeing a pairing of ATF technology with extension of burn-up into greater than 75 gigawatt days per ton, which is well beyond 62 we're using today. Also increasing enrichment that would go with that so that could have important impacts to the spent fuel community um both respect to maybe higher activity in specific fuel assemblies but fewer of those fuel assemblies in the long run so be prepared to manage that. I think as we look at what is ahead of us and some of the best transitions to support that we need to start focusing on the partnerships between the fuel development community and the spent fuel community to make sure that we are, as best as we can sharing information but also sharing materials in ways that we can collect the

informations that are relevant to those different users and those different environments. So I think this has been a useful exercise for myself and kind of recognizing some of the connective opportunity for that.

>>Jojo Lee: Thank you Dan. Next is Sylvia?

>>Sylvia Saltzstein: Hi and thank you for the opportunity. So the first thing I want to say is this extremely exciting to be able to see all of this new development and um so that's the first thing and I really appreciate this venue and other venues like John has said, to think about these new technologies and I appreciate the consideration of thinking about the back end. We in the back-end fully know that it's not the first concern, that the first concern is making sure the technology works, making sure it can be economically sustainable and viable and then other issues like the back-end and safeguards and security come in. Not that they are not important, but they don't matter if the technology doesn't work and they don't survive economically. So thank you for bringing us in at this early stage. And so we will, we will actively watch what is going on and what technologies make it and which don't make it and we will adjust the testing with the materials that we have and use our analytical tools to try and determine ahead of time where there may be concerns and we will communicate those to the broader community as we see them and have those discussions. And then we will sit back and wait to get some real material to test. But again we appreciate the discussion and the thought.

>>Jojo Lee: Thank you. Thank you for those responses, okay on to more panel questions.

Now for the next question I think David Hambley and Stefano Caruso could help us start the discussion. Question is for countries interested in ATF or other advanced fuel designs for their Light Water Reactors, what kind of R&D activities would help them understand the implication of such a change?

>>Stefano Caruso: Who'll start, David?

>>Jojo Lee: David, you are muted.

>>David Hambley: Okay um for me having dabbled in this for a bit now, I think the modeling that we have at the moment gives you a good idea of general conditions you are going to experience. When people are looking at qualifying ATF for use there is an opportunity there to do the research need to support the back-end. Demonstration of what you expect to happen. And if you can do that with material generated early on you can save yourself a lot of money I think on that. In terms of where to focus, there is lots and lots of work done on few behaviors and properties that react to temperatures obviously, our temperatures tend to be lower, time scales are longer, those are the things we need to concentrate on I think. Stefano?

>>Stefano Caruso: I agree with you, one major point also to benchmark or to validate the codes. We open a really new door and, therefore, we need a lot of data. Experimental data which are -- and we need cooperation concept back-

end I think there is a lot of research done. We can follow this and more fan of testing full system not only the cladding alone is a must, of course. But I like also to see the answer of the system together. For instance, the [indiscernible] test the [indiscernible] during the cladding of data is I think a bit, really real answer from the system, what is really need maybe is the fuel that has expedience [indiscernible]. For instance, or so we need ability to test the almost [audio cut out] -- makes with the stuff a bit more faster. We can [indiscernible] the line.

>>David Hambley: I think with some of the ideas we have a real chance to do, is it the same as, is it the same as UO2 fuel or sufficiently close that it sits within the population of what we already understand if you can demonstrate that with a small amount of data you can get a great degree of confidence but if you went through all the individual characterization test um you might make a much bigger work program than you need.

>>Stefano Caruso: Yes, I think so.

>>Jojo Lee: Thank you for that discussion. Would anyone else on the panel like to add anything to what's been said so far or Oak Ridge National Laboratory, or the Oak Ridge National Laboratory question?

>>John Wise: I will just build on what David just mentioned um, is it the same as and um I'm going to steal a little bit of Sylvia's thunder maybe, she emphasized that um they, we have been performing, you know, fuel research over the last few years and specifically Sylvia's work on the high burn-up demonstration cask and that infrastructure is there and that data set that Sylvia has been generating on the high burn-up data for standard fuels is a great way to compare the new fuels and so as Sylvia said yesterday um the infrastructure is ready and waiting for --

>>Jojo Lee: Sylvia, I'm try to go bring you live but your camera and mic, yes there we go.

>>Sylvia Saltzstein: Thanks John yeah and I agree with everything John just said. You know, the fuels that are similar to what we are testing were we're not that concerned with. The higher burn-ups we're not extremely concerned with. We think we can handle that. The um, you know, some of the things that are very different from that um we will have to come up with new ways to test; like the Silicon Carbide, if that proves to make it into the back-end inventory, we do need to look at how the ductility and the general mechanical robustness compared to the external loads that it may experience. And then also the TRISO we do have some experience with TRISO with [Port St. Reine]. I think the new TRISO designs are different and we have to keep our eyes on that and see where that goes. But, we're excited to keep our eyes on it and see where it goes. It is a wonderful opportunity for the whole industry.

>>Jojo Lee: Thank you, doesn't look like anybody else on the panel wants to add anything so I'm going to move on to the next question. The next question I

think Anders Sjoland and Sylvia Saltzstein could help us start the discussion.
And the question is, what opportunities do you see for international collaboration in planning for Spent Nuclear Fuel management of ATFs and advanced fuels?

>>Anders Sjoland: Do you want to start?

>>Sylvia Saltzstein: Sure I'll start, sorry I dropped my notes on the floor. Yeah so, you know, international collaboration is of course um, you know, what we really live for and we, you know, we're lucky here in the program um with the Department of Energy where all of our data is documented in reports and those are available for unlimited release to anyone in the world and um we hope they are used by everyone. And we would really like to have more collaborative research of any type to just add to the data that's out there and to add to the diversity of scientific and engineering thought in what we are doing and what we need to do to move this forward globally. Some of the specific things, you know, that we, you know, we really want to talk about is different countries have different burn-ups, different countries have different um different whole reactor history and burn-ups and so even if the research is similar to what we're doing, the basic conditions are different and understanding how that plays in to rod internal pressure and pellet swelling and hoop stress, that's and ultimately creep and hydride issues is all beneficial to the entire community.

>>Anders Sjoland: Okay, should I continue?

>>Jojo Lee: Please.

>>Anders Sjoland: Well I think representing a small country like Sweden, of course international collaboration has always been very, very, not only important but completely necessary and I think I myself has also been involved and also initiated a fair number of collaboration at least with the United States and we are very, very happy about that. These collaboration through Department of Energy to Sandia, Los Alamos, Oak Ridge, Pacific Northwest, et cetera. And, for instance, now resulting in the new safeguards technique that we think coming from Los Alamos think we will be implemented in our encapsulation plans, characterization system. So we are very excited about that. We also have run an international blind test on predicting DK heat, that's of course another thing that DK heat is very important as we said, at least economically. These new fuels of course will then be a bit different I think to calculate and particularly to calculate very accurately. I think that's another area of collaboration that will be very interesting. And of course our old card that we say all the time the dissolution rates, the dissolution rates, the dissolution rates. That's I think actually all types of repositories finally we come back to that issue because all repositories, in one way or the other, face the issue of water in a very, very long-term. So I think that's something we know how to, how to do, it’s damned expensive, it takes time. Yes I think we should

share costs and efforts on this. Yes there is real scope for even more collaboration. I have advanced this together with others of IEAE that show some of these recommendations some really to try to get some structure internationally to collaborate on this and another way there are really two in the world I think IEA and it is the United States and the United States can also I think play the same role and us of course historically, in many, we are very, very happy to follow your lead on many of these things and I think that most countries should chime in as best as they can.

>>Sylvia Saltzstein: Well and then I also, you know, would be remiss if we didn't think about the much bigger picture where Sweden, you've been very successful. Canada has been very successful, Finland is, you know, how do we site, how do we site a repository. How do we become successful because if we don't collaborate and not successful in this, you know, everything is sort of for naught.

>>Jojo Lee: Well thank you for that discussion. Would anyone else on the panel like to add anything?

Don't see any hands raised but I wanted to chime in and say an exercise like a blind study on decay heat, it's useful because what if you have um programmatic differences and then you also have some different results and how to resolve those, if you have some infrastructure there because a lot of countries are working on similar technologies right now, so it would be good to have a network, maybe do a round-robin those kinds of exercises to resolve any of these [inaudible].

>>Anders Sjoland: Yeah, I like blind test very much I think when working with particularly repository in claiming we can predict the behavior for millions of years. We are actually saying that we can blindly proceed ticket a lot of things so if we can't do that on much shorter time scale then it is not very comforting that we are trying to do. I love predictions. It is not easy but it is useful.

>>Jojo Lee: It does look like we have somebody with their hand raised I'm going to bring David Hambley to join the panel.

>>David Hambley: We’re all researchers so, yes, we like international collaboration, it is a good thing I think industry can help us by recognizing the international collaborations we do individual countries money by doing it. But we recognize there are commercial real issues for commercial companies in prepared to share data. But, hopefully, we can work together to get benefit for the industry from doing this sort of work. There is a big price to be gained um if we can trust each other.

>>Sylvia Saltzstein: Yeah. Well and there is a big price to be gained just with the intellectual diversity and to have the other thoughts and ideas and perceptions and backgrounds all discussing a similar issue.

>>David Hambley: Uh-huh, yeah.

>>Stefano Caruso: I totally agree, I just want to add the approach, the vendors also would the could share the data. Of course there is a competitor issue, there is a

commercial interest, but there is supporter and way to understand everybody in the same direction, we cannot, we cannot go further. And cost of transport of [indiscernible] embarrassing to -- not take over. So we need a coordinated approach and also in the past there were, [inaudible] was providing samples in many, many programs from projects, I think this is very good it should be kept on, on different levels.

>>David Hambley: I think also from our side I think our research labs need to recognize we can't do all the things we want to do and traditionally did. So we need, from our side, to help by having an efficient way of using our facilities for maximum.

>>Sylvia Saltzstein: Yeah and I would like to echo what Stefano said is, you know, the industry, the vendors, they need to participate as well and we can't -- it frustrates me personally when industry says you don't need to research that, we already know that. And I said well unless we see the data --

>>Stefano Caruso: It happens.

>>Sylvia Saltzstein: -- we can't just take your word for it. We share the data with us and save the government some money um you know, but that's the only way we can do it. We have to either reinvent the wheel and start over or have industry collaboration to share data.

>>Anders Sjoland: A special thing with back-end not so difficult in many ways, the temperatures are not so high, radiation level not so high as have a very, very interesting and very difficult to put into a lab and that's an accelerator for time. Sometimes of course there are appropriate accelerators but often there is not. And I think we have to have tremendous respect for time and also it seems that the time before final disposal is increasing and may perhaps get up to 100 or so years in some countries and that may happen in Sweden as well if don't know if we get a decision by our government. So I'm not speaking about everybody else, but so I mean we think we have to be very vigilant and respectful about this time, time very, very interesting and so difficult, time, and so easy to say that it is just looks okay at this time, must be okay forever but that's I think it is something in our -- we are kind of used to this long time and we speak with somebody on the street or even in the university if you speak about what are you doing and oh final disposal of nuclear fuel and we make an analysis of one million years and some issues actually go up to a billion years. Oh, but surely you can't do that, yes really we can do it, no, no, I don't believe you. I know you are speaking rubbish, that's politics. And I mean I think that's the normal way to look at and I think we would know what you are doing, but have to have a lot of respect.

>>Sylvia Saltzstein: I think that's a wonderful point, Anders, I think there is respect for time, one of the questions I got yesterday was why are your corrosion tests taking so long. Well if you accelerate the corrosion test you get wrong answers and um, you know, that's one answer. But then also, you know, the respect for time is also what we learned from Sweden, what we

learned from our friends in Canada is the citing process. It, you know, it takes a lot of time, a lot of patience, a lot of communication and we have to know that going in and we have to accept that and be respectful of that.

>>Jojo Lee: Well thank you for that discussion, it looks like we should move on to the remaining agenda topic. And for the next, the final question, I think John Wise could help us start the discussion.
The question is, what kind of changes in the regulations related to Spent Nuclear Fuel management need to be implemented to support the use of advanced nuclear fuels including ATF?

>>John Wise: Well in the short term, for what we consider the short term technologies, I guess the answer would be um, there are no changes to the regulations that need to be made to accommodate ATF. At least that was, you know, our determination for those technologies that are reasonably coming up in next five years was so for example, the chromium coated and the iron chromium aluminum. And those benefit because, you know, they are just so similar to the technologies that have already been in place. But having said that, you know, it is entirely appropriate to continually ask yourself that question, is it possible to the regulations are getting in the way of most effectively and safely, you know, storing, transporting and disposing spent fuel. And, you know, we have some examples in our past. In the United States, you know, we created um part 63 of the coat of federal regulations for disposal at Yucca Mountain and in that, that was a deliberate attempt to create a regulation that was performance-base and not prescriptive. Recognizing some of the limitations that the regulations part 60 the general disposal regulation, the problems that caused because of the over prescriptiveness and so ensuring that our regulations are written in a way that when new technologies come along um they don't, how do I say, go overboard in prescribing exactly how safety can be assured, you know, focusing in on optimizing the regulations to be sure the overall performance is being optimized as opposed to, you know, certain small prescriptive measures. And so, you know, we learn that lessen to an extent when we wrote part 63 for Yucca Mountain, and that's the kind of thinking we should be constantly revisiting as new technologies come forward. Like I said, in the near term didn't see any need to change a regulation, but that's not to say it won't be appropriate coming up.

>>Jojo Lee: Thank you for that. Would anyone else on the panel like to add anything?

>>Sylvia Saltzstein: I'll add and just add to what John said, I think I always like to sort of evoke the Hippocratic oath, first do no harm. And the current set of regulations help you think through that. And if we determine through that thought process a systematic thought process through PIRTs or whatever tool we want to do, changing things will first do no harm then let's proceed but um it has to be systematic and structured.

>>Jojo Lee: Okay. Anybody else? I don't see any more hands raised on the panel. Okay. I think, I think we better go on to Board member questions. Do any of the Board members have questions for the panel? Okay. Tissa, I'm trying to bring you live but you need to activate your, there you go.

>>Tissa Illangsekare: Thank you this is also a really good way to end the session there are a lot of interesting issues to the notes but I would make a confession I'm not a nuclear engineer, I'm a hydrologist and I'm going to [indiscernible] on the last system behavior. So I have been in the board for about four years now. I always enjoy the international meetings like this, especially to hear a lot of accents, including mine. So it was really nice to be part of this. So my first question is on collaboration. In some of the collaborations done in other areas in the DOE and things we have looked at modeling is one of the areas people have been sort of modeling. I asked some questions yesterday on the, on the full mechanics and how different foil configuration work with the flow and et cetera. So is there any possibilities for sharing um, first question are there any organized modeling efforts going on or people are just modeling themself or the opportunities for collaboration the respect on modeling and additional data sharing for example when somebody give us a model can the data by someone else can be used for validation, et cetera. It is more of a general question.

>>Jojo Lee: Any takers on the panel? Okay.

>>David Hambley: There are international benchmarks exercises that are, good to see Sylvia has chimed in on this because probably more active than we are on that. At the moment there is actually international thermal benchmark being organized by EPRI to benchmark modeling of thermal hydraulics inside the [indiscernible] storage canisters. Typically in relation to understanding what the uncertainties in the methods being used. But there are, other examples of international, big experiments are being used by modelers as test cases, yes.

>>Tissa Illangsekare: Also, you mentioned, Sylvia mentioned about the industry collaboration, is there anything going in industry where you have a re-collaborating or is it opened up for that type of collaboration, I'm following on Sylvia's comment that it can do more. This is an area I mean intellectual property can mean many things, but data itself, I do not call intellectual property, the data itself is very useful, useful in some ways to enhance collaboration with [indiscernible] more intellectual ideas and development. That's my point and comment.

>>Sylvia Saltzstein: So industry has been involved in the thermal model David mentioned and that's been a very large scale, blind round-robin and collaborative thermal modeling exercise and we also have extensive modeling going on to understand external loads that the fuel experiences through storage and transportation canister and then, as we need we will develop and build off of or validate other models for our spent fuel work. We're also doing modeling on the security side that we also further refining with data from

spent the fuel work, understanding respirable fractions during fuel failure and then also developing pretty extensive models, and industry has been very helpful here, in understanding corrosion, how corrosion, what are the important parameters for advancing or stopping corrosion, what are the doses to the community if we were to have a failed canister and so we have been working a lot to parameterize and build those models.

>>Tissa Illangsekare: Thank you.

>>Anders Sjoland: Could I comment on this too? Just saying that also we, I represent the industry you could SKB as actually industry company. And we have taken initiative from quite the number of modeling exercises international, the blind test on the DK power for instance is ongoing and being reported very soon. We have the task forces on modeling of the ground water in rocks, we have modeling of bentonite, task force on modeling of EBS, bentonite for instance, and have for many years. And, actually some more in addition to that. We've also taken part in some of those that Sylvia mentioned. So, yes that's very important and you do quite a lot I think. Thank you.

>>Jojo Lee: Lee, you have a question for panels.

>>Lee Peddicord: Yeah I wanted to come back to Anders with a couple of things. First of all, I think you've got a really good idea of coming up with what a buzz word or a catch phrase or something like that. That often works better than anything else in telling the story. So I want to build on that a little bit. I think your catch phrase needs work, okay. So Dan, Sylvia and I live in the Western part of the United States. We like the catch phrases that really says it all. So my suggestion to you is to change your catch phrase a little bit so it says, don't let these advance fuels come back to bite you on the back-end. Now I don't know if that works in Swedish, but down here in Texas we would know exactly what you are saying here, okay? I want to go back to the other points I made, favorite things as a teacher in your comments, both during your talk in the panel and that's when you said dissolution, dissolution, dissolution and you said about four or five times, six times and I finally caught on. But my question is the following, I think you might actually be on to something really good here. This is a hypothetical question maybe impossible to get to, but let me try this. That if one could come up with a dissolution parameter or rate that is so sufficiently long or slow or robust such that any place you put this in any environment for, let's pick a million years and there is no dissolution of a fuel, nothing else matters. Nothing else matters, we talk about the bentonite and talking about the host rock and talk about all these protections we have. No disillusion, so what. Would it be possible, hypothetically to come up with one parameter and if we could demonstrate that in our measurements, and as Sylvia points out, these are tough ones, with the modeling, no disillusion. You have answered the question, as we say answered the mail and that's really, that tells you

everything, that says it all and you can safely put the stuff in a repository and if there is no disillusion, that's it. It's good, it's safe.

>>Jojo Lee: Anders, you are muted. There we go.

>>Anders Sjoland: Sorry, got so excited with what you said that I forgot to put on the mute button. I think that's a wonderful idea, highlights another idea that I have for a long time that you can actually change perspective a little bit if you would begin by that what you are saying in developing new fuels then perhaps you actually could come up with a fuel type that has that or very nearly that property that you were speaking about, very, very, very low disillusion rate. But that I think would require you start with that as the aim. And then also try to make a good fuel out of it. I've never heard of anybody trying that, but I think it is a wonderful idea.

>>Lee Peddicord: Well, with that I'll quit that. I'll sign off.

>>Anders Sjoland: Maybe we can form a collaboration here.

>>Lee Peddicord: Let's do that, yep.

>>Anders Sjoland: For repeating things, I'm applying the pedagogic principle of the German, mathematician, David Hilbert who said, it is very easy to teach. [Inaudible] five times and then they learn.

>>Lee Peddicord: Well, with the Aggies, it's about [inaudible], so…thank you, thank you.

>>Jojo Lee: Now we have more board member questions, let's go with Paul first. Thank you.

>>Paul Turinsky: Lee, I have the material, it's called glass. It won't work very well in a reactor, but it retains the fission products minor aconites pretty well. [indiscernible] foreign silicate.

Okay, I'm very familiar with or fairly familiar with NEA and all their things, their programs about in reactors. They have the NEA data bank, collects all the experimental data, puts it in one place that the NEA member countries can address. They run numerous benchmarks and simulations and comparisons of different codes that are people are using, again always in the reactor. And they are doing it in thermal hydraulics, neutronics, fuel performance, is anything going on like that in NEA or anywhere else on the back-end issues? The silence mean nothing is going on?

>>Jojo Lee: There is some panelists trying to chime in.

>>David Hambley: I'm not quite sure what you meant. In one of the last European disillusion projects, it was an intention to pull together a summary of all the international measurements of instant release fraction from fuels. So that was a deliberate attempt to try to put our arms around 30 or 40 years' worth of work to produce a database that could then be kept up. But that's the only one I'm aware of, I must admit.

>>Paul Turinsky: Yeah I mean everything I have seen from NEA on back end is sort of very high level. You know, I don't read all the reports but it tends to be high level. And it would seem that there's an opportunity here to, you know, approach Bill [Magwood], the director and see if there is an opportunity

there. I'm not as convinced as some of you folks that have expressed there is all this international collaboration. What I saw was lots of duplication in presentations of people doing similar measurements. And there's only three or four fuel vendors out there. Not talking about two dozen companies, so everyone is using pretty much the same fuel, while some go five/six gigawatts days per metric ton higher, but at some sense that's a little bit in a noise on this. You have to account for it. I think there are opportunities out there for collaboration. The way NEA does it, not playing for anything, basically home basins of playing for things, they are just going to share. They are going to share it in such a way it is open to those members.

>>Sylvia Saltzstein: Paul, we know it is not exactly the same, we know what is being discharged, have this on the for non-commercial fuel in the United States. It is not the same but I think you are right that, you know, luckily also we, in our research, in our data we are not seeing terrible problems and that's of course a good thing, and so that takes a little pressure off of what you said were, we have what fuel vendors and we have slightly higher burn-up and different reactor conditions but it is not extremely different and we see our data showing that we have a nice margin of safety

>>Paul Turinsky: I wish this community would go and, you know, talk to NEA and see how they can get engaged like they have on the what's going on for all the analysis and data collected in reactors. Fuel tends to be much, much, more sensitive because of the fuel vendor but there may be opportunities there.

>>Jojo Lee: Okay I think in the interest of time we better open up questions between panelists. So do any of the panelists have any questions for other panelists? Just see, okay. Sorry. I think, there we go. Any questions amongst the panelists?

>>Sylvia Saltzstein: I think Bill Boyle has a question. Or maybe that was, yeah -- I see it in the chat.

>>William Boyle: So Paul Turinsky's question for decades countries have cooperated through the NEA for the back-end on a thermal chemical database. What is the solubility of this uranium mineral and this type water, what is the solubility of this other neptunium species and this different type of water, for decades have done it.

>>Jojo Lee: Any more questions among the panel --

>>Paul Turinsky: That's good to hear, I think other opportunities there also.

>>William Boyle: What was that?

>>Paul Turinsky: It's good to hear, I obviously didn't know that, Bill. Probably other opportunities and other areas on the back end. If they are not being pursued already.

>>William Boyle: There is a lot more cooperation, I just picked that one it is more cooperative where each country contributes, if you will, that there is all

kinds of other meetings, there's the Clay Club, the [Fault] Club, there is, yeah all kinds of back-end activities sponsored by NEA.

>>Paul Turinsky: Are there comparisons of predictive models?

>>William Boyle: There have been in the past, yes, yeah.

>>Paul Turinsky: Maybe advance fuels is another opportunity to revisit some of those items.

>>Jojo Lee: Any panelist to panelist questions remaining, John?

>>John Wise: I will pose something to Sylvia. We, you know, when we listen to DOEs initial presentation that kicked off this entire um meeting, you know, we have that chart that shows all those assemblies that are Lead Test Assemblies in reactors right now, has a really nice chart that shows ones going in, ones going out, just so much happening right now including stuff going out as we speak, you know. It will look continue to come out of the reactor of these Lead Test Assemblies over the next few years. How confident are you that you will get your hand that stuff? That that's my question to you. It is a test.

>>Sylvia Saltzstein: It's really, that's really a question for Bill Boyle but I know the discussions between Ned Larson and Bill McCaughey make me very confident that, I don't know exactly where they will go and exactly when, but I'm very confident the DOE will get them and they will test it for mechanical integrity and other properties that we might be concerned with. So, I'm personally not worried and everything is also always based on Congressional funding but this seems to be a strong bipartisan issue. And that combined with the desire for carbon free base load and I think that makes it -- this a, I think that reduce the risk in this not happening. Increases the chances that it will happen.

>>Jojo Lee: Any more panelists to panelists?

>>Sylvia Saltzstein: Bill Boyle may want to pop in on that one also, I don't know.

>>Jojo Lee: I don't see his hand raised. Go ahead David.

>>David Hambley: I have one question party prompted by Anders' dissolution, dissolution. And, for Aaron, really, it's the intention for the Lightbridge fuel that it will go for disposal, my thought really was that uranium metal is quite reactive material that behaves quite differently from UO2 in repository cases and situations and whether that had been thought about it.

>>Aaron Totemeier: Something David that we thought about and can't address at the moment until we get fuel samples for testing, might be an area where database in history or U10 Zirc family of fuels might be able to give us a little more information, what to expect in that regard. I will say that again the design of the Lightbridge metal fuel rod and the metallurgical bonding between the cladding and fuel, at least in reactor when there is a breach of the cladding that breach tends to seal up when the metallurgical bond is present. So again speaking way, way outside of the expertise that we have at the moment based on data, I would expect a similar situation, you know, in long-term storage but the presence of the metallurgical bond and

how it hold up over hundreds of years in long-term storage is something that we will have to look at in our development program.
If I can, Jojo, I would like to pose a question to John while I have the stage here. John, you mentioned in your talk um about the or your comments today about not being overly prescriptive with regulations based on lessons learned from that and I'm curious with regard to increased enrichment fuels and higher burn-up fuels been any discussion at the NRC that you are aware of about changing from enrichment based regulation rather to something more like a criticality based regulation. As you know, enrichment for one fuel form is entirely different animal when you change fuel forms whereas criticality is really the concern. Is that something that's been discussed or considered?

>>John Wise: Unfortunately I don't know. [LAUGHTER] I wish I could tell you. I am not aware of those discussions.

>>Aaron Totemeier: Okay, thank you.

>>Jojo Lee: Then, I think with the remaining time for the panel we should open it up to the board staff for any questions.

>>Jojo Lee: Once more does the board staff have any questions. I think I better turn it back to Paul.

>>Paul Turinsky: It is now time to hear the public comments that were submitted since yesterday and Brett Leslie is going to present them.

>>Bret Leslie: Hello. Thank you. Thank you Paul. About 20 questions, let me read through them. The first 18 are all by the same person so I will introduce who said the following 18 comments and then when it comes to a new comment I'll also indicate that. I will provide some context and I am Bret Leslie of the Board staff, these are comments that were submitted in the meeting. Early in the meeting Volker Goebel whose affiliation info@ing-goegoebel.com provided this first comment. As I said many more after that. His first comment is could it be that the Swiss GDF containers do not pass the under critical test? Could it be Swiss GDF idea is "undeep, wet, wet, wet and no gas type closure possible?" His next comment was around 12:30. Advanced nuclear fuel, ANF got a chrome cladding on the zircoloy pole tubes, also the density is a little bit higher and the enrichment too. Minimal changes in the fresh fuel sector, #Uranium #fresh, #fuel. DBHD takes ANF and good HLW containers. Next comment at 12:50 "Aging and dry storage is a good question." Next comment, 12:56, "why is cladding of fuel rods coming so late, is it applied by hot spraying on to prewarmed tubes." Now into the Swedish presentation at 1:00, Volker stated "SKB Sweden, environment pollution undeep, wet, wet, wet, no gas type closure possible. They did no geology search. Cited GDF near NPP. Granite is full of scarfs, wet, wet, wet. Sweden is facing a trail by EU Court, environment pollution plan." Next comment by Volker, "Shipping by ship is also recommended for NWMO in Canada." Next comment, "Super fuel ponds in Sweden, but GDF is not a fuel point. You

will never get a license for polluting the Baltic sea, we bring you to EU court, SKB." Another comment by Volker at 1:12, "you drill a shaft the water gets in, as soon as you have salt water in, you are illegal." The next comment by Volker I will need to spell out many terms. "Sweden got 7.4MRD.Euro for GDF. SBC drill tech for hard rock in pipeline at Herrenknecht. Find a new location further inland." Around 1:30, Volker gave the following comment, "as soon as you have 50 thousand liters of salt water per day in, you just built a shaft then your GDF is dead. It will happen. Find a location further inland, remote." At 1:34, "nobody ever proved that he is able to fill and SKAB3 container. Doing that you can never prove under criticality and GDF." Closer to 2:00, Volker said, "during the break, you can force me to join the video session to present capital BDHD within 15 minutes. All the files on desktop. Best regards by Volker, Goebel, GDF planner, DIPL.-ing.ARCH.Germany." His next comment, 30 seconds later, "engineer Goebel sitting in video light now." At 2:25 during the UK presentation, "Dear UK, only a geology can do nuclear repository. It is not about a decision of village mayor." At 2:26, "I hope you find the money to bring Hinckley.C to net." Close to 3:00, Volker indicated "550MO. pounds in government help funds. You can be happy in the UK." At 2:56 "do you know what the spent fuel of BN800 looks like after 156 days? Did you see the quote Kilos"?" And finally Volker's last comment and again his affiliation INFO@ ing-goebel.com. "Dear US-NWTRB, thanks for making your meeting public. I followed it, I'm off for family now. Hope that you invite engineer Goebel as speaker next time. Best regards from Germany, Volker Goebel, GDF planner, DBHD."

We have two other comments that came in late this afternoon and they are from Dr. Sandy Greer, she's unaffiliated. And her first comment was "I appreciate the final panelist recognizing more vocally the importance of attention to the back-end, ie: long-term disposal. But I request, please more research be done on potential even inevitable impact on national environment and secondly to do more research on options to deep geological repositories. I make this request given a bit of my research continuing from 2014 and learning that the international commission on radiological protection, ICRP, acknowledging that research was only in the early years of understanding the impacts on multiple levels of organisms as well sediment water and also in interactions. In other words highly complex yet imperative on life support system, thank you."

Sandy Greer at 3:34 unaffiliated providing the last public comment, "I regret to contradict about reference to Canada is successful because the siting process by the nuclear waste management organ organization, NWMO is not completed. And there is a large and public outcry because both regions still being considered to stop the proposed deep geologic repositories."

Let me check the inbox one more time. Paul, that is the end of the public comments.

>>Paul Turinsky: That brings us to the conclusion of the meeting. Let me take this opportunity to thank the folks who made this meeting possible. First, recognizing all our speakers for participating in this meeting. I know it takes preparation time. For some of you it is late in the evening. Really do appreciate your participation. To the Department of Energy supporting the Board through this -- making this meeting possible. To our technical staff Jason, John and others who provided the technical capability to do that. And then, finally to two staff members who really pulled this meeting together. That being Jojo Lee and Dan Ogg. My thanks to them for making this possible.

I hope it was informative for everyone. It is certainly was for me. And it was also enjoyable which is nice to be informed and enjoyed at the same time.

So that concludes the spring meeting of the Nuclear Waste Technical Review Board.