COMMISSIONER: Welcome back to a discussion of topic 16, High Level Waste Storage and Disposal and I certainly welcome Dr Felix Altofer from the Federal Nuclear Safety Inspectorate of Switzerland. Dr Altofer thank you very much for joining us your time this morning.

DR ALTOFER: Good afternoon.

MR JACOBI: ENSI the Federal Nuclear Safety Inspectorate is the national regulatory body responsible for the nuclear safety and security of Swiss nuclear facilities. Dr Felix Altofer commenced work with ENSI in 2002, where he has held several roles, including the head of the deep geological repositories and safety analysis section and directorate for waste management division. In 2010, Dr Altofer became a member of ENSI's executive board and in 2012 he was nominated director of staff of the legal affairs international affairs and communications sections. Dr Altofer studied physics before obtaining his doctorate at the Laboratory for Neutron Scattering at the Swiss Federal Institute of Technology in Zurich in 1994 and the Commission calls Dr Felix Altofer.

COMMISSIONER: Dr Altofer, if I might start, can you just briefly work through the functions of the regulator in Switzerland in relation to used fuel disposal?

DR ALTOFER: Yes. ENSI is (indistinct) responsible for supervision of all nuclear facilities and with respect to the fuel disposal or (indistinct) fuel. We're responsible to actually make the safety assessment of the project development (indistinct) by the implement (indistinct) in Switzerland. So what they do in (indistinct) approach, each step they have to (indistinct) to provide documentation on case on safety assessment and our job is to independently review that, make sure that the processes are (indistinct) and to make sure that the (indistinct) guidelines and the protection for the public is guaranteed.

COMMISSIONER: Could I just pick up that theme of independence? Could you explain to the Commission how ENSI is independent?

DR ALTOFER: Yes. They (indistinct) the ENSI Act, which sets up ENSI as an independent regulator and that means it's job to make these reviews are done in-house by ENSI itself. There's no direct government influence on ENSI decisions, it's (indistinct) ENSI to make the review process independently and the finance – is financed by fees paid by the operator of nuclear power plant, so there is no parliamentary (indistinct) because it's financed through up to 95 per cent through fees. And that allows us, again, to independent from parliament to – to have our staff, to build up necessary know how within ENSI to actually come up with our decisions.

COMMISSIONER: All right. If I take that to the next logical step, when you make a decision, how do you report that? Where is that reported to and what's the process that you use there?

DR ALTOFER: Well, the process now for setting up geological repository in Switzerland is now (indistinct) we are currently in the site selection process. Again, that's a (indistinct) approach. Initially, all of Switzerland was considered but whether it's feasible to build a repository and (indistinct) process of narrowing down the sites and each process, the implementing (indistinct) has to provide documentation, that our requirements are fulfilled. And we review that and then make a recommendation to the Department of Energy, whether what the implementor has proposed is safe. Whether we can support the selection the implementor has made. If so, then we (indistinct) Department of Energy that goes off to central government and government makes a decision based on all our recommendation, whether one can proceed with the site selection process. That's how the system works. So we make (indistinct) only (indistinct) makes the safety review in depth and our recommendation goes direct to the – in to the decision by federal government.

MR JACOBI: Could I just pick up from there, how transparent is the communication of your recommendation to government, to the public?

DR ALTOFER: This is completely open, I think all (indistinct) actually the whole process is completely open. All documents that the implementor presents to us is available on the internet, everything and our documents are also completely open as are all our review documents are – these are on our website, is provided to the general public and in Switzerland we also have the Freedom of Information Act, so even if the additional documentation – so let's say we are doing a safety assessment with (indistinct) whatever an assessment of the geochemical data of the – they provide us, that is documented in-house and (indistinct) since this is very specific (indistinct) interest to the general public but as a citizen you can demand to see that document. So you apply to us and it will be given to you. So the whole thing is completely (indistinct) open. I think it's a huge advantage also to the regulator because it's – it builds up confidence in the whole process. We are very much in support of that and we actually encourage all – also other bodies. We try to produce our documents as much as we can, so that it is (indistinct) to the general public.

MR JACOBI: I want to come in a moment to the particular disposal concept that has been explored but I want to come first of all to the source of the legal requirements that are required to be followed and that you as a regulator will be required to implement. And I am just interested, could you give us a bit of an idea about where – where are the source of those obligations with respect to geological disposal?

DR ALTOFER: Well, in nineties, the government set up an expert body to discuss all options of disposal and they made a very thorough job and discussed all options. The surface or near surface or deep geological disposal and they recommended – come up with (indistinct) all nuclear waste we dispose it in geological repository. And they recommend that government (indistinct) actually put that in to law and the Swiss law is in regard to the – the safe disposal of nuclear waste quite detailed. The law and the arguments that are actually (indistinct) to the law. So it is a legal requirement you have geological repository, it's the legal requirement that you have multi-barrier system. That means the waste containers, the (indistinct) currently is considered or the state of geological situation is almost a requirement by law. So whenever the implementor actually goes – looks at the Swiss map – geological map where regions are that might be feasible for hosting a repository, that's already the basic guidelines are already written in the law. And that makes the – I think it's also (indistinct) that also to the fact to the general public since it's in the law, it's well thought of, that the solution of the geological repository is – is the majority actually accepts that. That is the best and safest way because of the long timescales to actually go that route.

MR JACOBI: And are the - - -

DR ALTOFER: Although - - -

MR JACOBI: Are the safety case concepts also embodied in the law? That is - - -

DR ALTOFER: Well, some – some of the basic principles, say the multi-barrier system for example is in the law (indistinct) not – it's not very detailed, the (indistinct) the specific guidelines of course have to be spelled out by the regulator but the very basic concepts are already in the law.

MR JACOBI: In terms of there being a target with respect to long term safety, is that implemented and specified with respect to the target limits that need to be met?

DR ALTOFER: No, I think – well, that is something the regulator (indistinct) specify. For example the protection goal we have – we have now in Switzerland, in accordance with international recommendations by the IAEA, a limit of .1 millisievert per year just to give – give you an idea what that means, the average exposure in Switzerland is (indistinct) four to five millisievert per year, so (indistinct) exposure through the geological repository must be lower than say just a tiny (indistinct) .1 millisievert. So that is actually the protection goal and I think the IAEA recommend .3, so we're back (indistinct) lower than that. (indistinct) make sure that there is no (indistinct) influence on the general public.

MR JACOBI: Yes. Stepping away from the legislation of the ordinance, how did you go about developing the safety case requirements? That is including the requirement for .1 millisieverts per year?

DR ALTOFER: Well, the thing when we did that, I think there's a lot of work been done internationally and also the IAEA made – has documentation with the requirements set in, there are some safety guides that the IAEA published. What approach we have, we set protection goals because the basic idea of the Swiss law is that the implementor (indistinct) case has to develop project and the regulator is simply to review it to make sure that the goals are met. How – details how specifically you will achieve these goals, that is up to the implementor. There are some basic elements he has to actually follow up, that means it has to be in a stable geological situation, it has to be multi-barrier and so on but the detail, that's really up to them and he has to prove – he has to show or to demonstrate to the regulator that the solution, the implementor develop is safe. So that – that – these are the rules.

MR JACOBI: I want to come in a minute to dealing with the review work of the safety case that ENSI's undertaken but I think it might help for the purposes of where we're about to go, to perhaps get a brief update of the current status of the development of a geological facility in your country. Perhaps if you can give us that first and we will come in a moment to dealing with how the safety case is being assessed by ENSI.

DR ALTOFER: I think it might be helpful to show slide number 1. What you see here is just ENSI is around - the whole organisation actually comprises 150 staff. You see here the (indistinct) waste management division and there are four sections in it. You see (indistinct) disposal, geology disposal analysis (indistinct) We've got roughly 10 people full-time in sections geology and the other section disposal analysis who do - they mainly go over safety assessments. You see already you've got two component (indistinct) deep geological disposal you need a thorough knowledge of the geological aspects. That's one section who actually independently assesses that. ENSI has this goal of .1 millisievert. You have to model transport of radioactive substances from the repository through the geological waste, through the biosphere, and that is being done in the disposal analysis section. To implement, you have to demonstrate that.

The status of the project: I think if we go to slide number 2, we are in the middle of the site evaluation process and you see how that's the general thing done on this slide number 2 because we've got these four criteria group. If you go with Switzerland (indistinct) science you have to look at: the properties of the host rock, that's group 1; the long-term stability, group 2; the reliability of the geological findings, group 3; and also, as important, the engineering

suitability, whether you could actually build the repository.

If you go to look at the criteria side on the right side, if you go for a suitable host rock, so the extension of the rock has to be big enough to host this repository, then the next thing, the hydraulic barrier effect, it is ease of transport. I mean you can't guarantee if you build a good container that the whole radioactive substances remain in the repository over these extended time periods. In Switzerland, time periods where these safety assessments are being done is a million years for high level waste. You will have corrosion processes because of the chemistry - 600 metres deep. But these are very, very slow processes. But, nevertheless, if you wait long enough there will be a certain limited amount of (indistinct) radioactive substances.

We have to check that this trap is unable to transport radionuclide material - is very small indeed. That's what we have to make sure of to protect the general public. If you go to the long-term stability, you have to look at the rock properties, the stability of the site. So if you have - you see our situation in Switzerland, we are a rather mountainous country. Going south you have the alps, north you have the Jura Mountains. The country itself is very small, 300 by 200 kilometres. So it's a tiny place compared to Australia. The larger part of the country is not suitable because of the mountainous regions. So we do have some flat areas where the geology is rather undisturbed but we have to make sure that this is actually the case by drilling and by seismic investigations.

By the way, what you also see listed on the point 2.4, I just want to point it out - conflicts of use. I mean if you have coal or oil on your repository, you won't like to go there because future generations will drill and will want to explore coal and oil.

MR JACOBI: Dr Altofer, can I just pause you there. With respect to the slide that we're currently looking at, am I right in understanding that that summarises the effect at a high level of the regulatory guidelines, the things that must be assessed in conducting a site evaluation?

DR ALTOFER: I didn't get that one just because of the audio.

MR JACOBI: Sorry. Coming back to the slide that we're looking at, am I right in understanding that what that slide shows us is at a very high level what is required to be considered by the regulatory guideline?

DR ALTOFER: Yes. You see, what we are looking at is the safety or the limited exposure of the public to radioactive substances is actually guaranteed because it's like a system: if there's a lot of (indistinct) you need to have good containers to actually encapsulate these radioactive substances for a long, long

time. We made a requirement that our containers for high level waste must be proven that they're completely tight, remain intact for at least a thousand years, simply because in the first thousand years the radioactivity in these containers actually drops considerably and we want to have a complete encapsulation or an isolation of the radioactive substances. For longer time periods you can't guarantee that because of the chemicals in there.

So we have a whole set of requirements - high level waste. But since a repository interactions of the - say, for example, the container material with the buffer material or the buffer material with the host rock. There's always chemistry involved and we specifically did not come up with very detailed requirements because if the regulator does that, he controls the project now and he shouldn't do that just from the governance issue. We should leave that the implementor and then the regulator simply spells out the (indistinct) of important criteria and checks whether they've been met. That's why we (indistinct) to give opportunity for the implementor to develop its project.

MR JACOBI: And in terms of the current status of the Swiss project, am I right in understanding that you've moved beyond the development of the specific barrier system and you're now at the process of evaluating where that might be able to be sited and assessing it in its particular site characteristics? Is that right?

DR ALTOFER: That's right. I think we know that we've got the site selection process, that consists of three stages. Stage 1 was just to point out where our researchers said where you could build to fulfil the basic criteria and the requirements. Now we're in stage 2. Now we are (indistinct) That was approved by us and also by the Swiss government. We've got six regions suitable for low level waste materials and three regions for high level waste. In this current stage we are now doing the review work. I think we will publish our review next year. They have to now narrow down to at least two sites when they perform additional investigations. Then in the next phase we will be starting in 2019.

Then they will study the remaining regions for high level waste with additional geological investigations. They will have I guess in the order of seven to 10 bore holes to actually get specific local data for these regions. Simply the basic idea in the site selection process is actually first see whether the region is potentially feasible and then narrow down which are the better suited and then you make a thorough investigation.

By the way, if the whole process ends up with a proposal to be implemented that they want to site at a certain site, that has to be reviewed by us, it has to be approved by government, by both chambers of parliament, and there's also a possibility of national referendum on it. If it passes all that, we're not at the

end of the story. Then they have to go down till we make a rock (indistinct) I'd say at 600 metres deep and again prove that the properties needed to build a safe repository are actually there where they plan to build the repository. So it's a stepwise approach and I think stepwise approach has a huge advantage to - first of all, it's adaptable because any new knowledge coming in, you can adapt. Also, the (indistinct) implemented under that would be designed to actually improve the safety of the project.

MR JACOBI: Can I pick up on part of your answer there. You spoke of ENSI engaging in review and I wanted to pick up the aspect where you engage in technical review. What position is ENSI in in terms of being able to reanalyse the work that's done by the proponent?

DR ALTOFER: Okay. What we have is, we have our own experts that support us in those areas where we don't have the core confidence or knowledge in-house, but we have, for example, the modelling aspects. What we do in-house is the complete modelling of the rate of the transport, the complete modelling of transport of gas that's produced by corrosion processes. We do the geochemical analysis in-house for review. We are using an external expert in certain aspects of geological characterisation of certain geological layers, strata. So not the host rock, but on top of the host rock there are other geological layers. There are some independent experts who have a vast knowledge on that, so we use these external experts.

What we do is, the main points are done in-house. We are qualified people with an academic background; most are trained either in geology and we've got a lot of chemists and physicists and engineers who have done - well, actually if you look at the structure of ENSI what we do have is we have a lot of experienced people. Normally if they pass the steps of the academia, have some experience in their jobs and when they're 35 and 40, then that's the time when we hire them. So you need a lot of experience on the regulator side to actually do the review process properly.

So the correlations after modelling the geology is done in-house. That's why we have these two sections, and then it's like reviewing a scientific paper. I mean, every claim (indistinct) we measured the geophysical constant, for example, how strongly certain material absorbs radioactive material, then we go back. Where does this data come from? Who measured it? Was it published in a peer-reviewed journal? What is the quality of the data? Is it comparable with data, for example, of other projects like the French project which is also in clay? Is it comparable? Does it make sense?

So this is the typical review process we do, and you go (indistinct) everything, then in each of these stages of the (indistinct) process (indistinct) demonstrates points they have to make and they make a safety case. They have line of

arguments and we prove whether these arguments are actually based on scientific data or whether (indistinct) it's a sound argument. That's actually what we do.

MR JACOBI: To what extent has the Swiss program been the subject of other review? We read some material in terms of the NEA looking at the proponents work. Has that assisted ENSI in any way?

DR ALTOFER: Well, any radio marker (indistinct) we were there when his NEA expert, international expert, came and asked Nagra on their documentation. We sat there as an observer. It was an open process. We actually were very much in favour of that because we are very interested in other experts' opinion. We were more or less - actually majority of the main points were in complete agreement with the international experts, but we think and we actually (indistinct) a lot with international experts that it helpful to the project to see more than one opinion.

As an organisation, we try to actually always - whenever we go to the next step, to that review process with an open mind, but you know how it is if you're 10, 15, 20 years in business. There is always (indistinct) actually you unconsciously limit your point. If he was a regulator and we really actively want to (indistinct) bringing in young people and thermal experts, see if they can challenge (indistinct)

MR JACOBI: I just want to move on from that to deal with the safety case analysis that's been undertaken and the extent to which - in some discussions yesterday, we've been discussing the baseline scenario and then also the sorts of range of future scenarios that are incorporated. We're interested in the range of future scenarios that have been incorporated into the safety case work that's been done for Switzerland.

DR ALTOFER: Yes. In the Swiss case, we have a basis scenario. Simply, our basis scenario is actually simply to increase the impact on the general public that we (indistinct) standard scenario that got a farming community there and all the water they use and all the vegetables they eat and all the meat they eat is grown locally, has access from water (indistinct) the radioactive substance is where they enter the biosphere (indistinct) somewhere in (indistinct) whatever, and the basic assessment is people there eat meat, vegetable, eggs, whatever, but if everything is locally grown and everything is actually watered with the water that actually has a connection or is being fed by the repository, and that is a standard case.

You may say, "Well, that's rather unrealistic in modern times," but the thing is simply, you know, that's (indistinct) in order to protect the general public you need to conserve the consumption. That's to conserve the consumption that

they feed themselves from locally grown products (indistinct) do is you have a huge road (indistinct) in Switzerland of course, glaciation, that you have to go - and from the Alps we observed that it was, I think, in northern north Europe.

So every 150,000 to 200,000 years there's a period of glaciation in northern Europe and what it does in the Alps especially is they dig up the earth. They can go a third (indistinct) beneath ground several hundreds of metres and of course due to (indistinct) you have, you know where these glaciers normally go through in Switzerland and these regions are in site selection process excluded because you know glaciers have been (indistinct) area, so it's not suited for (indistinct) so you go to areas where that has not been observed. That's something.

But the other thing is also, for example, a drier climate, because if you have a dry climate and you use water to water your (indistinct) and so on from a well where (indistinct) material comes in, that (indistinct) actually increase your dose because you tend to - because on a normal - we are in a temperate zone here. You would think due to the rainfall which is not radioactive, you water down any amount, that range of material would actually (indistinct) so if we have a drier climate that could increase the dose.

So we look at that as well, and of course a wetter climate as well, because in wet climates erosion processes are faster. That's the other thing: if you bury your waste, say, 600 metres down and you observe the erosion rate at the top. Currently in Switzerland, over a million years the top 100 metres will be eroded away. So after a million years the whole repository from 600 metres actually is up to 500 metres below ground, simply because erosion processes are taking place.

Now, if you make (indistinct) first of all, you have to check if the erosion rate - you think, is it really right, and too, climate change is actually increased the erosion rate. So that's what the scenario is about. Since you really don't know what the specific development over a million years will be, you simply have to make the scenarios as broad as possible so that the real development will be included in that scenario.

MR JACOBI: In terms of the scenarios you've spoken about, glaciation, climate and erosion, are they specified in a legal instrument that's issued by ENSI to the proponent as to what they're required to address?

DR ALTOFER: Correct. That's in the guideline. We have a million years for high-level waste that has to be considered. Also the climate spectrum has to be considered. We have an additional protection. So if there's a glaciation we don't have any humans left in (indistinct) because the glacier is there. Nevertheless, the Swiss law says you have to protect the humans and the

environment (indistinct) despite the fact there are no humans around, the release of radioactive materials in the environment has to be so low in order not to endanger the remaining animals that still actually live there, but that's what they have and – one has to keep in mind that the IAEA has collected, as different scenarios it has to use in safety cases international and internationally – and there is (indistinct) so that the implementor worldwide can check that, double check that, confirm their scenarios for this would (indistinct) the IAEA simply to make sure that nothing gets overlooked, or (indistinct) That's also useful for us but you made – I mean, safety assessments have been done for many decades now and it's now a process that actually gets more and more standardised because it has been developed, you know what scenarios are important, they – in – in central Europe and that means that the confidence in – in that process, how to do safety assessment actually increases because it has control of several (indistinct) in Europe that it can be done thoroughly and in a safe way for general public. But the other thing is (indistinct) example, shows we have got now (indistinct) currently building a repository (indistinct) so there in Europe, the most advanced country, so – and they have done also their safety assessment, so it is – it is becoming more and more sound and also reliable (indistinct)

MR JACOBI: What is the requirement with respect, within those – what I understand are guidelines with respect to the scientific justification that's advanced for the modelling of the – those scenarios? That is, thinking about the failure of containers, thinking about corrosion, considering climatic models. What is the specification with respect to the science?

DR ALTOFER: I mean maybe it's useful to show slide number 3 in that case because it's just a sketch of the (indistinct) might be useful to explain that. What you see here, the surface – green surface, you've got a facility on top and shafts (indistinct) to access the repository in (indistinct) case around 600 metres deep, where the waste are deposited. Now if you look at this sketch, you will notice that there are a lot – lot of processes that have to be understood. Say from the safety perspective, you have conventional safety. This repository will be open for several decades. That means you have check whether it can be construction, whether it can be maintained over several decades. You have to consider (indistinct) worker safety and all that, so that is the basic – the conventional aspect of safety. But this alone, if you have a – whether it's a ramp or whether it's a shaft that goes through several layers of rock, is different chemical properties.

You have to understand that at the interface that can have no – that is constructed in stable (indistinct) You have to think about external influences, say what happens if there's a flooding on top of it. Thus, how do you prevent water is rushing down to the (indistinct) the waste are and so on. So we've got the whole prevention safety aspect. Then on the nuclear side, if you – you

have to bring in the nuclear waste on the repository 600 metres deep. You have to demonstrate that it's feasible, that it's safe for the workers. Then you have to demonstrate that you can backfill it properly, that the isolation properties, you have stated in your safety case can actually be done in practice. You have to demonstrate in the Swiss case that you can also retrieve it and in Swiss case, before you actually deposit the waste, you have to (indistinct) the depth of 600 metres, you have to deposit it on (indistinct) first in a separate part of the repository and then you have to demonstrate that you can also retrieve it. Because if something goes wrong, you have to make sure that you're able to bring these wastes back. That's one issue. Then if you bring it, so you have to go down your containers to the repository level, you have to deposit it down in – in the (indistinct) You have backfilled it. And in all – if you think about it, so you have to meet (indistinct) understanding, what is the interaction of the backfill (indistinct) where the containers (indistinct) the host rock, if you have – you have to seal it off at a certain point.

Do these seals work? Are they mechanically stable? What happens to the repository if you – if the geology moves, if you have say a sheer on it, are the containers stable enough, over 1,000 years? And so we have a lot of – lot of safety aspects you have to understand. What we do in (indistinct) is do we have an understanding of the main safety processes? Do we know all of them that are relevant? Never know – there's no proof that you know all of the processes but if you think long enough and compare with (indistinct) it's the collections of processes you consider, are they relevant for safety? Is your (indistinct) can you back it up with data? So that's how we proceed with the scientific method. But we see just from the sketch, there are several areas, it's not just the waste down there, it's also the operational, it's worker safety that also goes in to it and – and also that you can seal it off and that the seals remain stable for a long, long period.

And you won't do that – you won't go there, construct the whole thing and (indistinct) some experiments down there. What currently being done in Switzerland – Switzerland (indistinct) has two rock laboratories, one in (indistinct) rock, one in clay rock that (indistinct) experiment. Now also put (indistinct) experiment where (indistinct) big container in the (indistinct) there's a (indistinct) western part of the country where the (indistinct) tested with the (indistinct) clay model and his experiment run or will run for decades. That's (indistinct) experiments that happen in (indistinct) 18 years and after there was a – right now a (indistinct) field experiment being run in – at the crystalline rock site in Swiss Alps, that he made (indistinct) test backfill. What he did is they had (indistinct) there and the heater element that actually (indistinct) plus the heat (indistinct) stands in for – don't have (indistinct) produce the heat by heater element, then you see what is the influence on the (indistinct) After 18 years (indistinct) open it up, have a look at the – at the (indistinct) what are the properties of the new (indistinct) Will you see some

unexpected behaviour and so on? So in order to just prepare for actually construction, operating (indistinct) this repository, you need (indistinct) first then test all these things, just to get more confidence and not only on the regulator side (indistinct) also on the implementor side, that things that they are going to develop in (indistinct) as a system (indistinct)

MR JACOBI: Can I pick up in terms of the expectations of the timeframes over which particular states of affairs can be demonstrated. Over what sort of timeframes do the requirements under Swiss law are they required to be considered and addressed?

DR ALTOFER: Okay. We have – we have to – the thing is (indistinct) materials if you have uranium, spent fuel, that uranium has a half-life of 4.5 (indistinct) four billion years. That means spent fuel will remain radioactive forever, simply due to its very nature, which is not very surprising because you have got uranium all over the world in – in small doses. But on this, you have take the population in the environment and these (indistinct) that they (indistinct) for radioactivity actually decreases in the first 1,000 to 10,000 years very fast to a certain level. It will level off after – if you wait several hundred thousand years, radioactivity will remain very much the same due to the fact that we have a lot of uranium to (indistinct) which has this extremely long half-life. So – but since there are uranium mines worldwide which do not pose a real problem, if there – if they are buried and isolated from the biosphere. With the time period where you do (indistinct) safety of (indistinct) assessments have to be long enough to actually let the radioactive – radioactivity come down considerably and also it has to be short enough so that you can make an assessment. If you look at the (indistinct) in Switzerland with the (indistinct) with the Alps and the Jura Mountains, they are still active. (indistinct) they cannot make protection what will happen 10 million years or a hundred million years or a hundred billion years. There's absolutely no sense to make that. So you have to compromise. The time period for high level waste we have up to a million years. It's a good compromise because after that, after say several hundred thousand year, half a million years, the radioactivity is a lot more less constant. I show the calculation we have on slide 4, which might be helpful in this respect. These are calculations we made.

MR JACOBI: Sorry, can I just interrupt there. Are they made by the implementor or by ENSI?

DR ALTOFER: Pardon?

MR JACOBI: Sorry, the graph that we're looking at, you've spoken that they were your calculations. They were in fact made by ENSI and not by Nagra.

DR ALTOFER: These are our calculations we made. We have our own set of

codes. We have different codes than Nagra uses. These are completely independently done by us in-house. There are no external experts, it's just what we do. Of course the codes we are using are verified and tested so that the results they produce are correct but what you see on this graph here - I have to apologise, it's made for the general public and it's double logarithmic. It's not only logarithmic in time but it's always a factor of 10. So on the left side it starts with 100 years, 1000 years, 10,000 years, 100,000 years and it ends up 10 million years. Also, doses of millisievert per year is also logarithmic. What you see here is this dotted line, the protection goal of 0.1 millisievert per year. Again, the background exposure (indistinct) Switzerland of four is not even on this graph. It would be higher. Because this graph at ends at 1 millisievert.

So it's just a tiny amount. It's fortieth or fiftieth part of the average exposure we have. But what we see here, if you do the calculations - so the protection goal is 0.1 but the doses you get are a factor of 1000, lower than the protection goal. You'll see another thing, the maximum is reached not for a billion years. What that tells us is that the transport - first of all (indistinct) in these calculations show only a very tiny amount of radioactive material actually reaches the biosphere and at very, very long time scale. That's what the graph shows.

That's why we said if you look a the system behaviour, you must not restrict yourself to a thousand or 10,000 years because you will not see anything. It's reasonable (indistinct) point of view and from a regulatory point of view actually to extend that (indistinct) It is somewhere between a hundred thousand million years.

MR JACOBI: Could I just pick up, Dr Altofer, just a question of interpretation, I think we see a dotted line on the graph on the right which I think shows - am I right in understanding that's the total of all radionuclides?

DR ALTOFER: Yes, right.

MR JACOBI: And am I right in understanding that when it reaches its peak, which I think is at about a hundred thousand years, we see it at about one-thousandth of the regulatory limit. Is that right?

DR ALTOFER: Yes, that's correct.

MR JACOBI: I'm just interested in understanding, in terms of a graph like that, in terms of what's the implication of that - and I assume is that on the baseline scenario or expected scenario?

DR ALTOFER: This is the baseline scenario. The thing is, of course in our review process we would look at all the scenarios and see what is worst case

but basically it doesn't change much. The reason for that is that clay has excellent properties for retention of radionuclide. The most radioactive, for example, uranium or plutonium nuclides, they will travel in a million years only several metres. They get stuck. They absorb so strongly to clay that their transport is extremely restricted. What you see here - these are just nuclides that from their chemical properties do not absorb in clay systems and that's why they manage to get out. Anything that absorbs in clay, got stuck in the clay itself, you will find it down there. If you wait long enough, several million years, it will look like a mine for uranium.

MR JACOBI: I'm just interested, does any particular conclusion arise from the analysis that we see there in terms of a view with respect to the long-term safety of the system on the baseline scenario?

DR ALTOFER: Yes. We have recommendations. If you look at them, in the 80s up to the 90s the Scandinavian example - the Scandinavians, the Swedes and Finns - due their geology, they actually are building their repositories in crystalline rock. The Swiss, we also have crystallised rocks actually for that. In the 90s the implemented proposal was to build a repository in crystalline rock and the regulator was not convinced that it's feasible. Simply not through the actual chemical properties of the crystalline rock path due to geology because our crystalline rocks is different to Sweden and Finland due to the alps and the Jura Mountains. It is very much compressed. It's not uniform any more compared to the Scandinavian crystalline rock.

If the regulator says, "Yes, you could build a repository in the crystalline rock if the crystalline rock had these properties but we doubt that you're going to find anywhere in Switzerland the crystalline rock that is as extended as necessary to build a repository," and then how to stop the (indistinct) in crystalline rock and repropose goal settings. Looking to where suitable settings are situated in Switzerland, that changed the whole program of Nagra and they followed up with a thorough investigation of suitable crystalline rocks and that's why we ended in this clay rock in Switzerland.

You can demonstrate also if you investigate them, if you make a bore hole. What you can do is, there are like natural traces of radioactive materials that occur naturally in the rock strata. What you do there is, you can measure the profile of the density of these naturally occurring radioactive materials. If you just the transfer process by diffusion - just diffusion, there's no flow underneath - then they will transport very, very slowly. You observe them if you drill down the hole, through the clay, you will see that the concentration distribution actually increase very much with the diffusion control processes. That strengthens the argument that it has been shown through natural analogues we call it, that nature gave us an example that transport is very low down there and that experience, by nature, ran over several hundred thousand years.

So you have additional arguments. You do not base the whole safety case on it but you can show with data, say, "Look, the transport property down there is really diffusion, it's not groundwater hold or anything like it." As soon as you have diffusion, diffusion is a very, very slow process. If you can show that the dominating transport process is diffusion, you will actually get a very slow process which you see also as a result of the calculations.

MR JACOBI: Has ENSI come to any conclusions, perhaps at the point before sites have been found, with respect to the safety cases; that is, has it expressed any conclusions as a recommendation to government about the suitability of clay for a high level waste repository?

DR ALTOFER: In stage 1 all the considered reasons were in clay rich formations for high level waste on the (indistinct) We supported that. For the low level waste there are other - just nearby where you've got (indistinct) clay, it's on top of the other clay rich formations, that was also recommended. There is also a small advisory body in Switzerland that reports to government and they even made recommendation that all further studies should only remain in (indistinct) clay simply due to these excellent retention properties. So we didn't go that far. We just say yes (indistinct) simply state your case, develop your project, but for the high-level waste it's now again all regions that are being considered are now using (indistinct) clay as the host rock.

MR JACOBI: Moving on for now, what is it that ENSI expects the proponents to be doing for the purposes of developing the next safety case or the next iteration?

DR ALTOFER: Okay. Since they have to narrow down their selection, the high-level waste for three remaining regions, they have to narrow it down in stage 3 just to one, and in order to do that you have to compare different sites which is not that straightforward or easy because you can imagine if you're a different size you have to make your (indistinct) you have to put (indistinct) in one site the danger of deep glaciations could be slightly higher than the other side.

So you have to make your case, your arguments, what are the reasons, can I get away from where a glacier is going to move through to another region within the same siting, region and so on. The expectation we have is make further investigations with actual data from the 600-metre well. That means boreholes, several boreholes, make additional investigation from the top, 3D seismic measurements (indistinct) seismic lines to see where the waves are, whether they're formed (indistinct) and so on.

Also make additional experiments, the interactions, the waste containment

material with the (indistinct) with the host rock. We have in Switzerland every five years they have to come up with a cost estimate, how much is the whole thing going to cost, where's the (indistinct) measurements and disposal measurement and so on, every five years, and part of that is the research and development plan. They have to show which are right now the open points and how are we going to clarify the remaining questions.

That is updated every five years which is an excellent (indistinct) to actually - we are commenting on that. If necessary, we are demanding additional research in certain areas. That is open to the public as well. So you see what the open questions are and you see what additional research is needed, and the requirement is simply now to make a more detailed project. We have several recommendations in the engineering feasibility of the repository. Once you go to a specific site you have additional local data.

We expect the implement to actually detail its approach more and more and said, "Okay. These are buyers. These (indistinct) chemistry (indistinct) that will - if we use this type of concrete to build our repository it will actually cause these interactions." and you have to clarify that. So it follows straight from the stepwise approach that once you select you've got more and more detail and it's necessary simply to get the construction licence and operating licence.

At that time no fundamental safety (indistinct) must be open. Everything has to clarify that the moment where the operation licence is granted and simply we use now the time to simply narrow down, find out what are open questions, how to clarify with additional research simply to achieve that, that the implement, the proponent can demonstrate that all such relevant questions have been clarified.

MR JACOBI: I want to deal with in part a topic we mentioned earlier which was retrievability, but we're interested perhaps how in the long term the Swiss people could be assured of the long-term safety of the repository, and I don't online want to ask in these terms, but also, what's planned if something does go wrong in terms of the way that's contrary to the expectations of the safety case?

DR ALTOFER: Well, we have a part of the repository on slide 3. I apologise; it's labelled in German. You see there's a part of the repository called in German (indistinct) that will be the pilot facility, a thick, yellowish corridor on your screen. That's time (indistinct) repository. What you do there is you bring in the waste in that part and you start there.

You bring in the waste there. That's how you start. You fill it up, you seal it off, and this part of the repository is an instrument. Say, the re-saturation - you

mentioned temperature profiles and so on. You do a whole suit of measurements and what you do there is you know how this waste should behave because of your model calculations, and now you are going to compare the actual data.

So you do that first then you do the filling of the repository. You seal off the repository and it's possible to actually measure in this pilot facility for decades after you have closed off the rest of the repository. It's in the ordinance. You have to have that. That's in the law. Pilot facility is by law a part of the repository, and if you observe behaviour that is not explained, inexplicable, you don't know what's going on down there, first you should check is what is it that I observe, what is the safety rule.

I mean, it could be simply microbes that actually destroy my measuring or the probes, equipment. Is it really safe to go? If it is, then our guidelines are if it's (indistinct) it can't be repaired down there. You have to return this waste because you can't demonstrate after the knowledge you gained in this pilot facility the safety of the whole repository, so you have to take the waste containers back, and that's why also we demand in the guideline that you have to demonstrate down that you are actually able to retrieve it safely.

Of course nominally the expectation is after decades of research and careful preparation and careful reviews that this will not occur, but it's just also as an element of confidence building that people know that a part of the repository is being an instrument and measured in order that if something goes wrong that (indistinct)

COMMISSIONER: Dr Altofer, Thank you very much. It was very clear, your evidence, and every useful for us to think about our next step. So thank you for spending time with us in Switzerland and today as well.

DR ALTOFER: Thank you. It was a pleasure, thanks.

COMMISSIONER: We'll adjourn to 17.45.

ADJOURNED **[5.28 pm]**