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Introductory Jingle
Innovate UK KTN connecting for positive change.

Debra
Hi, everyone. Thank you for joining us and welcome to this new episode of the HydroGenerally Podcast Series brought to you by Innovate UK KTN. For those of you who have listened to some of our earlier episodes, you might be expecting to hear Steff Eldred, but as he mentioned previously, he's currently on a secondment with Innovate UK as Innovation Lead for Hydrogen Transport. However, he's left me with a checklist and given that the topic of today's podcast is nuclear hydrogen, I've roped in my colleague Ray to help out. So regular listeners will be used to our introduction information now, so I'll try and keep it brief. But for new listeners, the HydroGenerally Podcast Series is the voice of the hydrogen and innovation network of Innovate UK KTN. We work across the value chain trying to increase end user hydrogen uptake, particularly around clean hydrogen. So if you're interested in finding out any more, please visit our Innovate UK KTN website, through the link in the description, where you'll find all available episodes of this podcast. And you can also sign up to receive our regular monthly newsletters. So we'd better crack on with today's topic. Episodes so far have covered the colours of hydrogen and how they're produced, we've discussed some of the sectors where it can be used, including marine, glass, and also combustion for transportation. So today, we are almost back to the beginning to talk about a way of producing hydrogen that is pretty much unknown. So as I mentioned, we've got Ray Chegwin joining us today for this podcast. Hi, Ray, could you please introduce yourself and share a little bit about your role at KTN? And then if you could introduce today's guests, then we'll get started.

Ray
Thanks Debra. Hello, everyone. I'm Ray and I work in our Clean Energy and Infrastructure team, where I'm the Knowledge Transfer Manager for Nuclear and Fusion Energy. Obviously, we have close links with the National Nuclear Laboratory. So it's my pleasure to introduce our expert, Allan Simpson. Welcome, Alan, please, can you introduce yourself and your role at NNL?

Allan
Thank you very much, Ray. And, yes, my name is Allan Simpson. I'm a Technical Lead at the National Nuclear Laboratory, which is the UK National Laboratory for fission nuclear technology, and I lead an internal research programme on nuclear enabled hydrogen. We're interested in supporting the future of the nuclear sector and how it will contribute to a future clean energy system.

Debra
Thanks, Ray. Welcome, Allan. I'm excited to hear more about nuclear hydrogen. As initially I thought it was essentially green hydrogen produced via electrolysis using nuclear energy. But having done a bit of homework, I now realise how naive that was. So Allan, for those who aren't familiar with nuclear power, can you briefly describe the different types of nuclear reactors?

Allan
Yeah, absolutely. Thanks very much, Debra. And as you said, there's a whole plethora of things we can do with nuclear power and hydrogen. And that stems from the sort of key different types of reactors that we have available to us and there are four different types that we tend to think of today. The first type or the main reactors we see operating in the UK today, that's something called an advanced gas cooled reactor. They were designed and built back in the 1980s and they have been providing clean, reliable electricity 24 hours a day for 40 plus years, but they are coming to the end of their lives now. We're seeing those being replaced by something called a pressurised water reactor, large scale pressurised water reactor, that's the sort of thing we see being built down at Hinkley Point C in Somerset, and has been operating out in size since the mid 1990s. They're really good at providing large amounts of electricity reliably all of the time but as we see from the news at Hinkley Point C, big construction projects take a long time, they can be quite expensive because of all the complexity around them. So one of the things that's been developed very actively within the nuclear sector is something called a small modular reactor. And that's like a scaling down of the same technology that operates at Hinkley Point C, was being built at Hinkley Point C. In the UK, the project that we see that's really progressing that is something called the Rolls-Royce SMR reactor, and that's funded both by government and by industry, and it's developing a reactor that's maybe about a third of the size that we see at Hinkley Point C to deploy and really focusing on building more of the reactor in factories. One of the big problems we get with these large scale reactors is the components are so big that we have to kind of build a whole factory around the site that we're building the reactor, whereas with the smaller reactors, they want to be able to build more stuff in the factories, modules that will get put on the back of the lorry, transported to the site where we're deploying the reactor, plugged in and it'll be a much quicker and simpler build process. But these reactors, technically they're still kind of optimised for electricity production, they operated at a temperature of around 300 degrees Celsius. And that temperature is really important when we think about some of the hydrogen generation technology and the future clean energy system because there's lots of things in our energy system that require higher temperatures and higher heat that today is provided by gas, mostly. So the final generation of nuclear reactor that we're looking at is something called an Advanced Modular Reactor. Now an advanced Modular Reactor is generally based on technology that we know we've looked at over the past 30 to 40 years, but we maybe haven't brought through to commercialization. In the UK, we're interested in particular in something called a high temperature gas reactor, and the clue is in the name here, high temperature produces a higher temperature output, potentially around 753 to 950 degrees Celsius from these reactors. Which means we can do a lot more with the reactor, we can operate different things with reactors, and generate energy more efficiently and more efficiently means the cost of the energy to the consumer should go down.

Ray
That's great, Allan, thanks very much for that. So, as you said, we know that the UK has been using nuclear reactors to generate electricity for many, many years. So in essence, how can they be used to produce hydrogen?

Allan

Debra picked up on this perfectly at the beginning, the first thing we can do, we can do today, is we can take a big long cable, we can plug our electricity producing reactors into an electrolyzer and produce clean hydrogen straightaway today, and that has the same efficiencies in terms of converting that electricity into hydrogen as we see from renewables technology. But what's interesting about nuclear is that we've also got this large source of heat that is in the reactor being used to generate the electricity. If we can tap off some of that heat, then we can enable some other ways of producing hydrogen that are potentially more efficient. One of the obvious things for this is a solid oxide electrolysis cells, also known as steam electrolysis. That's where we have a type of electrolysis cell that we feed steam into or heat into, to help manage the chemistry and electrochemistry happening inside that cell to more efficiently produce hydrogen. And we can maybe see an efficiency bump there or maybe from a theoretical efficiency of the sale of maybe 60-70%, that we might see in some of the sort of water fed cells through to potentially 90% plus efficiency. So we get a nice bump in efficiency, more energy out, more hydrogen generated for the same energy in. They also benefit from, like, extra steps up in the energy. So we get a small bump of the energy efficiency when we may be connected those to the Rolls-Royce SMR, those small modular reactors that are cheaper to deploy, and can produce the steam at the lower temperature. But if we potentially connect those up to those higher temperature gas reactors, we'll get a bigger bump in efficiency as well. One of the other things though we can do with the high temperature gas reactors, which is really interesting, is something called thermochemical hydrogen production. That's where we really focus on using the heat directly to produce hydrogen and we use a chemical process to split the hydrogen away from the water. So using the same feedstock as electrolysis, it's still just water coming in and energy coming in. But we have a chemical process in there that splits that water down into hydrogen and oxygen, based on the incoming heat of those high temperature reactors. The thing with those processes is they require higher temperature heat, they require maybe 600/700 degrees Celsius plus, heat going into the system to make it work. They also require quite a lot of research and development to mature these technologies to a point where they'll come to fruition. So the Clean Energy System, they're dependent on us bringing those Advanced Modular Reactors out, and also delivering some of the research and development with what will make this a technology that can actually be deployed at scale. But potentially if we achieve that, definitely NNL modelling and NNL research has shown and also aligns with international research and this, that we get a significant bump in efficiency potentially up to 50% thermal efficiency of the plant. So, on a nuclear power plant, we rate our efficiency compared to the total heat output of the plant, for comparison an electricity producing Hinkley Point C type plant is about 33% efficient. So we get a big bump in efficiency and again, the higher the efficiency, the more units of hydrogen, we get out for the same energy in.

Ray
That's great Allan. I'm just wondering though, I've seen things, perhaps Hinkley Point C is obviously really geared towards producing electricity. But as you mentioned Sizewell, there's talk of another large scale reactor at Sizewell, Sizewell C. But I've seen talk that that could not only be used for electricity, but could produce heat for district heating or for hydrogen production, etc. So in your opinion, could we use Sizewell C to produce hydrogen? Or are we best thinking of the new reactors coming along, like the Rolls-Royce SMR, or indeed advanced nuclear technologies, the next generations of a reactor,

Allan
I would say we've got a big problem producing lots of hydrogen in the future clean energy system. And so we should use everything we can and Sizewell C is a great opportunity in some of the existing reactors, we've got to start doing something, it may not be the most efficient and perfect process that we could develop. But it starts us doing something, it builds confidence in the users of this hydrogen, that there's going to be that reliable hydrogen supply chain in the future, because one of the things about nuclear is it does take a long time to come online, these advanced Modular Reactors are going to take another 10 to 15 years before we start seeing them deployed at scale. So having something that we can do sooner with the likes of Sizewell C or existing reactors builds confidence that it's growing there. And we do get the benefit of the fact that, like you say, Ray, we can take some of the heat away from Sizewell C, and make use of that solid oxide electrolysis, that gives us that small bump up in efficiency, and every bump up and efficiency is good, it helps us, it means we're making better use of the energy sources in the energy system. And then further on with the Rolls-Royce SMR, because that will reduce the cost of deployment of nuclear by all these factory build techniques, we see the cost of hydrogen reducing and as the cost of hydrogen reduces, more markets, and more people can see it as a viable alternative to other decarbonisation options and start to build it into those plans. So it's really important from my perspective, that we actually have that stepping stone of, we need to do stuff soon, do stuff using the direct electrolysis, getting on with the likes of Sizewell C to do the steam electrolysis, getting that more cost effective with these small modular reactors. And that builds the opportunity and builds the market for maybe the advanced modular reactors that can achieve those super high efficiencies.

Debra
So we've often heard that nuclear and obviously other very large infrastructure projects are accused of being very, very slow to come online. So, you mentioned having proof of concept early stage getting the market ready. What kind of timescales do you think that we could see these SMR and the advanced reactor technologies coming online?

Allan
So I might step back from the question a bit there, Debra, and think about when we can deploy the different hydrogen generation technologies because the first thing to remember with nuclear enabled hydrogen is we can deploy electrolysis today with those reactors that are running and we can start doing something like I said, before we can get that long cable, plug it in and do something. What we're seeing with the small modular reactors and the advanced modular reactors at the moment is that the small modular reactors are expected to start coming online in significant scale in the early 2030s. That's a very ambitious timescale, there's a lot of work that needs to be done to make that happen. But we all know the challenges that are associated with net zero and we all know that we need to think differently and think innovatively, if we're going to achieve that across the whole netzero energy system. As we start seeing those coming online in the 2030s and being deployed at scale and expanding the capacity of hydrogen generation available to the energy system, alongside all the renewables technology that will be coming on at the same time and doing a similar thing. Then what we can expect is in the late 2030s, we'll start seeing the rollout of Advanced Modular Reactors and that will take all the learning in terms of factory build, that we built up in those Small Modular Reactors and apply it to this new advanced high temperature technology. And we'll start to see a roll out and the new reactors coming out will

be these Advanced Modular Reactors. But we've got to remember that every reactor we build today is going to be operating in 50, 60 years time, these reactors have a 60 year design life. So we're not going to be replacing what we build today, if we start making Sizewell C, generating hydrogen with the heat coming out of it, and that electrolysis in the early 2030s, in 2050, that is still going to be there reliably generating hydrogen for us. So every bit we add in, in the nuclear enabled hydrogen world, is a bit that's contributing to our 2050 goals. That's really important, when we consider that one of the constraining factors that we're going to see later on in the net zero energy system is we're going to start having to replace some of the systems that we're deploying today, because a lot of renewables energy systems have a 20 to 30 year design lifetime. 20 to 30 years means that come the 2040s, they're going to start needing to be replaced, so we need even more capacity in our system of building and deploying these technologies to get that out there. So everything we can throw in that will be able to generate more hydrogen, bring more hydrogen into the energy system is going to be beneficial in 2050.

Ray
In your project and the stuff that you're doing at the National Nuclear Laboratory, what are the key areas then for development? What are the areas that you really focused on? Are they purely technical? Or are there other aspects, other issues and challenges as well?

Allan
No, so it's a really good question, Ray. What we do at NNL is we try to do the research and development that enables things to come through to fruition for the future, the nuclear sector, and a lot of the time that is not technology alone. We all know that the world is a complex place, and making stuff happen requires both technical, political, economic factors, all to come together to make this happen. And so the internal research programme that we look at, is both looking at making sure that we're bringing forward the evidence that technically this is possible, and understanding what all the different people and stakeholders in this system require to enable them to have confidence in the future of this technology. But we also spend a lot of time just speaking to people and talking to people and working with the government and working with industry to help them understand how this technology might contribute to a future energy system. But also what policy factors need to be in place to enable that. One of the things we see with nuclear is it's a very complex policy environment that enables nuclear to happen, because it's such a long lead time, technology a lot of the time. So the government and industry all need to work in lockstep together to enable these things to come through and we need to make sure that some of those sort of future hydrogen policies account for what nuclear might contribute in the future. So we try to make sure we're supporting the government and all those stakeholders in considering what nuclear might need to support some of these technologies to come through in the future. A really good example of that is we recently saw the consultation responses to the low carbon hydrogen standard defining what counts as low carbon hydrogen in the UK. And NNL worked and responded to the consultation on that to suggest some of the things that need to be considered for how nuclear can be involved in that. One of the things that came out of the end of it, is that it was recognised within the low carbon hydrogen standard consultation responses, that the role that nuclear can play and the fact that it is a low carbon technology. But the fact that there may need to be some sort of subtleties and things that are thought about differently in how that's implemented to enable nuclear to contribute to a future clean energy system.

Ray
We're running near to the end, Allan. So just a final question for you, if you can. I know you've been doing some market analysis, are you able to share any of the findings so far ? And then supplementary to that where can people go to, to find more information about this?

Allan
Yeah, absolutely. We've been looking at the different markets and opportunities for this for a long time, we believe that, and our work is kind of vouched for, as someone ultimately needs to want to buy the product. So that's a really complex question, because different users have different demands. Like a lot of the hydrogen sector, there are some key sectors that we think will really benefit from hydrogen. And one of the things that we think nuclear enables is us to not have to talk about whether there's enough hydrogen and which sectors get the hydrogen, which sectors have to look for other decarbonisation we say, well actually, when we do nuclear right, we can bring so much capacity into the system that we can change that question, and we can actually say, there's enough hydrogen for everywhere that hydrogen is the optimal decarbonisation option. Some of the sectors we think that really applies to, when you'll have probably heard a lot about in all of the discussions around hydrogen, is aviation. Aviation has some fundamental, technical challenges to decarbonisation and hydrogen is a really good energy vector to support that. But providing enough hydrogen both in the UK and globally to support aviation, decarbonisation is a big challenge. One of the other obvious areas that again, is talked about a lot is hydrogen decarbonisation in the homes, you've got to remember that the gas network in the UK distributes around three times the amount of energy that the electricity network does today. So if we are going to decarbonize our home heating, our industrial processes with hydrogen, we need to be able to generate an awful lot. And we think that nuclear is able to give the confidence that that level of hydrogen can be generated reliably throughout the year and enable decarbonisation for home heating and NNL is supporting some different work that helps to build that evidence base. We also think there's roles in things like large scale, long distance transport, where battery technology isn't going to be so sufficient. So maybe in the trucking sector and trains, there's also potential opportunities to support the decarbonisation of shipping, and potentially through the generation of things like ammonia. And that's again, when nuclear becomes an interesting technology, because having that heat source allows us to generate maybe the onward products such as ammonia, using some of our tried and tested techniques in the same way that we generate ammonia today. So it becomes a clear route through to decarbonisation of those sectors. One of the big things for us, though, is that the more people that start to take up the technology, the more we can reduce the cost of the product. So it's a bit of a chicken and egg situation of, we need to be able to find the people that can maybe afford a higher cost product in the first place, it's not going to be the cheapest form of energy when we first deploy it, that helps us to reduce the price by building more and building out more. In the same way we've seen the Renewables Energy Sector, and particularly offshore wind do over the past 10 years, and how it can now generate electricity at those low price points.

Debra
Allan, as usual, we've come to the end of our 20 minutes incredibly quickly. The time always seems to fly by when we're talking and we've covered a lot of topics here, from energy production, decarbonisation of heat, maritime, aviation and even alternative fuels like ammonia. There's always so much more we could say. And I personally look forward to

hearing about the exciting future developments in nuclear hydrogen, both in the short and longer term. So I'd really like to thank you, Allan, for joining us and sharing your knowledge with our listeners. And thank you, Ray for co-hosting this episode.

Ray
Yes, thanks again, Allan, and thanks all for listening. All the links mentioned by ourselves and Allan and I'll link to the Innovate UK KTN website, have been added to the description and as always, don't forget to join the Hydrogen Economy Innovation Network or sign up to receive the newsletters and updates. Thanks again for following us and goodbye.

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