Note: This transcript has been produced verbatim and includes all the quirks and idiosyncrasies of the speakers.

Introductory Jingle
Innovate UK KTN connecting for positive change.

Steff
Hi, good day all. Thank you for joining us and welcome to Episode Eight of the HydroGenerally Podcast Series brought to you by Innovate UK KTN. I'm sure many of you have listened to previous episodes but if not, then I'm Steff Eldred. I'm part of the Clean Energy and Infrastructure Team at Innovate UK KTN. I lead on our Hydrogen Innovation Network, along with others such as Debra, that we will come on to shortly. It's also worth mentioning because it's particularly relevant to this topic that I am currently on a secondment with Innovate UK as Innovation Lead for Hydrogen Transport, so relevant to this. Regular listeners will be well used to our introduction now, so we'll try and keep it brief. But for new listeners, this HydroGenerally Podcast Series is the voice of the Hydrogen Innovation Network of Innovate UK KTN. We're trying to help with challenges to end user hydrogen uptake. To find out more, it's probably best just to go to the Innovate UK KTN website, where you found this podcast and through the link in the description. And there, you'll find previous and the next episodes as we record them of this podcast, and you will also be able to sign up to receive regular newsletters, but you'll get the history there. So moving on to today's topic, we've had seven episodes so far, covering production, we've discussed where it could and should be used. We've discussed maritime, aviation, waste and heat. When you sort of say it all like that, Debra, it feels like we've covered quite a lot of ground doesn't it? Today we're back on a transport theme and we're going to talk about hydrogen for combustion. So I mentioned Debra a couple of times. So Debra Jones is joining me, many of you will know she's hosted some previous episodes. So hi, Debra, for those of you that don't know you, can please introduce yourself, and then probably go ahead and introduce today's guest?

Debra
Hi, Steff. Thanks. Hi, listeners. I'm Debra. And I'm the Knowledge Transfer Manager for Chemistry here at KTN. I work with Steff within the Hydrogen Innovation Network, mostly in areas where chemistry can play a role in understanding the challenges across hydrogen production, storage, transportation, and end users as both a fuel and a feedstock. So with us today, as Steff mentioned, we've got Duncan. So hi, Duncan, would you be able to introduce yourself and tell us a little bit about your role?

Duncan
Hi Debra. Hi Steff. Thanks very much. So hi, I'm Duncan. I work in Cummins. I am the Director of Research and Technology here in the UK. My role is really to support all of our powertrain direction, in the low research space. But really one of my larger roles at the moment is supporting the work we do here on hydrogen engines.

Steff
Great. Thanks. Thanks, Duncan. Thank you, Debra. Let's move on to the discussion. Let's talk about hydrogen combustion. So, Duncan, if you don't mind, could you just explain to us a little bit of the background? So where does using hydrogen for combustion come in really?

Where does it fit in? There are obviously other options like fuel cells. So just set the scene really, if that's okay?

Duncan
Yeah, that's great. Maybe to start off with, can I just give a quick introduction to Cummins? Because I think it really fits in where the conversation is. So we're a $24 billion revenue global company, we've got 70,000 people across 190 countries worldwide. Here in the UK, we've got 5,500 employees across three or four large manufacturing sites. We spend about 70 million pounds on R&D, just in the UK alone and we're probably one of the largest UK exporters. And I think the key there is, one of the things that are important is we're in the commercial powertrain development space. We're not in the passenger car market, we've no interest in getting to that market. Therefore we have a different set of requirements and responsibilities for our customers. We're into machines that have got more power use, longer up times, dirtier environments and we support sort of a wide range of industries, from buses, trucks, excavators, trains, mining vehicles, and marine vessels. And if you think about that, from a CO2 point of view, it's not an easy to abate industry. If we think about hydrogen engines specifically, we shouldn't think of it as an us and them or a this and that, it's another choice in the varied mix of powertrains that are available to us. The three main routes, I think you can think about are sort of battery, fuel cell and hydrogen engine. And to a varied amount, we'd expect to see them all in most applications, I think there is no one size fits all. In general, we'll see batteries more suited to sort of low power, low distance return to base applications, your cars, your vans, your buses, fuel cells are going to be sort of long range, high efficiency applications. And then hydrogen engines for the sort of heavy haul, high power sort of industry. But the reality is, when you're in the world of medium and heavy duty application in the commercial world, the efficiencies of the fuel cell and a really optimised hydrogen internal combustion engine, they're likely to be similar. The fuel cells get less efficient as you go into the high load factors, the engines are less efficient at the lower load factors. But in reality, there are other questions that come into the mix as well. For example, a hydrogen engine powered vehicle is going to be significantly cheaper to purchase in your first price, your first attempt into the market than a fuel cell, it's gonna have a similar total cost of ownership. So again, going back to commercial vehicles, it's not all about the first price, very many people are interested in what it's going to cost me over the ownership of this vehicle. In reality, the two products in the hydrogen world and I'm gonna step away from batteries, are likely to be very, very similar in the long run. But that low cost is probably the interesting one for smaller businesses, for smaller industries that are very interested in that initial first cost.

Debra
Great. So we know that Cummins is going to be at the forefront of this development. Would you be able to tell us a little bit about your current focus? And are there any projects that you're able to share with our listeners?

Duncan
Yeah, sure and thanks for that. We feel we're also at the forefront of this. But I think we are one of many companies that are really seeing this as an interesting technology on our route to net zero. I mean, the likes of DAF, MAN, JCB, Bosch, BorgWarner, Marla, FEV, Dolphin-N2 the list goes on and on and on, of people that are really heavily investing in this technology. Because there is a view in the industry and in our consumers and our users of

this industry, that this is a technology that we need to push forward on. Our current focus is really on balancing the reliability of our technology, and the speed that we can get to market with it. Right now, end users and we met many, many of them at the Hannover transport show last week, who were desperate for this technology. Right now, people want to get involved in the ropes net zero, and they want to get involved as quickly as they possibly can. We could have put orders in for 1000s and 1000s of engines over the last week or two. But the reality is, we won't put something into the market until it's reliable and has passed all of our strict standard work practices and in reality that takes time. In terms of projects that we can share, and we can talk about, we have a really exciting project going on at the moment in Darlington in North East of England, it's partially funded by the Advanced Propulsion Centre, and it works on six to fifteen litre heavy duty engines. We're looking at the capabilities of low pressure and high pressure, direct injection, hydrogen internal combustion engines, working with a consortium of partners, we're working with Johnson Matthey, BorgWarner, and ZuciTech in that project. We're really excited to be able to start showing the results of that work probably in the first half of next year.

Steff
Great, cheers for that Duncan. I think on both of those two questions, we're really aligned at KTN, so, you know, again, what we're interested in is what's right for the end user and what's going to help us all on the journey to net zero in 2050. So, you know, different applications will require different solutions and we're definitely agreed on that. Also what we see, you know, most of us have been involved in industry in the past. So I'm very sure that your order book could fill up very quickly, as soon as you release something onto the market because I think the end users, particularly on the heavy side, rely on people like yourselves and all of the others that you kindly name checked, they have the confidence in people like you that when you bring something to the market, it's fit for purpose and ready to go. So yeah, that's really interesting. I suppose one of the debates, I was gonna say criticisms, but one of the debates that is often raised around combustion is emissions. So a lot of the time in the UK when we talk about moving to 2050, instead, we'll talk about zero emission. And so then a debate arises as to whether hydrogen combustion is, or, more importantly, probably can ever be true zero emission. Yeah, I just wondered what your thoughts are on that, and whether you think we can get there?

Duncan
Yeah, it's a really good one, because I talked about our primary focus being reliability and speed to market, our secondary focus has had to be education, and education of our global leaders, and our consumers and our OEMs about this technology. As you mentioned, often a concern from people is NOx emissions from the internal combustion engine. And this really is unavoidable, due to nitrogen in the air, we've got nitrogen in the air, we're burning it, we will create NOx as part of this technology. But to be clear none of these zero emissions vehicles are emissions free. If I wanted to pick on batteries, excess weight, leading to increased PM from the tyres is a big one that we can pick on. But the reality is, we're heading towards as low emissions as we possibly can. The level of nitrogen and NOx is perhaps not as understood as well as we'd like. NOx is not a greenhouse gas. The issues with NOx are fairly well understood, it creates smog in our city areas if it's not under control and it starts to affect lungs of people. The levels of NOx that we see, even from our Euro 6 diesel engines right now, in some studies are showing that we are cleaning the country's air. Moving all of the commercial vehicle trucks to just Euro 6 will make a significant difference to

the air quality in our cities. Therefore moving further into hydrogen powered ICE engines will further increase the speed at which we can support that. In our testing, we're seeing extremely low engine out NOx from our hydrogen engines and it's due to us running an extremely lean combustion system. So what I mean by that it's an extremely large amount of air, coupled with the modern capitalist systems that we even use on our diesel engines, we expect the long haul NOx emissions of these vehicles to be in the single digit parts per million output. And I think this is where we have to start asking ourselves sensible questions. The key question for me is, do we want to miss out on the speed to market of zero CO2 technology, due to the parts per million NOx that they could give out? We can get a stepping stone to hydrogen fuel cell and battery commercial vehicle use in the long run. But we can get there with hydrogen engines in very, very large quantities in the next five to seven years. The NOx emissions from these engines will have zero impact on health or the environment. It will enable our customers to hit net zero targets much earlier than other technologies.

Steff
Yeah, that's really interesting Duncan and from a personal point of view and from previous organisations I've worked for I have a similar view. So I guess, you know, to be fair to the drive to total zero emissions, I guess if it's a vehicle or an engine that's going to sit outside of school with the engine running, then we can all probably agree that yeah, we want to try and get that to zero. It's the right thing to do. But when we're talking about heavy machinery, 300 tonne dumpers, excavators, quarries, dockside cranes and what have you.

Duncan
Even if we're talking about 44 tonne trucks that are driving up the M1 or up the A1, that the level of NOx as I say, is in parts per million numbers, we're not talking about the effects of a heavy diesel, Euro 3 diesel sat outside of school idling.

Steff
Yeah, I think that's the point. I think what we're both saying is that, if we can move quickly, with combustion technology, you know, if we can get heavy, you know, 44 tonnes onwards, if we can get a heavy kit to parts per million levels very quickly with combustion, then it clearly has to be a great step forward, rather than holding out for zero emission. So I guess, with that in mind and with the expectation that we can move fairly quickly, is there a kind of roadmap in mind for trials and when it might make it to commercial operation?

Duncan
Yeah. As mentioned before, we don't want to rush this. But I think what you'll see is trials of Cummins technology across various countries of the world in the 2024-2025 timeframe. And you'll see us launch this as a global platform in 2027 and in reality, at that stage, it'll be up to the infrastructure to keep up.

Debra
So what data do you think we will need to collect, to show how efficient this is over different duty cycles? I mean, obviously, we know that pasture cars and all of the different cycles that you have to go through for a conventional engine. Will these be equivalent? Will we need to introduce new cycles? And how do you think that this will compare to a fuel cell over those same cycles?

Duncan
To be clear, we Cummins, see hydrogen engines as complementary to fuel cells, as I say, I don't really want to talk about a differing set of duty cycles, or a different set of technologies. I think they're complimentary, and probably a bridge, potentially a bridge and a catalyst to this technology. Just as I said, we can see this going to market in larger numbers using sort of existing skills in the supply chain and what we've got here in the UK. At the end of the day, the commercial vehicle sectors are hard not to track. I mean, there are many things that we're going to look at, during our trials, we will of course be monitoring the efficiency and power of the engine along with the emissions, and the drivability. We want this technology to be as easy to transfer for our customers as possible. There should be no feeling for our customers that this is alien to them. So when we're talking about how we're going to do these trials, it's not really about different duty cycles or different ways of working or different, frankly. We need our customers to be able to go straight into this technology with no fueling concerns, no worrisome niggles that you might not get to the end of your mission, and your day job. Because the reality is, our customers aren't driving their vehicles for sort of 5% of the day, and then leaving it in the car park or the driveway for the rest of the time. This is their livelihood. They need 100% uptime, for somewhere between 8, 16, and sometimes 24 hours of operation per day without it failing, without it going wrong, and without worrying they're going to run out of fuel somewhere. So that's really what we see the trial being and it's not just a trial on our engines, because we have absolute confidence in the engines and the technology. It's a trial of how we can convince and how we can ensure that our customers want to move to this technology and want to move to zero emissions technologies in general, as quickly as possible.

Steff
Great, cheers Duncan. Yeah, so it's very much a partnership really, with those end users and your customers. Obviously, we won't get into it now, but there's the infrastructure and refuelling side as well for them to be able to maintain. Just thinking in terms of, you know, maintaining those, those upcycles that you talked about, obviously, they need to make sure that they can do that as well. It always surprises me, once we get talking about these topics, how quickly time goes on. Our listeners will know that we do try and keep these fairly tight to time, so tight to our 20 minutes or so, so that people can listen and then get on with their day. So, thank you so much, Duncan, for coming along. Thanks for co-hosting Debra. It's been a great topic. I know that lots of our listeners will have thoughts and opinions on this as it develops. So, we may well pick up this theme again. But yeah, thanks for sharing your knowledge with our listeners. Debra, over to you.

Debra
Yeah. Thanks again, Duncan. Thanks to everyone who's listened. All the links that we've mentioned and a direct link to the Innovate UK KTN website will be added to the description of the podcast. And as always, don't forget to sign up to receive our newsletters and updates. Thanks again for following us and goodbye. See you next time.

Steff
Yeah, goodbye. Thanks.

Outro Jingle
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