**Back in June 2019 I made a video about energy storage in hydrogen. There was a lot of media excitement around at the time talking about how hydrogen could play a pivotal role in our transition away from fossil fuels, not least because of its ability to store energy for quite long periods of time and then release it whenever the electricity grid was falling short of power from renewables, like during the dark months of winter or on days when the wind doesn’t blow.**

**That media hype still exists today of course, in fact if anything, it’s got louder and more prevalent during the 2020 pandemic year as societies all over the world appear to have been afforded more time to stop and think about how we can all live and work sustainably on our march through the twenty first century.**

**Hydrogen is a very good energy carrier. It’s got a very high level of energy per unit mass. The trouble is it’s also a very low density gas at room temperature, in fact it’s about only about a third of the density of natural gas. So, in order to store it and transport it, we either have to cool it right down to below minus two hundred and fifty degree Celsius to make it into a liquid that takes up far less space, or we have to pressurise it to somewhere between a hundred and three hundred times atmospheric pressure. In that pressurised form though, hydrogen contains about forty thousand watt hours of energy per kilogram compared to only about two hundred and eighty watt hours per kilogram that the best lithium ion batteries can produce, so you can see why the energy industry thinks it could be an attractive option.**

**Both the cooling and pressurising methods are already commonly used today too, but they both take a lot of energy, removing about thirty percent of the efficiency from the overall hydrogen production and supply chain process. On top of that, hydrogen is a very reactive gas which tends to make steel become brittle. And that’s not ideal if you’re shipping the stuff in pressurised steel cylinders or transporting it through pipelines.**

**So, the latest industry buzz is all about how to store and ship hydrogen in a safer and more efficient way using a very well-established infrastructure that’s already in constant use every day all over the planet.**

**In order to take advantage of that infrastructure though, you first have to convert hydrogen into Ammonia, and that concept appears to have opened up a whole new can of worms.**

**Hello and welcome to Just Have a Think**

**The latest market reports on the global value of ammonia production tell us it’s worth nearly seventy-three billion dollars today, with an annual production volume of about a hundred and seventy-five million tonnes, the bulk of which is used for nitrogen fertilizers in agriculture. But the potential benefits of transporting and storing ammonia as a very long-term energy carrier are attracting a great deal of interest from all sectors of the energy industry.**

**Ammonia is comparatively easy to transport and store, certainly compared to hydrogen anyway. It liquifies at only minus thirty-three degrees Celsius compared to minus two hundred and fifty odd degrees for hydrogen and if you choose to pressurise it instead then it only needs to be compressed to ten times atmospheric pressure to make it practically transportable. And it doesn’t react with steel the hydrogen does either. It might sound a bit counter intuitive to say this, but it’s actually a better hydrogen carrier than hydrogen itself. For the same volume, ammonia contains fifty percent more hydrogen than hydrogen does.**

**3:27 A molecule of ammonia contains one nitrogen atom and three hydrogen atoms. The air we breathe is about seventy eight percent nitrogen 3:33 so there’s no shortage of that. And there’s no shortage of hydrogen either. 3:37 In fact it’s the most abundant element in the universe. 3:40 But here’s where the can of worms starts to peel open, because the industrial processes for liberating nitrogen and hydrogen and combining them into ammonia 3:49 currently among the dirtiest in the world, using about 3:52 two percent of the world’s fossil fuels and accounting for ONE point two percent of our total global CO2 emissions. 4:00**

**Why so nasty? Well, you first have to liberate the nitrogen and hydrogen atoms from their naturally occurring states. You CAN get hydrogen from water using electrolysis, and if you’re a regular viewer of the channel you’ll no doubt have heard me talking about that process before, but the reality is that the vast majority of hydrogen production is currently achieved through a process called Steam Methane Reforming, which essentially bombards natural gas, or methane with steam at extremely high temperature and pressure to force the carbon and hydrogen atoms apart. It’s certainly a very fast and effective way to produce hydrogen, but it’s also a very fast and effective way to produce carbon dioxide, which is generally not captured in the process, and just gets released back up into the atmosphere.**

**Separating NITROGEN gas out of the air is pretty easy using a cyrogenic process, but nitrogen exists in nature as N2 and breaking the strong chemical bonds that hold nitrogen molecules together is no mean feat. 4:57 The existing method is to compress the nitrogen and hydrogen at about two hundred and fifty times atmospheric pressure 5:02 and temperatures of about 5:04 four hundred degrees Celsius in tall, narrow steel reactors 5:08 where an iron catalyst helps to LIBERATE the individual nitrogen atoms 5:12 so that they’ll react with the hydrogen atoms in the right proportions to produce ammonia. 5:17 It’s a process called Haber Bosch, 5:19 named after Fritz Haber who discovered the reaction in 1909 and Carl Bosch who industrialised it some years later.**

**The process uses a huge amount of energy, which is usually provided by fossil fuels, which of course means more CO2 released into the atmosphere.**

**Now, those market reports I mentioned earlier also project that the commercial ammonia sector will grow by at least another six billion dollars, just in the next five years, and keep growing after that, so as you can imagine, our friends in the fossil fuel industry are extremely keen to ensure that the process for creating ammonia continues to use as much of their steam reformed methane gas and fossil fuel generated electricity as possible. That’s one of the reasons why you may have seen the big fossil fuel producers getting all evangelistic about the new hydrogen economy that everyone’s now talking about in the media.**

**But, there other ways of producing ammonia which are rapidly being developed, all of which would eradicate fossil fuels entirely from the process. The details are set out in this comprehensive article researched and written by Robert Service for Science magazine, and this 2020 paper written by chemist Douglas MacFarlane and his team, published by Cell Press.**

**And as always, I’ll leave links to both those papers in the description box below this video.**

**MacFarlane’s team at Monash University in Melbourne, Australia has come up with what they describe as a reverse fuel cell, which bypasses both the steam reforming and Haber Bosch processes in one go. It works like this**

**6:48 Renewable energy from wind and solar drives an electrochemical reaction involving an anode and a cathode, 6:54 both coated with specially formulated catalysts, 6:57 with a separator membrane 6:59 sitting between them in an ionic electrolyte. 7:01 Water reacts at the anode to form hydrogen ions and electrons. 7:06 The hydrogen ions are able to pass through the separator 7:09 and they get attracted to the cathode on the other side. 7:12 The electrons make that journey via the electrical circuit. 7:15 Nitrogen gas comes in at the cathode side 7:18 and combines with the hydrogen ions to produce ammonia 7:20. All of this happens at low temperature and low pressure. It’s a very efficient way to make ammonia, but it’s currently still extremely slow compared to the Haber Bosch system. 7:30**

**Other methods are in development that can significantly speed up the process including a development at Australia’s Commonwealth Scientific and Industrial Research Organisation, or CSIRO. 7:40 It’s called a membrane reactor. A pair of long concentric cylinders 7:45 are heated to four hundred and fifty degrees Celsius. 7:47 Hydrogen is forced into the space between the two tubes 7:51 where catalysts lining the space split the hydrogen molecules into individual atoms 7:55 that can then pass through the atomic lattice of the outer tube wall 7:59 to react with nitrogen gas which has been pumped into the inner cylinder. 8:03 The inner surface is lined with a catalytically active metal like palladium 8:07 which does the job of splitting the nitrogen into individual atoms 8:10 and causing a reaction which combines the newly liberated hydrogen and nitrogen ions into ammonia. 8:17 This set up produces a much faster reaction than the electrochemical one, but at the moment only a small fraction of the hydrogen gas is reacting, so the team are working hard on ways to improve that efficiency.**

**A third method has been developed by a team at the Colorado School of Mines led by Ryan O’Hare. It’s a button sized version of the reverse fuel cell we just looked at, but O’Hare’s version is made of ceramic materials and operates at much higher temperatures. The reaction in that set up is about five hundred times faster than the Monash University system, but still not yet fast enough to hit the criteria set out by the US Department of Energy. All these teams are working fast to get the improvements they need, but right now the trade off seems to be between efficiency of reaction, and speed of reaction. The team that finds the right combination to improve both these factors will have themselves a very valuable commercial commodity.**

**Outside of it’s current main function as a fertilizer feedstock, ammonia as a liquid energy carrier has until recently been regarded purely as a supplier of hydrogen energy, with a final step in the supply chain being a process that can crack the ammonia back into hydrogen and nitrogen at the point of delivery. But the potential scope of ammonia energy applications has been widening and it’s now also being proposed as a direct fuel for shipping and heavy transport vehicles like buses, and in power generators, direct ammonia fuel cells, power turbines, and even jet engines. The only exhaust outputs from these machines would be pure nitrogen and water.**

**There’s clearly still some development to be done on these systems, and that’s raised some serious questions from environmental groups who are concerned about that fossil fuel industry hype I mentioned earlier. Governments around the world are now enthusiastically launching themselves toward hydrogen as an apparently green solution, not just for storing energy, but also directly heating homes and fuelling vehicles. These are all ostensibly very positive developments, but the caveat offered by environmental groups like DESMOG is that we risk building out national and international supply chain infrastructures based on large scale supplies of apparently green ammonia and hydrogen only to find that the new zero carbon methods of production are not able to keep up with demand, at which point the fossil fuel boys will wade in with their existing, carbon heavy technologies.**

**That may be an unnecessarily pessimistic projection, but I guess only time will tell.**

**Now I already know from the amount of emails and comments I receive on this subject, that it’s one that provokes strong sentiments on both sides of the argument. That’s why the comments section is there of course, so if you’ve got views on this or some direct experience from inside these industries, then jump down and leave your thoughts there.**

**That’s it for this week though.**

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**As always, thanks very much for watching, have a great week, and remember to Just Have a Think.
See you next week**