**Podcast #68 – Clean Hydrogen from Petroleum Wells**

[00:25] **Brian:** Hello, everyone, and welcome to episode 68 of the Hydrogen now cast for December 23, 2022. The hydrogen nowcast is sponsored by New Day Hydrogen, who's helping fleet owners meet their zero emission vehicle needs. If you're with a fleet or transit operator and your fleet is wondering how to convert to zero emission vehicles but still meet your operational needs, New Day Hydrogen can give you the option of fuel cell vehicles by providing public hydrogen fuel stations near you and showing you the available fuel cell trucks, vans, and buses. To find out more information about both vehicles and fueling, visit the newdayhydrogen.com website, where you can also submit requests on the contact page.

Well, on the podcast today, I'm going to do something I haven't done before, and that is to repeat a previous episode from November 2020 which is about extracting zero greenhouse gas hydrogen from petroleum wells. Now, the HydrogenNowCast has many more listeners now than we did two years ago, and this is such an important concept that I wanted to bring it to everyone's attention a second time.

This underground hydrogen generation process not only creates no CO2 emissions, but it also has no fugitive methane leaks, like typical petroleum extraction does, because the petroleum never comes out of the ground, only pure hydrogen does. So I'll make a few additional comments at the end of the podcast, but for now, let's go on to the interview with Proton Technologies from the 2020 episode.

[01:57] **Brian:** Until just recently, there were basically two ways to make hydrogen: by Steam, Methane Reforming of natural gas, which generates CO2; or by splitting water with electricity into hydrogen and oxygen, with zero carbon emissions if renewable electricity is used.

But now there's a third way. What if we could pull just hydrogen out of petroleum wells and leave the carbon in the ground? Our interview today is with a Canadian company, Proton Technologies, that's doing just that. But it gets even better. It turns out that the process works with any wells, light crude, heavy crude gas wells, and even fracked wells. It actually works best with wells contaminated with water. Now, what's most exciting about this is that it gives all the oil and gas companies a zero-carbon use for their petroleum wells. Plus, it gives them an off ramp from the oil business and an on ramp to the hydrogen business. So now let's welcome our two guests for today, Grant Strem, who's the chairman of Proton Technologies, and Calvin Johnson, the head of commercial at Proton Technologies. Grant and Calvin, welcome to the show.

[03:01] **Grant:** Thanks very much. Honored to be joining you.

[03:03] **Brian:** Well, it's great to have both of you with us today, and we really appreciate your time today.

Through the course of the show today, we'll want to talk about, of course, the technology, that is, how to pull just hydrogen out of petroleum wells. And we'll talk about the business aspects, and then we'd like to know a little bit about the history of Proton Technologies, and that is how you got started and plans for the future. But why don't we start with you explaining the fundamental principles of the technology and maybe the history behind where it came from?

[03:31] **Grant:** Sure. I think the fundamental principles are fairly straightforward – it's oxidation of hydrocarbons, which is well known in furnaces, stoves, car engines, all these different things we're used to. But, of course, those all have carbon dioxide dimensions.

And the other thing that can be done is by actually, instead of taking these fuels to the receptacle, actually trying to move the oxygen to a fuel supply. And old oil field is a huge fuel supply that just can release a tremendous amount of energy if you oxidize it.

So there was a recognition from more than 500 projects worldwide that have injected air into oil reservoirs that hydrogen is always a byproduct within the gas stream. So we looked at that and thought, how do we turn this into a new concept where that's our target, instead of an evented byproduct or something that we have to incinerate and get dispose of, hydrogen is the main game.

So the easiest way to do that, in an emissions-free way, is by using downhole membranes that only allow hydrogen to pass through. So these downhole filters work as a system with oxygen injection into an oil field to allow only hydrogen to pass through up into the surface. There's still CO2 created as a part of the reaction. However, that CO2 can't make it through the filter, so it ends up trapped in the reservoir, forming carbonate rocks, carbonic acid, and participating in other side reactions and even diffusing in the bottom water.

So, volumetrically, it's something that people are already intrigued with and doing worldwide. Canada has some carbon sequestration projects that have been going on for more than 20 years. So there's a large industrial history of carbon capture and storage around the world, usually with a goal of enhancing oil production. But regardless, the best places to store $CO_2$ are in geological formations that have proven themselves that they can hold in a buoyant column of fluid, and they've already demonstrated it for millions of years, for example, oil and natural gas fields.

So those are some of the criteria we look for. We need to find something with a lot of fuel left in it (so unswept oil) and something that can contain the $CO_2$ that will be produced as a result.

And, of course, the infrastructure on the surface is a factor. If it's close to customers, that's ideal, or if it's close to pipelines, power lines, or any end use that can really use very significant volumes of hydrogen. And I think that that's another factor here. It's not just the cost structure, and I'll get into that more. It's the volume potential, the scalability of this process.

So oxygen is available in essentially unlimited quantities worldwide, and it's always easy to know where these remaining fuel deposits are. So to capture oxygen out of the air, and we do that through air separation units at large scale, it looks to be cheapest to use cryogenic distillation, which means cooling the air to -185° until the oxygen becomes a liquid. And then once you have a vessel full of liquid oxygen, letting it go through a one-way valve, warming it up just enough that it starts to expand and warm up and has a phase change back from a liquid to a gas. And that's the pressure. That volume expansion is what provides the pressure to get the oxygen down into the reservoir, so there isn't any additional compression of the oxygen to get it into the oil field. And in fact, the pressures that you can get up to are you're really only constrained and limited by how thick of pipes you can have on surface. The depth of the reservoir is not very relevant because that phase change.

So it's, I think, a fairly elegant solution where the fuel is essentially free for the life of the project. Most abandoned oil fields are – if anybody's claiming responsibility for them – a usually on the wrong side of the balance sheet. So there's somebody's abandonment liability, and if we can repurpose them for clean energy and as a giant fuel supply for making emissions free hydrogen, it's a win-win for everyone.

[07:55] **Brian:** Boy, this certainly is a win-win for everyone. I'm really excited about this technology. A couple of questions, though. How pure is the hydrogen that actually comes out of the well? Does it need a lot of further processing?

[08:07] **Grant:** The hydrogen goes through the membranes we use are actually a palladium alloy, and the only thing that can dissolve through the palladium is hydrogen. So it actually comes to surface in very pure form at large scale. Depending on how pressure vessels and things like that were evacuated, there might need to be some final filtration for surface contamination from air or things like that, but it does come out well, it has to pass through a palladium filter, so it comes out very pure.

[08:36] **Brian:** Interesting. So another question that I've been asked by people is how secure do we think the storage of the carbon is underground? Is that any kind of a concern, or does it vary by well, or how does that work?

[08:50] **Grant:** The situation is variable. I would say that as a general rule, you're looking for geologically stable areas. So if there is recent glaciation or an active fault system, you have to be a little bit concerned about what might be a possible pathway through. We're not over-pressuring the reservoirs. In fact, we try and operate everything below the natural virgin reservoir pressure so that we have no chance of breaking rocks that have proven themselves to not be broken at those pressures for millions of years.

But it does need an assessment, and as a rule of thumb, we abide by, in Alberta, there's something called Directive 86, where they had some steam projects break through the surface about 15 years ago. And as a result, they had these very strict and conservative, and I think highly useful regulations about cap rock integrity analysis. So, understanding the geomechanics of the overlying rock, making sure that there's no probable or reasonably possible path for the reservoir to come through to surface, that's an important consideration. So I do agree that that should be part of the analysis on every project we touch.

[10:02] **Brian:** Yeah, it sounds pretty secure. So the technology for this is my understanding, came, was it from the University of Calgary? Maybe. Could you talk about that development a little bit?

[10:16] **Grant:** Sure. So in "ancient history", I did a master's degree in mostly engineering courses. It was reservoir characterization. I'm a professional geologist and I sort of was doing the evenings and weekends master's program, and three of the courses I took were from a guy named Dr. Ian Gates. And we ended up staying friends for, I guess it was, I think it was about twelve years after the master's degree. We were out for breakfast one day at a Denny's and came up with this concept together. He said, grant, I was just looking at this paper and look at how much hydrogen this Marguerite Lake project created in 1983, and it was getting up to 40 mole percent hydrogen. The data is really interesting. And my jaw dropped. I said, “Ian, if we had a way to only let the hydrogen through some kind of filter, then that hydrocarbon reservoir, an oil reservoir, is hydrocarbons, hydrogen and carbon. And the other fluid down there is H2O, water. So there's hydrogen. It's a very hydrogen rich system that's energy dense”. And so Ian said, I think I know of a material that we could use as that filter.

So we did a bit of homework, and then some hired two law firms, actually, to do prior art searches, and they came up with nothing that this process could have been sort of derived from previously. So we ended up taking these older technologies, and I mean separately, distinct technologies. So there was, injecting oxygen into oil fields was always done with a mind to warming them up, to reduce the viscosity of the oil and thereby being able to flow more of the oil towards a production well bore. But those always had hydrogen as a byproduct in the gas stream. And then in the separate industry, the hydrogen production industry, there was a steam methane reforming process that basically perfected a lot of these various types of palladium alloys. So we're using old alloys that 80 years ago were preferred because they didn't allow H2S to cause the palladium to swell and crack. So we're using old fashioned technologies, but combined into a new process. So that was kind of the realizing that we could patent that and build a business around. It was essentially the genesis of our business five years ago.

[12:39] **Brian:** Well, this sounds like one of those ideas that we can look back on and say, why didn't we think of that sooner? Kind of like wheels on suitcases.

[12:47] **Grant:** Yeah, it's often the simple things, isn't it?

[12:50] **Brian:** Yeah, absolutely. But that's all right. So why don't we maybe change gears a little bit and talk about some of the business aspects, and maybe we can kind of end up bringing Calvin in a little on this. So I think one question a lot of us think of when we hear about this is we're kind of wondering if proton technology is going to license these techniques, or do you act as a developer of existing wells? I mean, what's your business strategy on that?

[13:18] **Grant:** Well, I'll give you a little more of our history. Our initial intention was to strictly license out our technology to oil companies worldwide who wanted to get in on this. And we thought they'd be all very excited and jump at the opportunity. And we were very disappointed when, after a couple of years of knocking on doors all the time, we couldn't find anybody who would even let us give them a license in exchange for playing with a couple of their wells that they may not even be using. So everybody was worried about liability, and we were disappointed and kind of shocked.

So we ended up buying an oil field and doing it ourselves. We've done demonstrations of separation of hydrogen at surface, and we're increasing. I guess there's a technical program I'll go through a little bit more detail later. But the short answer is, we've come to the conclusion that it's very hard for a leopard to change its spots. We think that we have sold some licenses. So in nine countries we have sold the license. However, it wasn't to oil companies, it was to huge wind and solar companies and aspects like that. In a geothermal company, one that's chasing helium plays, there's different companies that were unexpectedly very interested and motivated to go on this new energy vector of clean hydrogen.

The short answer is we are in some discussions with licensed deals with oil companies, not huge oil companies, I should clarify, and I think we'll sign some of those. But oil fields are easy to get. Our main focus is to find a customer and to lower the cost of oxygen plants. So if our cost per ton of oxygen drops, and that is the main cost of our process, then the cost of our hydrogen, as a result can drop.

So instead of trying to go with off the shelf solutions, I think in the long term we will go off the shelf for the first probably dozen or more large-scale projects that we build with oxygen plants. But we are looking at if we're going to build thousands of these things and we need to reduce the cost of our oxygen dramatically, what do we need to do? So that puts us in a different direction. It's uncharted territory that oil companies don't have experience with. What they do have is assets that are useful and in many cases already an abandonment liability on their balance sheet.

So scooping up the reservoirs is kind of, I guess, a less important aspect to this whole trajectory we're bringing in. We want customers who are willing to sign up for very large-scale supply of hydrogen, and we want to be able to build very low-cost oxygen. And usually that's cheaper if it's all under one umbrella. So if we know we're building 2000, it's cheaper than if 2000 other companies are each ordering one oxygen plant. So we're looking at it that way, that the race to drop the cost even further is easier done if it's centralized. Calvin, would you like to jump in on the type of contracts that we're exploring?

[16:18] **Calvin:** Sure. Yeah, absolutely. Maybe what I'll do is just to briefly provide a little more background on the commercial perspective. I think the reaction from the oil and gas sector, I think up until this point, has probably been slower than we anticipated, as Grant has mentioned. And I think there are some reasons for that. It's no surprise that that industry in particular is at risk going through the energy transition and they've obviously had some financial difficulties probably over the last five years or so, I would say, and particularly this year.

So I don't think your average oil and gas company has a lot of money for, quote-unquote, commercializing hydrogen production or sinking money into R&D, although I think we're well ahead of the R&D process. I think also the oil and gas industry was, climate change debate has really been us versus them. And so I think what you've got is you've got this reluctance to kind of bring in the existing energy industry into and pivoting so that they can move forward with an energy transition and start decarbonizing. And up to this point, I think it's been fairly adversarial. I think our perspective is that as far as addressing climate change, it's all hands on deck and we're agnostic in terms of technology and pathways and approaches. But certainly by just saying to the existing oil and gas industry that you guys can't play in this sandbox, I think is just going to create a lot of reluctance. It's going to create a resistance to change. And there's a very significant amount of assets that are still up in the industry globally, upstream, midstream and downstream, and you're certainly not going to strand those assets. I mean, it's just when you look at every energy transition, whether it was from wood to coal to fossil fuels and so on, you're always going to be able to use the existing infrastructure. And so what this technology does is it helps kind of bridge the gap. And I think the industry have a pivot point in terms of the energy transition. And I think up until this point, the industry has kind of been grappling with the US versus them. And how do we actually have a strategy around hydrogen or a strategy around decarbonization? And hydrogen is certainly one pathway. So I think a lot of companies have been kind of in that space, if you will.

So from a commercialization perspective, our technology is very cost effective. It's disruptive, I think, to the existing SMR, well, the existing methods for making hydrogen, whether that's Steam Methane Reformation, or whether that's through renewables plus electrolysis, and we can produce it at significant scale. And our cost structure is so low that we're able to price our hydrogen off of other indices. So we can price it off of natural gas, for example, which would really be the feedstock cost for existing steam methane reformers. We can price it off of any other structure as well. So what we're currently in the process of doing is trying to commercialize that hydrogen market, if you will. And as your listeners are probably aware, most of the hydrogen markets these days are really on purpose demand.

So whether it's an SMR facility in a refinery, or whether it's in the ammonia or the agricultural market, or whether it's petrochemicals and so on, and certainly, when you look at all the different pathways for hydrogen, there's a pathway, obviously, I think, for fuel cells and growth and transportation, whether it's heavy transportation and so on. The good news about this technology is we don't have to wait for that to happen. We can start using the existing infrastructure today to start the decarbonization process. And so, given our cost structure, we are able to, from a commercial perspective, start selling hydrogen priced off of natural gas. And so we're in the market trying to crack that net open, if you will. And part of the challenge has really been finding large buyers of hydrogen. There's lots of bits and pieces of hydrogen here and there. We're really finding that things are still really clustered around demand centers. So we have to see how that hydrogen economy or that ecosystem continues to evolve.

There's other limitations as well. And I would say the ecosystem, from a regulatory perspective, still has to, I think, evolve. There's obviously some low hanging fruit in terms of blending hydrogen into the methane stream. I think most distribution companies could probably take a blend of 5% to 10% without any issues. They're doing a lot more of that, a lot higher percentages in Europe, you can blend into the power generation markets, you can start decarbonizing today. Part of the challenge is that whether it's pipeline companies or distribution companies, or they still have to go back to the regulator and say, well, there hasn't been a cohesive body of sort of hydrogen regulations. And then certainly over time, as you could say, okay, if we migrate completely to a hydrogen-based economy, can the distribution systems retrofit, can you put in hydrogen compatible furnaces and so on? So what we're finding is that there's still a lot of that, quote, unquote, infrastructure needs to, or that ecosystem, I should say, needs to get to the point where I think you'll have complete sort of large scale commercial production and consumption of hydrogen.

[21:12] **Brian:** Well, there's no question that as this issue of creating hydrogen and the demand for hydrogen are being ramped up and growing together, there's a lot of difficulties there. If you produce a lot of hydrogen, but the users aren't there, that's an issue. So I guess it'll remain to be seen how we solve that and start bringing things up together.

So I have a question about getting the hydrogen basically to market. As you guys know, and as I'm sure all our listeners know, transporting hydrogen is difficult. It's very voluminous. So by truck or by rail car, that's a problem. You can't transport much. There aren't a lot of pipelines, and they need special materials because of the way that hydrogen in brittles metal. Now, we mentioned earlier that the air is separated into nitrogen and oxygen, and so you've got some nitrogen you're producing. And of course, if you mix nitrogen with hydrogen, you get ammonia, which is a lot more energy dense than hydrogen is. Have you thought about, do you see that maybe as a possibility of turning the hydrogen to ammonia so that it's easier to ship?

[22:19] **Calvin:** I was just going to say absolutely. The good news about hydrogen, as your listeners are probably aware, is that there's a multitude of applications, and one of them is certainly the ammonia avenue. And that has lots of appeal and is kind of a quick win in terms of being able to not only help decarbonize the energy sector, but you can also start decarbonizing the agricultural sector as well. A lot of the ammonia production uses SMR. And so there's a huge opportunity to not only do at the margin, new ammonia facilities, so you can transport ammonia around as an energy carrier, but we can also start the decarbonization process in the agricultural sector, and there's numerous other sectors as well, electrification, power generation, oil operating, transportation, and so on.

[23:07] **Grant:** And as a further thought, the very front of our project is an air separation unit. So we have oxygen coming out on one side and nitrogen coming out on the other side. So it's co-located with our hydrogen production. We have a stream of pure nitrogen, and there's also likely to be some process heat from how we power the oxygen plants, the air separation unit. So there's a big efficiency potential here for us, in particular with our process, because we have nitrogen and hydrogen and power and in large volumes all in one location. So we have received a number of inquiries about the international shipping market. So the big bulk carriers, the huge boats moving goods from one continent to another, and huge ocean liners, a lot of them are talking about the challenge of decarbonizing has a volumetric challenge when you're talking about basically gaseous hydrogen. I think liquid hydrogen, a case could be made, but the existing internal combustion engine methods that are used lend themselves well and fairly easily to conversion to burn internal combustion ammonia. And in that way, there's no $CO_2$ emissions from these huge ships, which have a lot of emissions. So that's viewed quite broadly, and there seems to be a lot of interest in the potential for low-cost ammonia to power these huge ships.

So, yes, ammonia is a market that we're looking at, and I think it's going to be a mix of things through time. I think there's an elegance to liquid hydrogen storage and fuel cells. But I can understand the practicality of incrementally shifting towards a different form of internal combustion. And that's not new either. Somebody forwarded me an article about buses in. I think it was in, oh, what country? Off the top of my head, it was a European small one, Wales, maybe, and they ran on ammonia, internal combustion in the 1930s, however, through diesel, sort of grabbing global market share faster than they could. I'm not sure if they had the worst solution, technically, but often its economy of scale wins the day. So ammonia hasn't been a popular transport fuel for a while, but it does have a history.

[25:30] **Calvin:** I would also add that there's numerous other pathways as well. Once you've kind of got hydrogen, you can obviously start combining it with other things in the periodic table. So to the extent you theoretically could compare it up with negative emissions in some respects, but getting carbon from. And there's some technologies, I think, that are already being deployed in British Columbia in that regard. But you can certainly start pairing that hydrogen up with carbon and creating environmentally like, emissions-free diesel so you can recombine those molecules and still use the existing energy infrastructure. The only question is, what is the cost and efficiencies and all that kind of stuff throughout that, through all the various pathways? The good news is you're not really reinventing the wheel. So, for a refinery, for example, that's co-located in the right area – which is mostly around existing oil and gas reservoirs, and most of them have probably been depleted – you already have this existing infrastructure that you can start utilizing to either take an ammonia pathway or maybe do oil upgrading, or maybe even, like I said, combining it with negative emissions carbon to create diesel and other products. So it's got all of those pathways that are kind of on the table, which I think is the attractiveness of hydrogen, frankly.

[26:40] **Grant:** One other versatility that we intend to take advantage of, to a large extent, is also the existing power line grid all around the world is very, very interesting. One example is a coal-fired power plant that has a huge transformer, all its permissions, and it's grid connected and sitting idle because of emissions problems can be repurposed, typically to burn pure hydrogen. And that's in the existing burner. And it boils the steam through a separate steam loop, just as it would. Instead of burning coal dust, you burn hydrogen. So there are a lot of these different ways, even dedicated new steam turbines and other large scale installations, to basically power the grid with clean hydrogen power. And I think whether people are in favor of cyber trucks or hydrogen pickup trucks, either way, at the end of the day, if it's the lowest cost way to electrify the grid in a clean way, it's going to be a meaningful portion of the transportation network.

[27:45] **Brian:** Right. Well, I really think we're going to see in the future that petroleum is not replaced by one other substance like hydrogen. I really think we're going to have a mix, which I call the energy triad of electricity and hydrogen and ammonia. And the ammonia may not even be used as a fuel. You may decide to crack it back to hydrogen and use hydrogen, but it may be a lot easier to move around and a lot more efficient to move around the ammonia than to try to transport the hydrogen. So be interesting to see how things evolve in the future. So, one thing we didn't talk about is what I would call the technology readiness level of your techniques. I know it's based on very old technology, so I would think it's ready to go. But is development complete? And now, are you really kind of in the deployment phase?

[28:34] **Grant:** Yes, we're already making hydrogen. Unfortunately, we're just burning it in our incinerator. So large volumes of hydrogen today and worldwide throughout the last hundred years from projects like these have made a lot of hydrogen. So, as mentioned, the individual elements are very long industrial heritage types of situations, and ours is just combining them in a new way so that they work together as a system to give us clean hydrogen. So the short answer is yes, we're scaling up in Canada. People that we've sold license deals to overseas are scaling up. I think you'll see some big headlines coming out of Australia in relation to that in the next few months, for example. And, yeah, we're doing it. It is commercial. Calvin, do you have further thoughts on that?

[29:23] **Calvin:** Yeah, I mean, I think I would say is path has always been to show us the path to commercialization and show us how the projects, the technology has been de-risked. The good news is when you're just recombining existing technology, if you will, and repackaging it and repurposing it, you're certainly eliminating a lot of that. The amount that you have to de-risk is significantly lower. So we continue to work on building more data sets, more hydrogen production. We're working on scaling up projects now to significant projects. We'd like to target our next project to be probably 500 to 1,000 tonnes a day of hydrogen production. And so we're working on all those commercial paths. And like I mentioned earlier, I think some of the challenges really are the ecosystem. I think everybody's interested, everybody understands it. Everybody sort of gets the benefit of hydrogen, its flexibility, and how it can be widely used for a variety of different pathways. The challenge is that I think we're still waiting for the regulators to catch up. So whether that's existing codes or whether that's methane blending into pipelines or blending into power generation and so on, we're sort of fully commercialized, I would argue, at this stage, or, well, we're commercialized. What we're trying to do is take it up to the next step, to scale up to massive projects.

[30:36] **Brian:** Right. Well, I think there's no question that trying to develop the market for the hydrogen users kind of in lockstep with the hydrogen generation, whether it's even electrolysis or from wells like Proton Technologies is doing, that's really the hardest part, is to bring those two up together. And really, that's one of the reasons that we formed the Colorado Hydrogen Network, was to try to start engaging the hydrogen users in sync with deploying the hydrogen generation. So that's the name of the game. We've got to get some users developed out there, and the more the better. I think I'm out of questions. Is there anything else that two of you would like to add that we haven't really covered?

[31:15] **Grant:** I've got a couple I'd like to push. One of them is that at the fundamental level, I always like to make it clear that personally, my feelings about CO2 are not strong. What I do have a very strong feeling about is air pollution, and especially air pollution in concentrated population centers like cities where we know that millions of people a year die from air pollution. COVID is nowhere near the number of deaths this year as air pollution. And to not take this seriously, I think there's an on-line clock website that's showing we're over 7 million deaths this year. If there's about 7 billion people, that's a one in 1000 chance that any one of us in any given year is going to die from air pollution. And I think that that's. I don't know how we don't talk about this more, but it's a significant factor in why I personally am working really hard to try and get everybody using hydrogen as fast as I can because there was a terrorist group that was that good at killing people. At that rate, we would spend a fortune trying to stop that. We have a way to save money and stop all those needless deaths. I don't understand why we aren't all rallying together to try and do that. The other point I'd like to leave you with is if any of your listeners have an ability to blend large scale volumes of hydrogen into their methane stream at a cost per gigajoule identical to their methane stream, Calvin and I would love to hear from you.

[32:52] **Calvin:** I think there have been a lot of false starts in the past with hydrogen, but I think the ecosystem has improved. And what I mean by that is the ecosystem is really the energy transition, ESG requirements, certainly deflation in terms of renewables, increased capital availability, you hit capital tipping points and you've got rights, law and learning curves and all that stuff. But probably, perhaps most importantly is policy support is increasing. So hydrogen is probably $170 billion a year, industry and probably growing, and there's massive policy support for it. So we think the hydrogen era is here. It's different from some of the false starts, if you will, in the past, and we're commercializing it. So, yeah, we love to talk to large scale hydrogen buyers.

[33:34] **Brian:** All right, well, to that point, why don't you tell the listeners the best way, maybe to get more information about Proton or to contact you.

[33:42] **Grant:** Our website, ProtonH2.com, is a source of information. And if you'd like to reach out and contact us more directly, info@protonh2.com is a good email address to use.

[33:58] **Brian:** Okay, and I will say from experience that going through the info works because that's how I contacted you. So obviously you are listening and responding to people with inquiries. Anything else before we close?

[34:11] **Calvin:** Not from my perspective. I think we've covered everything.

[34:14] **Brian:** All right, very good. Well, listeners, I will also put a link to Proton Technologies on the Colorado Hydrogen Network website, which is www.colorado-hydrogen.org. And I want to thank you both again for your time to be with us today.

[34:33] **Brian:** So that concludes our repeat broadcast of the interview with proton Technologies, but I'd like to add a few comments. So the first is that during the recording in November of 2020, we didn't cover the fact that in addition to producing no greenhouse gases whatsoever. This underground process from proton Technologies is able to sequester three times as much carbon dioxide as the hydrogen that's extracted. So the process can be substantially greenhouse gas negative. Now, the way this works is that carbon dioxide, along with oxygen, is injected into the well. Now, the carbon dioxide becomes locked into the minerals within the well, and only pure 99.99, which is four nine s, hydrogen, is brought out of the well through a palladium filter.

[35:21] **Brian:** Now, the second point is that throughout the world, there are abandoned oil wells that need remediation. Now, for example, in Colorado, there are over 20,000 such wells. Now, this method could be used on most of these abandoned wells with two benefits. First, wells that need remediation to stabilize them would receive the care and attention that they need. And secondly, and most importantly, it would turn liabilities into assets. Now, it's my understanding that around the world, about half the petroleum ever pumped out of wells still lies in the ground because it's not economical to recover it. Now, this process gives a way to turn that vast amount of petroleum into hydrogen. Now, granted, this isn't a sustainable process, because eventually the petroleum will be depleted. Yet it's the lowest cost way to generate hydrogen. And with zero greenhouse gas emissions, electrolysis is not the only way to create zero greenhouse gas hydrogen.

And my last point is this. I'm often asked, if this down-well method of generating hydrogen is so productive and so inexpensive and so green, why aren't we seeing it everywhere? And the answer is simple. There's no market for the hydrogen. You see, although this down-well method of generating green hydrogen produces hundreds of tons of the lowest cost hydrogen per day, it costs millions of dollars to set up the well, plus the capital equipment. So unless you have a huge hydrogen off-taker from the very first day of operation, it doesn't make business sense to proceed.

Now, an electric utility with the turbine that's converted from natural gas to hydrogen could be the initial customer. But the technology for converting gas turbines to hydrogen is just being developed.

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If you'd like to contact me, I'd love to hear from you, and you can reach me through the website at Colorado-hydrogen.org or on LinkedIn. So until next time, this is Brian DeBruine wishing you health and prosperity and happy holidays. Goodbye.