Podcast #51 – Direct Air Carbon Capture Using Algae

[00:25] **Brian:** Hello, everyone and welcome to Episode 51 of the HydrogenNowCast for April 29, 2022.

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Today, I'm pleased to have Richard Sayer, PhD, who's a biotechnology scientist formerly with Los Alamos National Labs, and we're going to talk about biological carbon capture and sequestration. So Richard, welcome to the show.

[01:25] **Richard:** Well, Brian, thank you very much. I'm very pleased to be here.

[01:28] **Brian:** Well, thanks, Richard. We're so appreciative of your time to talk with us today. So I think probably one of the best places to start is with you giving us your background with LANL. And for listeners, Los Alamos National Labs is known locally as LANL. And then, Richard, why don't you also tell us how you came to be involved with biological carbon capture and sequestration?

[01:52] **Richard:** Okay, well, I'm going to actually start a little bit earlier than LANL, about three years earlier, in 2008. In 2008, I was recruited to the Donald Danforth Plant Science Center in St. Louis to be the first director of the Enterprise Institute for Renewable Fuels. And this is sponsored by Enterprise Rent-A-Car , which is a local company in St. Louis.

And while I was at the Danforth Center, we had an opportunity to apply for a major US. Department of Energy grant program called the Energy Frontier Research Centers. And so one of my first jobs was actually to put together a team of research scientists to apply for this Energy Frontier research program. And we were actually successful in getting one of the 40 Energy Frontier Research Centers that were actually awarded by the DoE.

The focus of our program was on biofuels, and more particularly on using plants and algae to produce lipids, which are the highest energy density form of fuels, other than hydrogen, on a mass basis, which could be used in a carbon negative or carbon neutral way to drive transportation. And so through that experience, we started to develop algal systems that would have improved photosynthetic efficiency.

So in any biomass to biofuel conversion process, one of the major constraints is always yield. It's the same thing, of course, in agriculture – it's all about yield. And one of the upsides, actually, of working on algae is that algae naturally have about five times the biomass productivity or CO_2 sequestration capability of land plants. And that's due to a number of reasons. Most simply, every cell in algae, and most of these are single-celled algae, is actually photosynthetic. It's capturing light, using that energy to reduce carbon dioxide to carbohydrates or lipids. And that's in contrast to plants where actually only the leaves are doing photosynthesis. So there's a large fraction of the plant, the stems, the trunk, in the case of trees, the roots that are not doing photosynthesis and essentially serve as sinks for carbon that's actually captured through the process of photosynthesis.

But in addition, algae actually have more efficient photosynthesis than plants. They are able to concentrate CO_2 from the atmosphere, directly from water inside of the algal cell. And by doing so, they can actually saturate the enzymes with CO_2 that convert that eventually into the algal biomass. Plants can't do that, with the exception of a few types of plants called C4 plants. But most plants are much less efficient than algae.

And so we started working on algae as a way to make biofuels more efficiently than in plants. And in my lab in particular, we are interested in how to improve the efficiency of light utilization. So 75% of the light at full sunlight intensity at noon is actually wasted in photosynthesis. The light is still captured by the pigments, the chlorophyll molecules in the leaves and in the cells. But most of that energy is reemitted as heat rather than being used to do photosynthesis. And the simple reason for that is that plants actually hog light. They try to capture more light than they can actually use so that they can out compete their competitive plants. And so by shading their competitors, they can actually be more evolutionarily fit and grow faster. So there isn't actually an evolutionary reason for why plants are so inefficient, but if you want to produce biofuels or eventually sequester carbon, you want to make that process even more efficient. And so we went about doing that.

And as a result of those studies that we were doing, and through interactions with others, I came to know Jose Olivarez at Los Alamos National Lab. And in 2010, under the Obama administration, there was a major influx of research dollars for the American Recovery and Reinvestment Act to support the development of biofuels. And so there was a national competition for a $70 million program to optimize from cradle-to-grave all of the components of making biofuels from algae. And we won that award. And Jose Olivarez was the executive director. I served as the scientific director. And through the relationship that we built, I was eventually then attracted or recruited to go to Los Alamos lab.

And so in 2011, I moved to Los Alamos, and there we built a brand new laboratory – state of the art laboratory – that was almost entirely focused on biofuels and carbon sequestration. And there I also led a number of other research programs. But perhaps the greatest accomplishment of that large DoE program is we moved the price point for making fuels and this is cradle-to-grave, again, from cultivation all the way to the oil refinery from $150 a gallon gasoline equivalent to $8 a gallon gasoline equivalent – and we did that in three years. Subsequently, the other programs that actually served as director, we moved that price point to around $2.50 a gallon gasoline equivalent, where it more or less stands today. So it's now approaching parity with petroleum, which was our overall objective.

Now, one of the advantages of working in biofuels is you're producing an end-product that's very carbon-rich. These are lipids, which are then eventually converted into what we call biocrude. And these lipids actually have 30% greater carbon density than does carbon dioxide. And they can be moved and transported around the country through the existing oil field infrastructure of pipelines. And in fact, our biocrude can be reinjected back into the ground to serve as a permanent reservoir of sequestered carbon, with the added advantage that this sequestered carbon can serve as a strategic energy reserve that is, again, carbon neutral and can provide multiple functions.

So recognizing that we could also use algae not only to produce biofuels, but to produce a biocrude that could be buried essentially in existing oil fields, we then refocused our attention on using algae as a way to sequester carbon dioxide and do that very efficiently with the existing infrastructure. So I think that sort of gives you an overview of the transition from biofuels, actually, to trying to sequester carbon permanently by bearing it in the deep wells.

[09:14] **Brian:** Wow, very interesting process. And interesting, too, how it started out as just looking at creating biofuels and now really, I think it seems like - it sounds like - the focus is more toward, as you say, trying to capture carbon that we don't want in the atmosphere, of course, and sequestering that.

So why don't we talk a little bit about maybe a little bit more of the details here, which you've kind-of gone into. But the idea is, of course, to capture from a concentrated stream of carbon dioxide rather than direct air capture. But let's talk a little bit about maybe just what this looks like physically and also talk about the inputs and the outputs and how much percentage of CO_2 from a stream that can be captured and some of those things and the light shifting, too, that you mentioned.

[10:01] **Richard:** Yeah, very good. Well, let's start with the cultivation. So, again, as I mentioned earlier, one of the major constraints that we recognize for making biofuels affordable, or for efficiently sequestering carbon dioxide, is all about biomass yield. It's the same thing that farmers are concerned about what is going to be my yield per acre? And we use the same metrics. What is our yield of carbon dioxide we pull out of the atmosphere per unit, land area. And as I mentioned earlier, algae are pretty efficient at that. But when we look at the thermodynamic efficiency of photosynthesis, it's only about 3%. So if you account for the energy coming in from the sun, only 3% of that energy is actually captured in the energy of chemical bonds that are formed when carbon dioxide is converted into lipids. So theoretically, we know that we can go as high as 11% efficiency. So that means three-to-five-fold increases in biomass yield, potentially. And so we started focusing on that. But to do this, we needed an algae strain that was actually very robust in open pond environments. And by being robust, that means it can tolerate wide ranges of temperatures, potentially wide ranges of salinity. But most importantly, the biggest challenge turned out to be actually pathology, and that is disease and herbivores, small organisms, microorganisms that will feed on the algae.

And so there was a major effort, really, in screening wild algae from all over the world to identify those that would actually be most stable in an open pond cultivation system. Now, fortunately, just in the last year or two, there's been a general consensus is that we're actually pretty close to knowing what that best algae performer is. And so once we've identified that algae that's quite stable, then the next stage is you go in and you make it even better. And that improves the photosynthesis and increases the amount of carbon that's sequestered. So that's sort of, we'll call that the first stage. The cultivation – there's always been sort of two schools of thought on how to do that – one is open pond and the other is closed systems called photo bioreactors. Now, photo bioreactors have the advantage that you can actually get higher productivity, but they have the disadvantages of very high costs and they're also very difficult to clean and manage at a commercial scale. So, in contrast, you get lower productivity in open ponds, but they're very low-cost and they're very easy to manage. And so, in our work through these consortia and doing lifecycle analyses, we came to the conclusion that the only financially operable system was actually open ponds. So that gets us to cultivation.

The next really important hurdle in all this technology was actually harvesting. So traditionally algae had been harvested by centrifugation. But you're talking about millions of gallons of liquid that have to be centrifuged to recover the algae that are found at only 0.1% of the mass of the water. So you've got nearly 1,000 times more water than you do algae. That's a lot of energy to get rid of that water and concentrate the algae. So, again, our lifecycle analysis told us what the optimal energy input should be to economically recover the algae. And it turned out that that number is what we call a 10% parasitic energy cost. And again, what that means is that you can only use 10% of the energy content found in the algae for the harvesting to be economically viable. And so we looked at 10 or 15 different systems, we did a lot of research on improving the cultivation system.

But now we have a system that actually meets that less than 10% parasitic energy cost, and it's essentially ultra-filtration, so using membranes to pass the water through and concentrate the algae, but to do that in a very sophisticated way. And so that solution now exists.

The third step then was how to convert that algae biomass into a fuel, or in our case, into a biocrude, which can be transported through the oil field infrastructure to be sequestered. And again, we looked at a number of different technologies, but we found one that worked really well. And this process is called Hydro-Thermal Liquefaction. And what HTL does, is essentially recapitulate what happens in geologic time when algae are converted into petroleum over millions of years at high temperature and high pressures. And so what the HTL apparatus does is under high pressure and high temperatures – so this is about 350 degrees centigrade – in a matter of 30 minutes, we can convert that biomass from the algae into a biocrude. And the biocrude is actually very close in its properties to petroleum. In fact, with one of our commercial partners who builds many of the world's oil refineries, they took this algae biocrude to the refinery and they found that it actually performed better than petroleum at being converted into the full range of fuels.

And so this HTL system was really a breakthrough for making biofuels from algae. But the other important aspect of the HTL is that there is a lot of water still left in the material. And what happens with that water is that the essential nutrients, the inorganic nutrients like nitrogen and phosphorus that are some of the most expensive inputs, those get converted into soluble forms in the HTL process and they partition into the water fraction. And so we can actually take the water fraction from the HTL and recycle it back to the pond so that we actually substantially reduce our requirements, if not eliminate them for nitrogen and phosphorus. And that's a very important aspect because it's part of the circular economy of making algal biofuels.

And that doesn't exist in land-based systems. Fertilizers are applied to the soil. And most of that, as you probably know, washes out in Mississippi, eventually into the Gulf of Mexico. But that's not the case if you do it with HTL and recycle those nutrients back to the pond. And so HTL made a big impact on biofuels, but also on carbon sequestration, because now we can take that biocrude that comes out of the HTL process and again put it back into existing pipeline infrastructure, transport it to dry oil wells and pump it back into the ground. So essentially, we're reversing what we've done for the last 150 years, where we've been pulling oil out of the ground. Now we're going to put it back in and refill those reservoirs.

Now, you've also asked about carbon dioxide. And carbon dioxide, as you might imagine, is actually a fertilizer for growing algae. The more carbon dioxide, the better. And so, in the biofuel models for algae, all of those models include high concentrations of carbon dioxide, which are injected into ponds. And that carbon dioxide would come from point sources such as cement factories or other oil refineries, or it could be beer or alcohol fermentation facilities, et cetera, any point source of CO_2, including coal burning power plants. And under the right conditions, you can actually get 100% capture of all that CO_2 that's injected into the water. And one of the nice things is when the carbon dioxide is actually injected into the water, it forms bicarbonate. And bicarbonate is no longer a gas. And so that carbon dioxide then is now a nongaseous form in the water, which is actually taken up by the algae. So high concentrations of CO_2 effectively act as a fertilizer, and you get enhanced growth.

So, the last thing I'll comment on as far as the technology platform is the idea of generating essentially or converting sunlight into more useful colors or wavelengths of light that can drive photosynthesis. So much of the solar spectrum actually will not drive photosynthesis. It's not absorbed by the chlorophyll molecules. Chlorophyll molecules basically absorb red light and blue light. So yellow light and orange and green, which the green, of course, is the color you see in the chlorophyll. Those are not well absorbed. Ultraviolet is not well absorbed. And then long wavelength infrared is not well absorbed. So one thought was, well, what if we could frequency-shift light that's not useful for photosynthesis to wavelengths that actually is useful for photosynthesis? For example, what if we could frequency shift ultraviolet light to blue light, which is thermodynamically downhill, by the way, and increase the number of blue photons that are available to dry photosynthesis? And it turns out that LANL had been developing a technology called Giant Quantum Dots, which actually does this at 100% efficiency photon-to-photon. And it doesn't break the laws of thermodynamics because the energy of the photons that's emitted is actually lower, but it's photon-to-photon.

And so these Giant Quantum Dots, which are essentially small metal particles – which are nontoxic metals, by the way – will capture the photon and then reemit it at a longer wavelength. And that frequency shifting then can be taken advantage of to increase the amount of light for photosynthesis.

Now, as I mentioned earlier, this may not make sense because I said there's already too much light for photosynthesis. But one of the tricks that we developed in our biotechnology program was we were able to adjust the size of the amount of chlorophyll actually in each cell and do that in a light dependent manner so that the amount of chlorophyll it's capturing light at low intensity is actually higher. And we do this by various genetic manipulations. What that allows us to do is actually more efficiently capture light and use it from high intensity light sources. And using this approach, we are actually able to double the amount of biomass that algae produce.

And so one aspect of the technology integrated platform then, was to incorporate these giant quantum dots as a film over the surface of ponds and actually provide even more light that can be used by photosynthesis more efficiently in these genetically engineered algae to produce twice the yield of biomass.

So that pretty well covers the integrated platform. But there were so many investigators, we had 50 different teams over the years involved in this and probably close to 500 investigators working on these integrated systems. But at this point in time, I'd say **we are capable of not only making biofuels that are very close to parity with petroleum, but we have a system now that can capture carbon at a scale that can remediate the atmosphere using algae.**

And just one last comment on that scale aspect. We calculated the land area of ponds that would be required to capture ten gigatons of carbon dioxide per year, which is a goal that's been recognized by the International Panel on Climate Change. And to capture ten gigatons in a system where we're actually making money – and I'll comment later on that – would require a surface area of ponds about the size of Texas, or 61 million hectares. Now, we’re not we're not going to cover Texas with one pond, we're going to break these ponds up into manageable units and spread them around the world from about 35 degrees north and south of the equator, which are the optimal areas for growing algae. But it's a doable space or area, and we now feel that biological carbon capture and sequestration can be done at scale.

[23:39] **Brian:** Well, that's fantastic, Richard, and so glad to hear that this can be 100% efficient. Now, I had assumed that you could only capture carbon from point source concentrated streams, like you mentioned – steel making plants, concrete making plants, cement making, those kind of things. Could this be used for just direct air capture?

[23:59] **Richard:** Yes, it can. And that goes back to the fact that algae are really efficient at taking concentrations of CO_2 – at low concentrations of CO_2 – from the water bicarbonate, actually. And they use energy from photosynthesis to actually pump that bicarbonate into the cell and drive it against a concentration-gradient. And inside the cell they convert it back into CO_2, which is what they use for photosynthesis. So that machinery is really quite efficient. There are some energy costs associated with that, but there's been a lot of research on how to make that work efficiently – actually, just in the last five years. And I'm confident we can capture CO_2 directly from the atmosphere efficiently as well.

[24:45] **Brian:** Very good. So maybe to just back up a step here and just talk about the big picture. So basically, the inputs are, of course, light, which drives the photosynthesis. There's the carbon dioxide, which could come from the air or from a point source and then of course, water – and I’ll come back to the water in a second. And then the outputs are the biocrude. But I think also you hadn't mentioned this, but from the algae you can also produce animal feed and then other what are called kind of industrial co-products. So those three outputs give you the income stream-funding basically to keep producing this. So talk a little bit about the type of water that could be coming into this and used and then talk about those three products that come out. And I think that kind of leads us into the economics of this.

[25:37] **Richard:** Yeah. So starting with the water, there are two potential sources of water. Of course. One is fresh water and the other is saline water. And in many lifecycles and technoeconomic studies, the investigators came to the recognition that really the best place to site these ponds is near oceans, and particularly in flat areas, near oceans that are of low value and importantly, very near existing oil field and oil transportation infrastructure so those costs are reduced. So sighting near the oceans allows you to recycle water and to have really a virtually endless supply of water, of course, from the ocean. And so evaporation issues, which are one of the major concerns in any algae production system, are really minimized because you replace that with water that comes from the ocean.

So that's the most economically feasible way to manage water. Now, that doesn't exclude using fresh water, but I think one important point that many people probably intuitively would not recognize is that the amount of water that's lost through evaporation from a pond is really one and a half fold less than what happens in a cornfield. And the reason for that is that plants lose water through their leaves. And if the area of the leaf is actually substantially larger than the area of the land (and that's called leaf area index) then the evaporative surfaces are actually much greater than the surface potential evaporation. And that's what happens in crop plants. They actually have three times the amount of surface area as the land on which they're growing. And so they're losing water very, very fast, in fact, faster than open lakes and oceans because of this increased surface area. But of course, at night they're not doing this. So you have to cut it in half. So then you end up with about one five greater loss of water from a cornfield than you would from an algae pond.

That being said, of course we want to minimize water losses from algae ponds and recycle as much water again as possible. So in our HTL process, as I mentioned earlier, and in our filtration processes, we really recycle all of the water that we can and our major losses and are only restricted to evaporation. Now, in the future, there may be the application of film technologies or covers over ponds that will further reduce the water loss. But freshwater loss is still a concern. But largely that issue is addressed by siting your ponds near the ocean.

Now, on the income-stream side, in our analysis of this carbon capture and sequestration system, we set an objective of actually trying to make the whole process profitable. And we felt that was critically important because if you can make carbon sequestration profitable, then the government doesn't have to get involved – a it's managed by private industry. And if you can do it without carbon credits, even better because there's a lot of uncertainty right now about how carbon credits are going to be managed and what the payout is on carbon credits.

And so to make this economically profitable, we have to give up something. And of course, that's the carbon that we're burying in the ground. There's no profit there. But if we produce co-products that have value, and if the value of those co-products is high, then we can actually, potentially make this profitable.

So, as you mentioned earlier, there are two streams of co-products that we looked at for generating income, and one is animal feed. Animal feed was chosen because we can take concentrated algae, dry them, and use them directly as animal feed for cows, chickens, fish and sheep. It turns out that pigs don't like algae very much, but in our earlier studies, we showed that algae – dried algae – actually performed as well as soybean meal for cattle feed, for example.

And so if we assume parity for the price equal to soybean meal, we can generate $200 a metric ton from algae just using it as animal feed. So the question then is how much do you want of the algae do you pull off to make animal feed? And it turns out it's roughly 45%. And then you're getting close to making a profit.

But the final component to generate income is actually high-value co-products. And these are things like industrial enzymes in particular, or organic materials that are often used in cosmetics or in biomedical applications. And so the value of those products generally is in the range of about $75 a kilogram or up to $150 a kilogram. And we identified several products that we could produce in ten-kilogram quantities per metric ton of material produced that would actually get us to profitability in conjunction with producing the animal feed.

So the models are out there, they are on paper, they are lifecycle and technoeconomic analysis, but we now recognize that the highest value is actually from the co-product. The lower value is either the biofuels or the zero value is sequestering, the carbon in the deep oil fields. So there is a pathway to make this work.

[31:29] **Brian:** Well, I'm listening here, just getting really excited because this makes technical sense, and it sounds like it either absolutely does make business sense or could make business sense. Now what about using wastewater and oilfield water and getting paid to do that? Does that help the economic model as well?

[31:49] **Richard:** It does very much, and I'm glad you brought that up. Coming back to the freshwater first. So municipal wastewater is a great resource because it's generally just dumped into rivers, and it's rich in nutrients that are required for growing the algae. We actually did a study for the government of Kuwait, where we looked at the municipal wastewater coming out of Kuwait City in terms of its volume and its nutrient content. And we estimated that if we took all of that freshwater waste and used it to grow algae, we could produce enough algae biomass and convert that into animal feed to meet over 60% of the protein requirement in the diet of the Kuwaitis if we fed it to fish, for example, for aquaculture. So wastewater is a great resource not only for maybe making biofuels or sequestering carbon, but in agricultural models – particularly in desert regions where wastewater is that a premium – can be a very high value input into the system and generate income through a combined effort of producing animal feeds, and then perhaps with aquaculture, producing high value meats, that generate a lot of income.

So that's one attractive use of wastewater. The oil fields, as you're aware, particularly in the Permian basin, actually the largest fraction of the material that comes out of the well is often what's called “Produced Water”. And this is ancient water from the oil beds, from the seas of those oil beds. It's high salinity, it varies a lot, and dissolved inorganic content. And this produced water is a problem that the oil fields have to deal with. They have to remediate it, in other words, remove the carbon and re-inject it back into oil fields. And there's a great cost associated with that. And so one of our partners, actually, in New Mexico, looked at the feasibility of using Produced Water to grow algae and had very good success with it. So there is an opportunity there to use Produced Water. The one challenge with Produced Water is you still have evaporation, of course, going on, and so the salinity potentially will increase to some point where it's not manageable anymore. And so there has to be a way of mitigating the salt as it concentrates. And there are various ways of doing that, and one is obviously dilution with fresh water, but the other is to make what are called dry-down or blow-off ponds where the water simply evaporates and you're left with a salt cake, which then has to be dealt with at some point. But there's a lot of opportunity in in working with undesirable water sources, and I'll leave it at that.

[34:50] **Brian:** Okay. Well, thanks, Richard. I'm listening to this, and it sounds to me like this is technically very feasible. It sounds like it financially makes business sense. Then I start to think about all of the press releases I hear where people – especially environmental organizations – a say, oh, baloney, There's no such thing as carbon capture. It's not a real thing, it doesn't work, it's inefficient, blah, blah, blah. What do you say to that? Do you say, well, they just don't know about this and they're wrong?

[35:21] **Richard:** Well, that's the quick answer, but it's not the diplomatic answer.

[35:27] **Brian:** Well, okay, but what is the diplomatic answer? Because I've said so many times in this podcast that our technology is changing so fast that we all have to update our opinions weekly. And this sounds like a good update. What do you say?

[35:41] **Richard:** Yeah, well, there's another bit to this story, and that's the history of algae and algae biofuels. And there was a great influx of investment and a lot of hoopla about making biofuels from algae back around 2010. And a lot of start-up companies got into this space, and they all went under – every one of them. So then there was the pushback. “Well, you told us that algae was ready for prime time, well in reality, it wasn't ready”. Those companies took on a lot of risk by using the existing technology that was available in 2010. And honestly, it wasn't there. It wasn't ready to actually make this work financially. And so I think part of the reticence from the investor community and also environmentalists is, well, let's look at the track record. And it's not been good for algae.

Now, all that being said, the needle has moved tremendously in the last five years, and that was largely through the investment of the Department of Energy. They have to get a lot of the credit for that. **But I'm at a point where I'm more optimistic than ever that the technologies that I shared with you are now off the shelf. They are commercialized. HTL is now in commercial production. The ultrafiltration systems are in commercial production. The algae that can grow continuously for nearly a year without a pond crash due to a pathogen or an herbivore are now in production. And that's all just happened in the last three to five years**. And we've also figured out how to make algae grow faster by two to three-fold. So a lot has happened, and as you know, there's often a lag time between new technology developments and their commercialization and translation into something economically viable. My rule of thumb is usually takes 20 years from a really good patent until it's actually in place and being used. And that's what needs to happen. And so I think the story needs to be told to the investment community and to government institutions around the world that we're really ready here. We know how to pull this together now, and what do we do to make it happen? And that's the hard thing. It's hard to get folks excited about it for some reason, but that's where we are right now.

[38:26] **Brian:** Well, I'm excited about it, and I'd like to think that a number of our listeners, which probably includes venture capitalists and others, are excited. So let's talk a little bit about the commercialization here. I know you were involved with a group that was called Kontra Carbon, which I love that name, it's K-O-N-T-R-A new word C-A-R-B-O-N. So where are we on the technology readiness level? The TRL. And who is . . . I understand you're going to be doing some other things . . . so are some of your colleagues going to be trying to promote this and get a company going or find some investors? Let's talk about the business parts of this.

[39:04] **Richard:** Yeah. So Kontra Carbon . . . thank you. So Kontra Carbon was really an integrated approach to bringing the technology platforms I described earlier together in a way to make carbon sequestration profitable. And one of the drivers actually for Kontra Carbon was the Carbon X prize that Elon Musk announced the winners, the early winners today. So we put together a team of 20 companies, universities and research institutes that would integrate all the technology platforms that I've described previously on the cultivation side, the harvesting, the HTL, and the high-value and low-value co-products. And these were the best people in the industry. One of the upsides of being in the industry for so long, as I have the go-to players that I can call up and say, we want to do this in a coordinated way. And they all bought into it and they all lined up. So we assembled this team or consortium and then we set out to find investment. And the unfortunate thing is we ran into walls. We could not identify the appropriate investors. We actually asked our consortium members if they could put up some seed money to get us off and going, but they were unable to do that for various reasons and prior commitments. And so our management team then was faced with looking at the only option to fund this was the Carbon X-Prize. And in the application for the Carbon X-Prize, most of the weight for the evaluation of any proposal focused on lifecycle and technoeconomic analysis. Now the unfortunate thing for our consortium is that we didn't have access to the standard software programs because they were very expensive, and we didn't have the investor input at that time to actually carry out the lifecycle and techno economic analyses that were required by the X-Prize. So we were unable to make a credible application for the X-Prize. So at that point then, when we realized that, which was about three weeks before the X-Prise was due, we got together as a team and we discussed what our next steps. And we came to the realization – two realizations. One is that to actually make a business model out of Kontra Carbon, it probably wasn't a good idea just to form a coalition or consortium because investors would say, well, anybody can form a consortium – where's the value in your consortium? And we came to the realization is that if we had value in the consortium, it had to be IP. We had to generate our own unique IP around our systems. And we had some ideas, and we still have some ideas about how to do that. And that mostly comes back to the yield issue because that's the one area that has the greatest opportunity for improvement. And by yield I mean both the biocrude that goes into the ground as well as the animal feed and the high value co-products. How do we increase their yields? And so there definitely are ideas around that.

But while we were discussing how to make Kontra Carbon a better business model, our management team all had counter-offers from other start-up companies and they scattered to the wind as CEO’s of other companies. So unfortunately, we sort of disbanded. We have a model in place. We have a consortium that we can call upon. We have ideas about intellectual property that would be unique to the Kontra Carbon story, but then it still comes back, how do we raise money to make this happen? And so these are ideas that can be shared with the appropriate types of investors or others who may be able to carry the ball farther than we carried it. So we're in a transition right now. We're waiting sort of for something to happen, but I'm not sure how fast it's going to be.

[43:29] **Brian:** Well, so obviously any great idea that's going to move forward needs a champion. It needs somebody to really lead it and take it forward. Is there anybody left from Kontra Carbon that is willing to do that? Or do you just basically have the pieces of the puzzle here that you'd like to somehow hand off to somebody else to take forward?

[43:49] **Richard:** Well, I'll take credit for Kontra Carbon. It was actually my conception. And the intellectual property that we could help monetize Kontra Carbon with is IP that centers around some of the technologies that I described earlier that we developed in our own lab. That's where it was about six weeks ago. I've had a little bit of discussion with some carbon credit blockchain groups actually, that are looking at ways of generating income through trading in carbon credits. That may be an angle to go. And so I'm still talking to people in that space, but I'm somewhat unfamiliar with it. So it's a bit of a challenge on the blockchain aspect of this. The irony is that blockchains use tremendous amount of energy and emit a lot of CO_2 as a result, so how does that work anyway? So I'm happy to talk to people if there is interest and see if something can be pulled together. But all the pieces of the puzzle are identified. It's a matter of pulling it together right now.

[45:13] **Brian:** Okay. And one of the things I asked you last time we talked was this has been proven at scale. And by that what I mean is, a lot of times something works really well in the lab, in a test tube. And then when you try to do it at swimming pool size or a pond size or acreage size, things fall apart. Has this has been proven to work at the large scales?

[45:34] **Richard:** It's been proven at a pilot scale, and by pilot scale, I mean a pond area about one acre in size.

[45:43] **Brian:** Okay, well, that suits me, not knowing that much about it. But well, I guess so if maybe to sum up where we are in the business part of this, if we've got some listeners out there, whether they're venture capitalists or investors or entrepreneurs or whatever, they ought to contact you and just maybe see where this could go?

[46:03] **Richard:** Yeah, I'd be happy to entertain ideas.

[46:09] **Brian:** Okay. And I can certainly put your contact information in the show notes, but do you want to just give an email address? Does that work?

[46:18] **Richard:** Yeah. So I can be reached by email at richardtsayre@gmail.com.

[46:34] **Brian:** Okay, very good.

[46:35] **Richard:** Thank you.

[46:36] **Brian:** Well, Richard, I want to commend you for taking this at least this far. To me, this sounds like it has a lot of hope to really do some serious benefit for the planet and hopefully we can find somebody to take the standard and run with it. So, listeners out there, if you're not sure, maybe give Richard a call and talk. You might find out, maybe it is something you want to try to take on. And again, I'll put the information in the show notes or you can find me through Colorado Hydrogen network on Linked-In. Reach out to me as well to try to connect you with Richard. And by the way, listeners, don't try to find Kontra Carbon on a web search. You'll come out up with some shorts, some pants, men's hiking pants is all I found under contra carbon. So they've already grabbed that name. Maybe there's a patent or a trademark infringement there, I don't know. Anyway. Well, Richard, what haven't I asked you that you want to mention – anything else?

[47:35] **Richard:** Oh, this has been a great interview and very thorough, so I appreciate questions and your insights and also the opportunity to share our thoughts with you about using biological carbon capture and sequestration to not only mitigate atmospheric CO_2 and address the challenge of climate change, but potentially make this into a business as well. So, thank you very much.

[48:02] **Brian:** Oh, absolutely. I'm so happy to do it and appreciate your time to do this. And listeners, if you've got any inkling about trying to pursue this a little bit, please do contact Richard. We need help. We need people out there who are willing to take this forward. So. Alright, Richard. Well, thanks again.

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And lastly, if you'd like to contact me, as I mentioned earlier, you can reach me through the website at colorado-hydrogen.org or on Linked-In. So until next time, this is Brian DeBruine wishing you health and prosperity. Goodbye.