THE BREAKTHROUGH

Alex Trembath: Welcome to another episode of Breakthrough Dialogues, the podcast for pragmatists and problem solvers brought to you by the Breakthrough Institute. I'm Alex Trembath, Communications Director at Breakthrough.

Emma Brush: And I'm Emma Brush, Managing Editor of the *Breakthrough Journal*. Breakthrough Dialogues invites leading thinkers to talk technological and modern solutions to environmental problems. It's part of our effort to move beyond the tribalism and polarization that too often characterizes environmental thought in politics today.

Emma Brush: So, for this episode we sat down with Julio Friedmann, who may be the world's leading thinker on carbon capture technologies. Julio will convince you, or at least come very close, that tackling climate change will require that we capture, utilize, and store a lot of our carbon emissions, and indeed that we're much closer technologically and institutionally to be able to do that than many people might think.

Alex Trembath: Julio Friedmann, thanks for joining us.

Julio Friedmann: Thank you for having me. This is a treat.

Alex Trembath: So a lot of people who might follow you on social media know you as the "Carbon Wrangler." That's your handle on Twitter. Give us your elevator pitch. What is carbon wrangling?

Julio Friedmann: It's really three things: Keeping carbon emissions from the air and oceans; taking them out of the air and oceans; and making a circular economy where that carbon is used and restored. I had an epiphany in Marrakech. I was at the side bar of COP 22, which was really not much fun, but that side bar meeting was fabulous, and at the end of it, it all came together. I said, "I'm a carbon wrangler. This is what I do."

Alex Trembath: Also, you mentioned before the show that you were a fan of our first podcast interview with Charles Mann, whose book was *The Wizard and the Prophet*. You said you think of yourself as a bit of a wizard.

Julio Friedmann: Thank you, I do. I consider myself a wizard tribe. I also, though, work with many prophets in the field. As he said on your podcast, bridging that Cartesian gap is difficult work, but since we both have the same goals in mind, both tribes should be able to contribute and I'm glad to traffic back and forth between them.

Emma Brush: Who are some of these prophets, and how do you traffic with them, among them?

Julio Friedmann: For me, a really good example is somebody like David Hawkins, who I revere. David's been at National Resource Defense Council for many years. Armond Cohen at Clean Air Task Force is another one. And these people understand the limits of a petri dish, using Charles Mann's example. Their response to that is not to say, "Eat your peas. Change your lifestyle," but they simply say, "We have to start changing aspects of what we do." And one of the things that I like about both of these guys is that they are very open to new ideas, and they are very open to technical approaches that can help solve the fundamental constraint problems.

Emma Brush: Okay, so speaking of technical approaches, you've worked at Exxon, you've spent many, many years at National Laboratory's Department of Energy. How did you go about wrangling carbon, and wizarding in all those places?

Julio Friedmann: I spent a lot of my time actually developing and fielding projects and technologies to store carbon dioxide underground, and to understand how that works. Then later, to actually capture it mostly from concentrated sources, things like power plants or cement plants, or something like that. One of the things that you realize quickly is that those technologies are actually pretty mature.

Julio Friedmann: After about 10 or 15 years, I was like, "There's nothing left for me to do in this space." So the technology exists and it's already priced competitively. The difference though, that I realized, is those projects and those technologies couldn't be financed. The reason they couldn't be financed is because the policies were not in place to enable project financing. So I spent more of my time doing that. In part, when I was working in

government at the Department of Energy, but also in part of what I'm doing now.

Alex Trembath: So, I want to get to the policy horizon and the potential for market deployment of CCS technologies, but something you just said I feel will strike a lot of listeners as surprising or counterintuitive, the idea that carbon capture is a mature technology. I feel like actually often carbon capture and storage gets lumped together with other technologies like nuclear or even further field technologies like hydrogen that are not widely deployed in the world today. The contention is that we don't have time to wait for these technologies to be deployable, to be ready, that the climate targets that we're trying to hit, we're going to hit them too soon so we need to rely on the more mature technologies: solar, wind, batteries, whatever. What do you say to that?

Julio Friedmann: Hogwash. I can't be charitable to that perspective, on two grounds. First of all, we don't have enough time and I certainly agree that we should put the foot to the floor on things like renewables and efficiency and conservation. Unquestionably, those are good investments; it's also not sufficient. We are all on the clock and winning slowly is the same as losing. What we need is a bigger boat, to quote Roy Scheider from Jaws. We need more options, we need additional stuff, and in fact if we want to go after carbon emissions, then regulating carbon is the most obvious thing to do.

Julio Friedmann: The first carbon capture technology was described in 1930 and fielded in 1938. If you've ever drank beer or soda pop, you're drinking CO2 that was captured by a capture device, almost certainly in a power plant. The first pre-combustion separation was done in the 70s. The first multimillion ton injection of CO2 was done in the 70s. For 20 years we've been injecting carbon dioxide under the North Sea, just to keep it out of the atmosphere. We've known how to do these things for a very, very long time. What is not mature are these integrated systems, but we've got 20 of them or so. 17 is the actual number working around the world. More to the point, what is not mature is the financing mechanisms and policy. But if in fact we need to deeply, swiftly reduce our emissions, here's an interesting thought: go after the emissions themselves.

Alex Trembath: Carbon wrangling.

Julio Friedmann: Carbon wrangling.

Alex Trembath: I think the other problem that people have with CCS is the moral hazard problem. The idea that if we can just capture the carbon from coal and natural gas plants, and industrial plants, then we are sending a lifeline to the fossil fuel industry and we're getting ourselves off the hook from having to deploy zero-carbon technology. That we won't have to deploy solar, and wind, or nuclear or whatever as fast, if we can just capture the carbon from existing facilities. Is that moral hazard problem, a problem?

Julio Friedmann: I have a hard time with that specific philosophy. It essentially says there is only one right way to lose weight, and that's my way. And the problem is that that's not true in many markets. There is a whole bunch of markets where renewables are going to be the winner. And we have put 20 years of investments into those, in terms of cost reduction and policy and additional support, and that's great. So in California we might never deploy CCS at scale, and that might be okay. But it's not okay in Saskatchewan, it's not okay in Northern China. There are big parts of the world where they don't have good renewable resources, or where those renewable resources are just not competitive. Said differently, the Intergovernmental Panel on Climate Change is pretty clear about this. 7 out of 11 of their models, never solve without carbon capture and storage. They can actually solve without expanded renewables and they can actually solve without expanded nuclear. But they can't solve without CCS. Part of the reason why is industrial emissions, but part of the reason why is that thing that I was talking about, in some market, CCS is the thing that matters.

Julio Friedmann: For the 4 out of 11 that do solve, the cost goes up over 150% or so. And it's the same thing. You actually have to waste capital shutting stuff down, and spend more capital building stuff that has low efficiency or low success. We'll see what the next IPCC report lays out, but those results are very robust. We've seen this result over and over and over again. And it's not just the IPCC, it's MIT, its the International Energy Agencies, it's the World Economic Forum, these groups keep doing the same thing. Stanford. They all get the same result, and so I can't be cavalier about that, because I care about tons in the atmosphere. If you can stop the tons, that's a win.

Alex Trembath: I feel like another part of this conversation that has gotten a lot of attention in the last few years is bioenergy with carbon capture and storage, what we call BECCS on the internet. What's your take on BECCS? I feel like a lot of other folks attach this same moral hazard or modeling question to BECCS, that it's a sort of get out jail free card for deep decarbonization. That if we just assume that we can grow a lot of

bioenergy, burn it in power plants, and then capture it, then in a model, that's a really easy way to fix the CO2 problem, but in the real world, a lot of people are skeptical. So where are you at on BECCS?

Julio Friedmann: Well, how much time have we got? Because you've unlocked a lot of things that I have a lot of problems with, but let me start with the big one. Which is the way that these things are modeled. There's kind of a cottage industry out there now of people who just throw rocks at BECCS, and the reason why is because they way that it is modeled is not very sophisticated. They took a kludge of a biomass module in the models, and they took a kludge of a CCS module, and they threw them together like a Reese's Peanut Butter Cup and said "That will handle negative emissions." It is not meant to be an accurate representation in the world, nor does it represent all the other technologies that pull CO2 out of the air and the ocean, including planting trees, including direct air capture. So, the fact that those models come up with funky results, is kind of beside the point.

Julio Friedmann: With respect to the moral hazard position on this, I object when people say these models rely on BECCS. It's the opposite. BECCS is a consequence on the constraint of the model. When you say we gotta hit a 2 degree world, guess what? 87% of the models require negative emissions. And those models, by the way, end up getting to price points of $600 a ton, $700 a ton; at that point, a bioenergy plant with CCS is in fact the cheapest option. And it goes after the hard-to-scrub parts in the economy — things like planes, fertilizer and soils, these are things that we don't really know how to get rid of yet, in terms of managing the greenhouse gas budget.

Julio Friedmann: So negative emissions is a mathematical consequence of the way these things are configured. It's not that the politicians rely on it, or the models rely on it. It spits it out because it's so hard to get there and if you think that's true for the 87% of the models that do 2 degrees, wait until they get the 1½ degree report later this year. That moves the timeline for carbon removal even closer. Right now, we have to start doing this at a billion ton a year scale or so, sometime like 2030. That's two senate cycles. That's really close. 2030 is not far away. It's going to be before I retire, we're going to have to have a billion ton a year industry to pull CO2 out of the air and oceans. So, if you go for 1½ degree, you have to move it even closer, and that means we just need to get going. We need more oars in the water.

Emma Brush: Well, so there has been some recent progress on the negative emissions front. As you've written much about, Congress recently passed carbon

capture tax credits. Can you please tell us a little about why we should all be so excited about this?

Julio Friedmann: Absolutely, and I had a small part in this. A big part of the credit actually goes to what is now the Carbon Capture Coalition, which is a whole group of NGOs, and companies, and scholars who came together in support of getting policy done. The most important thing this does is it creates a market opportunity. That's the thing that the matters most. Up until February 8th, you just couldn't make money building a plant. You'd have capital outlays upfront, and people would build these things and they'd keep losing money. Now there is at least some market, somewhere, in the form of tax credits that allows you to get paid if you do a project like that.

Julio Friedmann: One of the things that's important about it is now an explicit price on carbon. They're saying that it costs about 50 bucks a ton, so we're going to pay you about 50 bucks a ton if you keep it from entering the atmosphere. That's for sale information storage, but if you go to a power plant, or a cement, or an ethanol plant, or a refinery, or a biomass plant and you capture that CO2 and store it underground, you can get paid 50 bucks a ton in the form of a tax credit. And, that tax credit is good for 12 years. So you can literally take that to the bank now, you can get a loan to build the plant, because you have revenues and you didn't have those before. I'm very excited about that, because something has now gone from not viable to viable, commercially. And that means that private capital is going to start flowing into the research and development, we're going to ratchet down the costs. That means there is going to be tax equity exchanges that are set up by lawyers, and by financiers and all that stuff which was necessary to get renewable energy to it's current point of excellence is now available to some part of the carbon market.

Alex Trembath: And you think something like the new tax credits for carbon capture are fundamentally different from other technology or climate policies that we have instituted in the past, things like tax credits for renewables, or renewable portfolio standards. So what's so special about tax credits for carbon capture?

Julio Friedmann: It's simultaneously radically new, and kind of the same. So, the kind of the same part is essentially a production tax credit. So it functions like the wind production tax credit, which means if you do the thing you're supposed to do, you get paid. In this case, the thing you are supposed to do is not emit. That's a distinction, because unlike past tax credits where you

get paid for, say, generating power or generating some material product, here you get paid for an environmental outcome where you're not emitting. In that case, there's a further dimension that's even more radical. Because the point is, that is explicitly then a price on carbon. Strangely, this congress has said it is somewhere between 45 bucks a ton and 50 bucks a ton to not emit. That's the social price on carbon and that is very close to the Obama and the Bush estimates for the social cost of carbon. So, that's the thing that's radical. The thing that's radical about it is we're saying, we are going to provide a tax credit for an environmental outcome.

Julio Friedmann: The good news is, the people who were getting into this knew what they were getting into. There's a whole bunch of other outcomes that they want too. One of those is a clean manufacturing center. We're going to have the lowest carbon footprint for manufactured goods in this country by a lot. For ethanol, for cement, for steel, for plastics, for all these things we're going to have the lowest carbon footprint. They also know that there are going to be jobs that are in this. Communities at risk are not going to be at risk anymore. And there's an opportunity for heavy equipment manufacturing, for export, that are going to be supported through these kinds of tax credits. So, it is a very wide platform, but it augurs in on carbon, and that's the thing that's different.

Emma Brush: What kind of emissions cuts are we talking about? You know, if we had ideal implementation and all these kinds of settings and also enhanced oil recovery, which is also kind of a point of this deal. What would we be looking at?

Julio Friedmann: So, for the easiest stuff, you're going to be going after the pure sources of CO2. And we did an analysis from the department of energy and you can get something like 40 million tons a year, from this "low hanging fruit." From this stuff that was close to a sink or an EOR opportunity or pipeline. 40 million tons a year is a lot, that's like pulling 8 million cars a year off the road, and we're going to get most of those. The reason why it's cause to capture and store is gonna be about 25 bucks a ton. So whether you're getting paid 35 or 50, you're getting revenue out of that. For a bunch of power plants, whether they're coal or natural gas plants, this will not be enough. Many of those will continue to run unabated, which puts them at risk.

Julio Friedmann: There are going to be a handful of coal plants and of gas plants though, which are close enough that it makes sense. They're close enough to that

price point. Or they're close enough that a public utilities commission can take on the extra cost in terms of a rate hike. Or there's some industrial ecosystem that requires them to function properly. So I'm looking at all these things come together: the International Energy Agency spitballs it at 10 to 30 million tons a year. I'm more optimistic, I think it's going to be more like 50 to 100 million tons a year. What's interesting is that with a little extra policy support, it could be a lot more than that. With a little extra policy support, with a more comprehensive representation, we could get maybe as much as 300 million tons a year. And that's a good prize, we should be shooting for 300 million tons a year.

Julio Friedmann: It might interest you to know that some of this is going to be written up in a report from the Energy Futures Initiative. This is not for profit organization and company where I work today. It was started by former secretary Moniz and his colleagues Joe Hezir and Melanie Kenderdine. We've been working up a report on some of this stuff and we hope to have it out soon.

Alex Trembath: We'll be very happy to tweet that report. So, the technology is in many ways there with some probable room for improvement. We've got some really promising policies now, another thing I've always really enjoyed hearing you talk about is what the hell we're going to do with the carbon when we capture it. What are the opportunities for markets around captured CO2? What are the opportunities for products made out of captured CO2? What are we gonna do with the CO2? What's the low hanging fruit for markets for capturing carbon, maybe in the next few years, next couple decades, and what are some more far-fetched or more expensive things that you could potentially do with captured carbon?

Julio Friedmann: So, in part because of the technology, in part because of the policy, in part because of the market pull, I'm telling you guys, carbon is the new black. Everyone is getting into this business. So let me tell you what we must do, what we will do, and what we can do. What we must do under all circumstances, we must do some storage. We just can't get the tons we need if we don't do geological storage. Because if we wanna get 300 million tons of CO2 in this country, we don't make 300 million tons of anything. Like we just have to store some of it. We will do a certain amount of enhanced oil recovery. And the reason why is because there's revenue and people understand it. If you use man-made CO2 to do that EOR, you truly decarbonize the barrel by about 60%. That's not my number, that's the International Energy Agencies analysis and it's pretty robust.

Alex Trembath: So you're not just capturing CO2 to burn more fossil fuels and produce more CO2? There is an actual, significant it sounds like, benefit to using captured CO2 to EOR.

Julio Friedmann: Right, and in fact, you can change the practice of EOR to get lower and lower carbon footprints. There are parts of the country already today where they are ejecting farm more carbon than is produced. And that carbon could credibly be called carbon negative oil, depending on how you do the accounting. That's a longer story and I'm sure some of your listeners will take me to task to it, but I'm happy to explain the math another day.

Julio Friedmann: That's what you must do, what you will do, I'm excited about what you can do. So, let me tell you about my second favorite thing in the world, which is coffee. So, when you roast a bag of coffee, you emit two bags of CO2. Most people don't know that but when you pulverize the beans, that's what you get. What is new is that you can take that CO2, turn it into a plastic, print it out on a 3D printer and a drink a mug of that coffee with the CO2 you just roasted. Like that's awesome.

Julio Friedmann: So let me talk about what you can do with CO2. You can basically put it into three classes of things. One of these things is cement and concrete, okay? And the nice thing about that is you don't need energy to do that. Those are exothermic reactions and so it's a question of the kinetics and you can actually just do that in an fairly straightforward fashion. And there's many companies that do that today, where you put CO2 into cement and concrete.

Julio Friedmann: The second thing you can do is you can put it into fuel or chemicals. So you can make carbon dioxide if you want to, into carbon monoxide, or methane, or methanol, or ethylene, or polyvinyl carbonate, or any other number of things. You can just turn into fuels, you can turn it into chemicals. There are in fact companies out there now that turn CO2 into diesel, that turn CO2 into gasoline, and turn CO2 into jet fuel. So, for that you have to put a lot of energy in. That, by the way, is a party foul for the second law of thermodynamics. You're putting more energy in than you got out in the first place. The thing is that we have so much low cost, abundant clean energy now, that that's no longer crazy. You can imagine arbitraging cheap electrons for higher value products and actually scrubbing carbon dioxide in that process. And there's a handful of companies that are doing that.

Julio Friedmann: The more exotic and interesting stuff, is stuff I call durable carbon. Carbon composites, carbon black like goes into tires, carbon nano fibers, diamond, all these things are made out of carbon. And so in fact, you have to put a lot of energy into it, but you can do it. And if you can get carbon dioxide into these kinds of durable carbon and we start building out of it, then there's an opportunity for disruptive architectural changes and new industries that I haven't imagined. A specific feature of this stuff that I love is that this can be done distributed. You don't have to have a big honking dow chemical plant in order to make this stuff work. The technologies today are born modular. You can pull CO2 out of the air modular, you can convert those CO2 molecules into stuff in a modular framework, that can be done electrolytically say with a reverse fuel cell or in a thermal process like Fischer-Tropsch or whatever, and then you can have modular production. So you can start to imagine a distributed manufacturing economy which is born out of carbon recycling. That's a great future and one I cannot wait for, which is why I am working to make it.

Emma Brush: Yeah, these sound like amazing opportunities and I think one of the most interesting things is the kind of shift in thinking about carbon, not as a bad thing necessarily. But we've also talked a lot about the Paris timetables that we're working to address, and also, I think you've referred to cinching our carbon belts a little bit. So, how does this fit into the wizard profit framework, to return to where we started. I mean, is there a way to think about carbon capture both as a kind of innovative, tech-forward opportunity and also a way to change our behavior and scale back?

Julio Friedmann: So I recently heard an economist say that the best marginal use of capital for society, period, is just to give money to innovators. And that is true to my wizard tribe, but I think it's true, we just need a lot more wizards. Because all of this will make the timetables for Paris easier, all of this will make it cheaper, easier, and faster. We still need the profits and we still need that work, but fundamentally, we do have to lose weight. We do have to cinch our belts. And in doing so, having more options and having those be more cheap, I think is always welcome.

Julio Friedmann: I was very pleased when at the Department of Energy to be present at the birth of Mission Innovation. And that was an overt effort by the Obama administration and 20 governments around the world, simulated in part by Bill Gates to put more money into inventing stuff we don't have yet. If we know we need it and we don't have it, we better get inventing. And the more of that that we can stimulate through these kinds of policy, the more

of this we can incent through new market mechanisms, the richer and happier our whole world will be.

Emma Brush: Absolutely.

Julio Friedmann: This also gets to a particular sticking point lying back on the moral hazard point. One of the things with moral hazard that we have seen already, was that moral hazard argument was used about 20 years ago to tamp down talk about adaption. People said if we even talk about climate adaptation it will disincent mitigation. Well guess what? We can't wait anymore and now we're paying for adaptation and we could've saved money and we could've made better investments if we would have just talked about it when we understood it. The same thing is happening now with carbon. The same thing is happening now with negative emission, carbon removal, and we'll probably have this conversation again in ten years around solar radiation management and geoengineering, where people will say it's too big a moral hazard! Well, do you want to lose the arctic or not? If you don't, maybe we need some of that.

Alex Trembath: Yeah, that's the thing that's bugged me about the moral hazard argument. I think it assumes two things that are very difficult to defend. The first is that fewer tools make the job easier than more tools. And the second is that we don't have enough time, we have to decarbonize now using the most widely available tools to do so, we're only going to be decarbonizing for the next ten years or something. We shouldn't be planning on innovating for the 20-30-80 year time horizon? So, that's always seemed just not to hold for water me.

Julio Friedmann: And the punchline is we need more. We need to spend more money on more kinds of things, and we need to spend more money on the things we already know how to do, right? And that's not crazy. Spending that money actually tends to stimulate jobs, it makes us more competitive, it provides optimism for the future. I don't see that as a truly resource related limited issue right now. There's lots more that we can do.

Emma Brush: Speaking of optimism for the future, thank you for that cue, where else outside of energy innovation do you see hope for the world?

Julio Friedmann: Well, I'm a fan of a number of things, among other things that you guys are a fan of. I am a big fan of intensive agriculture. This gives me terrific hope. Like you mentioned on your first podcast, the C4 Rice Project is an

awesome, awesome project and example of that kind of innovation. I'm enthusiastic about some of the speed and opportunity that's provided by social networks and by things like blockchain. I try not to get too silly about it, but fundamentally, there's grounds for optimism in that. A lot of the work that we've been able to get going in Carbonville, has happened because networks around the world have pulled together spontaneously through social media and it looks like money is going to start moving into these arenas through things like blockchain.

Julio Friedmann: I can't be upset about that. It makes me happy when I wake up. A wizard is born optimistic and when I'm in the shower and I'm having a good day that's the stuff I think about. I think about 3D printing, I think about advanced manufacturing. I think about materials by design in super compute. I think about human capital building and new curricula around these topics. I think about academic institutions creating whole new fields of research and whole new disciplines around this set of topics. And that's starting to happen. So, I'm happy a lot of the time. On my bad days I think about the Dilbert aspects of our silly inter-human interactions. That's part of the reason, again, why I have a hard time with the moral hazard argument. It assumes that social engineering is easier than engineering. I don't think we've ever seen that.

Emma Brush: Last question, Julio. What would you say your story is, in six words?

Julio Friedmann: I came, I saw, I carboned. Veni, Vidi, Vici.

Alex Trembath: That's fantastic, Julio, thank you so much for joining us.

Julio Friedmann: This was a treat, thank you for having me.

Alex Trembath: That's it for this episode of Breakthrough Dialogues, if you like our show, tell your friends, rate us on iTunes, and subscribe on whatever platform you get your podcasts. We want to again thank our guest Julio, our producers Alyssa Codamon, and Tali Perelman. Until next time, I'm Alex Trembath.

Emma Brush: And I'm Emma Brush.

Alex Trembath: Thanks for tuning in.