Stanford eCorner

Climate Tech Insights [Entire Talk]

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Sarah Lamaison is the co-founder and CEO of Dioxycle, which is pioneering sustainable chemistry by building breakthrough technologies that convert industrial carbon emissions into everyday chemicals with unprecedented energy and cost efficiency. In this presentation, Lamaison explains how her company fits into the future of carbon-capture technology, then shares advice for tech founders — especially in the climate tech industry —who want to build successful companies.

Transcript

(lively music) - Welcome everyone to Entrepreneurial Thought Leaders, 00:00:19,683 the Stanford Seminar for Aspiring Entrepreneurs. ETL is presented by STVP, the Stanford Engineering Entrepreneurship Center and Basis, the Business Association for Stanford Entrepreneurial Students. I'm Anthony Ruth. I'm the Director of Strategic Communications at STVP, and today I have the pleasure of welcoming Sarah Lamaison to ETL. Sarah is the co-founder and CEO of Dioxycle, which is pioneering sustainable chemistry by building breakthrough technologies that convert industrial carbon emissions into everyday chemicals with unprecedented energy and cost savings. In 2021, Sarah received a L'Oreal UNESCO French Young Talent Award for her research and CO2 conversion and received the French National iLab Innovation Prize with her teammate Dr. David Wakerley. She was selected as a Breakthrough Energy Innovation fellow, and that was in 2021 and featured in the Forbes under 30 list in 2023. Sarah also holds a bachelor's from Ecole Polytechnique in France and a master's from the University of Cambridge, and she carried out doctoral and postdoctoral studies between Stanford and College de France. Everyone, please join me in welcoming Sarah.

(audience applauds) - Well, hi everyone. 00:01:41,010 It's a great pleasure to be here and I mean, as it was said, I'm partly pleased to be here after spending two years here in between like 2019 and 2020, which were like really amazing research years with my co-founder, David. So yeah, very excited to to discussing what we have been doing so far. And so today my goal is for you to leave with like free takeaways. So first an overview of like the carbon utilization field and high level vision of the different technologies and approaches. Second, an overview of what we are doing in that field at Dioxycle. And finally, some learnings gathered in the making from myself as a researcher transitioning to a climate tech entrepreneur. So yeah, so first, what is carbon capture and utilization and why does it matter? So as you know, we do need to drastically reduce our carbon emissions and remove CO2 actually from the atmosphere to stay way below the two degrees Celsius trajectory. And so here, as you see in the background, the stripes, the color stripe represent the level, the atmospheric level of CO2 that have been going from 280 ppms in the 18 hundreds pre industrial area to right now 420 ppm, which is far above the 350 PPM level where you start to have adverse climate impacts and all these greenhouse gases effect. And so one question some of you might have here, if you're familiar with the question of like climate change is why have I put like two degrees Cs as a target and not 1.5 degrees Cs, which was the target set by the Paris segment in 2015.

And the reason is, I mean, quite sad and simple, it's because, I mean there is actually an open debate right now on whether we can still reach the 1.5 degrees Cs because like we have been too slow already over the past years at reducing our carbon emissions. And so it's really a question of now trying to limit this global warming to 1.7, 1.8 degrees Cs, which is already gonna be a challenge. And so, you know, how do we inflict that trajectory? How do we reach net zero by 2050? Well, I have a good news, which is the fact that the first answer to climate change is sobriety. And it's like each of us who can have an impact, you and me by changing our daily behavior and, you know, reducing the frequency of our flights, eating less meat and doing different things like this. And so this 5% is the projection of emission reduction we can target by 2050 by just sobriety. And so just to give you a few order of magnitude, today, on an average, the average carbon footprint of an American is between 15 and 20 ton of CO2 per year. And so we emit equally one ton of CO2 when we do one round trip flight between New York City and San Francisco, when we eat twice a week, a steak, beef steak, all of that for a year, or when we commute 15 miles per day to work for one year. And so by changing any of these behavior, by cutting down any of these, we can actually already diminish by 6% our personal carbon footprint, and of course even more if we do all these different things. The second path we have to reduce these emissions is through the massive deployment of existing technologies like electrification for industrial usage, for example, the deployment of the use of a heat pump in your house, or like the electrification as you know, that the, sorry, the development of renewable energy, developing solar or windmill. And so again, to give you a few order of magnitude by upgrading your house with a heat pump, you can save up to eight ton of CO2.

So quite significant, again, if you compare that to the carbon footprint of an American, or if we shift now to 100% renewable, our own electricity, personal electricity consumption, we can save up to four tons of CO2 per year. And the last thing, and here's, it's actually a picture of one of our lab. We have two labs, one in France in Paris, and one in Menlo Park. And the last option is by using technology that are currently still under development. And so of course we need to deploy massive research to deploy this technology so that they meet this 45% reduction target by 2050. And so as I said, these new technologies are gonna be needed to cut down the emission of what are called hard-to-abate sectors, which are the industries that are really difficult to decarbonize, that you cannot electrify easily, et cetera. And so these hard-to-abate sectors include the following, cement, steel and aluminum, aviation, chemicals, heavy road and shipping. And so for example, the reason why steel is hard to decarbonize is because in steel making, the first step of the process is actually the conversion of iron ore into iron. And so to do that you basically need to pull out an oxidant from your iron ore, and the way it's done right now, it's in big blast furnaces where you have a reducing gas such as carbon monoxide that is produced from coal institute that is gonna pull out this oxygen from your iron ore to just leave behind the metal iron. And so you're converting your iron ore into iron, but in turn you are emitting one molecule of CO2.

And so it's very difficult to decarbonize because now like your, I mean you have to really change the full process if you want to stop emitting this CO2 molecule, which mean reinvesting a lot of CapEx and really changing your infrastructure. And so basically the way we are gonna decarbonize these different industry, is either by developing completely new processes and so it's done in steel right now. I mean there are a lot of projects going on to replace these carbon monoxide reducing gas by hydrogen or by deploying sort of ADOC solution, which is like, for example, carbon capture utilization and storage also referred to as CCUS. And so in carbon capture utilization and storage, what happens is that you have a first step of capture. So you're gonna capture either like your emission on the point source. So as I was talking about like for steel, you would capture the CO2 emissions and it's very concentrated emissions, so it's kind of like energy efficient or you have another path where you're now capturing CO2 directly from the air. Of course it's much more diluted as a stream. And so it's much harder to do in terms of energy consumption. Once you have your carbon emission, your CO2, you're gonna transport that either through pipeline or through a ship. And you have two options.

Either you're gonna store it underground in geological formation on shore or offshore or you can utilize it. And so if we zoom in on the utilization, well there are many things you can do with utilization. So these are all the blue items here. And so the first thing you can do, which is the oldest way of using CO2 is using it as is. So basically you just take your CO2 molecule and you do something with it as is. And so the first thing, the most obvious thing that you can do is use it for food and beverages, for example, to make your soda sparkling. Then there are industrial use of it such as enhance oil recovery, where you're basically pumping CO2 down depleted oil fields to push more oil out of it and hopefully leave the CO2 in there. It's quite a controversial use of course, but it's not the topic today. And so like apart from using it as is, you can also convert it. And so in terms of conversion, I mean the use that requires the less energy is by mineralizing it.

So you're basically gonna convert your gases CO2 in a mineralized form. And this is often like useful to make additional building material. And if you're now like willing to do a product that is a bit upgraded, you can go to synthetic fuel, but of course it's gonna consume more energy, or finally you can convert that into chemicals. And so now if we zoom in again on the chemicals, it's actually very interesting and carbon utilization is particularly suited for the chemical industry to reinvent the chemical industry, which is the industry of carbon. You know, right now you can't make textile fiber, plastics, windows frame without carbon. It's a question of matter, you know, so that's really where carbon utilization makes a lot of sense. Reinventing a carbon cycle where you source like sustainably your carbon in order to invent everyday product. And so I mean, what is interesting about that, and a good way to phrase it, and hopefully you can remember that is, you know, the chemical industry cannot be decarbonized because it's the industry of carbon, but it can be de fossilized. And by this, what we mean is that, you know, when you look at today's in 2020, the source of carbon in the world's chemical production, you see that 85% of this carbon is coming from a fossil source. There's a lot of studies that say that, you know, by 2050 we could completely displace that proportion of fossil source of carbon with sustainable sources of carbon and really reach a world where, you know, your carbon come from either recycled plastic or material, but also carbon emission derived carbon and bio-based, I mean biomass derived carbon.

And so if we now zoom in again on this thing and really deep dive on how we can make a sustainable chemical, well the way to look at it is very simple. You just have to think about what is a chemical. A chemical is basically a long carbon based molecule, I mean a carbon based molecule that is filled with energy. And so understand where your energy come from. You understand how you can make a chemical and a sustainable chemical if your energy is sustainable. And so on this graph, basically on this diagram, I've represented just different sources of energy to make this chemical. So in light green, you see biomass fermentation, here your energy source is your biomass. It's already filled with energy. And so you can just basically take that biomass and further upgrade it to a chemical. Then on the dark purple you have the hydrogenation technology.

Here, the energy source you're using is hydrogen. And so you're basically gonna use hydrogen, combine it with CO2 carbon emission in a hydrogenation reactor, sometimes with some heat, some pressure. And you're gonna really use that energy carrier that is hydrogen, to reenergize your carbon emission and convert it back into a chemical. And so on the dark green diagram, this is biological processes. So here again, you can take carbon emissions, but this time you're gonna basically use bugs that are capable of sourcing their energy into, like sort of metabolic energy source. It can be a sugar, it can be anything in their environment they're capable of digesting. And with that energy, they're going to be able, again, to convert your carbon emission into a chemical. And finally, when your source of energy is electricity, well you're in presence of electrolysis. And so that's basically what we do a Dioxycle. So we develop breakthrough electrolysis technology to convert carbon emission using just renewable energy into sustainable feedstocks and in particular chemicals.

So I think by now you've understood that society does need to reduce carbon emission and still needs to produce cost effective chemical. And so that's what we are focused on with a big emphasis on the cost effectiveness of the process because, you know, if you really want to trigger fast adoption of a technology, you have to align economic incentive with the environmental incentive, or at least that's what we strongly believe at Dioxycle. And so the way we position ourselves is that we provide a solution to help carbon emitters decarbonize their process cost effectively by basically helping them to reduce their emission while profiting from the sustainable chemical they're producing. I mean, another way to present it is that we deploy this solution onsite, modular solution on site where we are gonna capture the emission and convert this emission into low carbon chemicals. And again, the big emphasis on what we are doing is that we are bringing this technology with a no or negative green premium, which is cost competitively versus fossil. Whereas all the current sustainable alternatives for this process have a green premium, which is an overhead cost compare to the fossil cost of your chemical, which is a thing. And so we start, as I said, with ethylene, which is the most produced organic chemical in the world used in textile fibers in PVC, in PE, polyethylene piping, plastic packaging for, you know, many different usage. And because of the size of the ethylene market and the carbon footprint of the ethylene making process, by displacing the way we are making ethylene, we can actually cut the equivalent of 1% of the world emission and look at a $170 billion opportunity. So it's really like an untapped environmental and economic opportunity. And the reason it's untapped is because it's, I mean, there's a huge barrier to entry, technological barrier to entry to actually do that cost effectively.

So our team, I mean we were introduced before, but David and I, we co-founded the company. So in January, 2021 after five years of academic research between College of France, Cambridge, and Stanford, and now we bring together 20 people. Some of them are in the room from 10 nationalities comprising 17% PhD because as I said, the biggest barrier to entry is technological. And we operate from two sites in Paris and Menlo Park. And so in terms of funding, we've raised 26 million to date, latest round being our series A led by Breakthrough Energy ventures and lower carbon capital and with the participation of Gigascale capital. And we were very lucky to be part of the Breakthrough Energy fellowship before. And so how does it work? So how does it work? So basically we developed this novel type of low temperature carbon electrolyzer where we fit in carbon emissions, water and these are gonna be exposed to what we call catalytic core, which are like active surface areas, which are gonna be able to convert this carbon emission into the product, the main product, ethylene, and some byproduct using electricity. And so each catalytic core comprises three elements, an anode that is doing an oxidation separated by membrane from a cathode doing a reduction. And so after we pile them, we pile this individual cells on top of one another in between these metallic plates that are called bipolar plates. And the roll of the bipolar plates is to funnel the reactant ins and the product out of this stack.

And so what's unique about us, apart from the product we are making in the electrolysis field is that we innovate at all level since day one. We had a very integrated approach, innovated on the component level developing high energy efficiency catalyst, super low cost membranes, at the system level by developing novel stack design, which are extremely energy efficient and reach high yields and a software layer also like continuously improving the operation of the stack. And finally, we also innovate at the industrial level by developing integration schemes to really like make sure we integrate these technology within existing processes so that we minimize the overall costs. And we also valorize trended assets, which are like the industrial assets you have on these plans. And so by doing that, we are the really, the first one to put forward the following value proposition, which is like producing sustainable ethylene at fossil ethylene price. And so if you remember my little diagram from before, if you want to produce sustainable ethylene, again, you have these four different pathways based on the way you're bringing the energy to make your final molecule, but as you see, none of them, whether it's like biomass from hydrogenation or from biological process, I mean none of them right now is cost competitive with fossils. They all suffer from a green premium. And on, you know, by contrast, we come in with like a value proposition of no or negative green premium, which again we believe is gonna be key to trigger large adoption. And so I mean this is again, a huge opportunity in terms of like environmental impact and economic impact, because right now ethylene is made through steam cracking of fossil feedstock, whether it's NAFTA or ethane. And the carbon footprint of that process is between 0.9 and 1.7 ton of CO2 per ton of ethylene.

Instead, not only, you know, by using our process, not only we cut down this process emissions, but we also are gonna now, you know, take some other carbon source from another emission and embed it into the ethylene so that the net difference between this process and the fossil process is between life free and five tons of CO2 per ton of ethylene we produced depending on the carbon footprint of our electricity. And so in terms of like total carbon impact potential, given that the ethylene production in the world is around 200 million ton, I mean you do the math, it's somewhere around 700 million tons of CO2 per year that can be displaced, which is over 1% of the world's emission, far over 1% of the world's emission. So that's what we do. And so now in terms of like the learnings, I just wanted to give you like a kind of unpolished, some unpolished opinions about the traps to avoid when you're starting a climate tech startup. So, you know, I was there before like you, finishing my academic studies and you know, the goal is to, I mean, what is success when you're starting a climate tech startup? Success is developing a company that is capable of cutting million tons of CO2 per year. So, you know, that's the definition of success. And so there's a lot of things that can happen along the way. And yeah, again, these are my opinions. So I think the first trap that we can fall into, you know, when you come out from school is that you think you know a lot of things because you went to a top school. And so I'm saying that laughing because, you know, it's actually a good thing sometimes to be very confident when you don't know a lot your industry because sometimes you probably wouldn't take the risk of starting a company if you knew like how hard it is later and how little you actually knew back then about everything that was waiting for you.

So I would say that is kind of the first trap that can happen. And so my advice for this would be to always keep an underdog mindset. And by this I mean don't assume that academic knowledge is real life knowledge, although it's very powerful, very important to have it, there's so many other dimension in the, I mean, in the rest of the world to optimize for and that are needed to have a successful career and to do something meaningful, that I think it's really important to keep this growth mindset and keep asking for advice all the time early on. A second thing I have perhaps for people joining companies early on, especially in startups, is don't care too much about the title. You know, I mean there's always a lot of like inflation around titles, but actually what really matters, I believe, is like the team you work with and you know, the mission and like how much you believe the team you're working with is capable of delivering on that mission. So I think that's really important. And the third thing I would say that is also probably quite controversial about salary, especially if there are MBA in the room. I've heard they were trained to like negotiate their salaries, is to not to negotiate too much, like salaries at the beginning, but instead like getting the company over deliver and then negotiate because we, you know, as a founder, I see that a lot of people in the company when they're in and they're delivering, they're so good at what they do, like you really don't wanna lose them and then they have much more leverage to actually like really ask for something. And, you know, if you negotiate too early, I would say that it's a missed opportunity for some startup where, you know, they perhaps don't have a lot of resources at the beginning, so they wanna make sure they don't take too much risks in terms of like hiring. And so yeah, I think that's an interesting way to look about it.

The second trap, I think, especially when you're a technical founder, is to start your company not talking to client until your product is ready. And so, you know, like in that case, I think, you know, you can get in the trap of, you know, working on your own to perfect the tech for a lot of years and actually going in the wrong direction, spending a lot of resources and actually doing something that doesn't answer any needs. And so my advice for that would be to just like start talking to clients and have this like very nice cycle where you talk to client, you make sure there is an actual need for what you're doing, then you look at technology as a mean to get there and really as a mean to develop a product. And then, you know, based on that you get some contracts or letter of intent early on that allows you to raise funds and attract talent to have more resources to develop your technology. And so as a result you're improving your product and scaling it up and you go again, you go back, see your client as that is this time your product is answering their needs and you improve based on that. So that was for the second trap. The third trap, and again, I think quite controversial is, you know, you've done all these things now, you've talked to all these clients, you've started pitching this to a lot of venture capital and now you like, you like talking too much and you lose sight of what you're here for. And so I think it's important to remind that, you know, climate tech needs much more science than talk. And by this I mean, you know, it's not a type of industry where like making an iPad where like the idea of the product itself is quite genius. Like here, the problem and the need to solve is quite obvious.

Like we have to reduce our carbon emission. Industrial players are happy to do so, but they need something costs competitive. That's quite simple. And the question is, who can do it like cost efficiently, energy efficiently, so that they will adopt that at a price that is competitive with what they used to do before. So this is I think, quite important. And I would say, you know, based on that, the main thing if you want to work in that field to do, is to really get technical, and by this I don't mean just scientifically technical, just like knowing your industry, understanding your industry, understanding even how like sales are done in your industry, but like really understanding your industry from like a process perspective, et cetera. And so I think that, you know, in climate tech, and it's pretty obvious, but technical breakthrough are the main unfair advantages. You know, you're always asked, "oh, what is your unfair advantages?" And in climate tech, I have hard time thinking of any other, like any other unfair advantage other than, a technical one so that you have something that just is actually better. The second one, I mean, the second thing also is I mean you see that when you talk to VCs and you talk to client, a working pilot, you know, is much more convincing than a slide. So it's also why I think really like trying to deliver technically very fast is really important and yeah, and so that's really important.

And so to be, again, a bit boring, but I think in terms of like thinking about a career being mission driven, when you really think about it, what does it mean? I think it's to really apply your skills where they are the most valuable. And so perhaps it doesn't mean founding a company and perhaps it means like joining a company that is actually already answering, I mean, working on the topic you're working on. When we started the company Dioxycle, there was one company in the US, I mean, most of what was done was in the US, in America, there was nothing in Europe. We wanted to start something in Europe. And so we were like, okay, perhaps we do have to start on our own, but you know, like we really ask ourselves, is there another force we can join to help before starting a company? Because there's a, you know, because there's a lot of hype around climate tech and I think we, I mean it shouldn't be because it's not really cool. It's just hard and it needs to happen. So we really have to make sure we allocate the resource where they're impactful. And then, so once we've done all this, I think one of the traps you can face is you don't ask yourself the hard questions. So now the problem is, you know, if you're a technical founder, a founder in particular, you have a technology you've been working on for five years, you really like it, you think it's really great and you know, you really want to push this technology and I think you have to make sure you don't blindly hang on to this technology and instead actually analyze it, compare it, benchmark it, and perhaps even change it if you need to change it. And I'm saying that not lightly.

And you know, at the beginning we started with David working on CO2 to CO, so conversion of carbon dioxide to carbon monoxide, which is a precursor for jet fuel. And so like we really pushed like the performance of the technology to top level, like we really delivered on the different milestone we have set for ourselves. And at the end of the day, we did the math, we did the techno economics, and even then with the best, like best performance possible, we realized, you know, perhaps it wasn't like so better than other options that people would actually take the scale up risk and pay for that scale up risk. And so at that point in the time, which was very early on, we were like, okay, let's go back to the drawing board. And we looked at the different products we could make and we decided to go to ethylene, which is a much higher added value product, harder to make. But we were like, if there's a play, it's there, it's where it's hard, where no other technology can deliver on that. And so I think that's really, really important. And not only you have to like coldly look at your like own technology block, but you also have to coldly look at the full process and make sure you look at the full process when you think about our technology electrolysis. So you're converting, you know, you're making a product, but it's like mixed with un-reactive carbon emission. And so, you know, there's always a question of, you know, you wanna separate this, these un-reactive reactant from the product.

And so there's a balance, for example, to strive between the yield of your reaction and the separation cost at the end. And so you want to really make sure you're analyzing your full process and not just focusing on optimizing one thing in the middle so that at the end you're really optimizing for industrially relevant metrics. And so I would say if you're a scientist, perhaps bringing a process engineer early on so that someone is really like telling you about the balance of plans, which is, you know, all the auxiliary systems that are around a central technology. So now you've made all this thing, you've bet on the right technology, it's working, but you know, you've made the analysis of the process and you realize it's still a bit expensive. And so one of the trap you can fall in right now is to think that people will actually pay more for a sustainable alternative. And they will probably do if it's like for, you know, like a customer product that is very high-end, but like most of these products, they have tiny markets. And so you're not gonna have a big carbon impact by addressing a tiny market. And so like the mistake is when you're like, oh, I'm gonna make ethylene or e-fuel and it's gonna cost like four times the price of fossil fuel and it's gonna be fine because people are gonna pay forever. The fact is, you know, perhaps the government is gonna subsidize for a while, but at some point the most energy efficient and cost efficient technology will have to win and you better be on the side of like the most efficient technology or have started doing something else at that point. And I think this, we can kind of summarize by this sort of diagram where, you know, you have on one side the goodwill and there is goodwill in the world.

That's great. And you know, climate philanthropies are in this category and it's really important the work they're doing. But I mean I think it's really important, but that's my opinion, to see business as a separate category and not try and mix these two categories and serially climate tech businesses in the business categories where you really have to have like economic performance in addition to your like sustainability performance. And I think the danger zone is in the middle, you know, and it's when people assume you're gonna have large long term green premium, which is like people paying much more a long time. And so that's, I mean, I was saying for sustainable aviation fuel, for example, well we really need to take the cost of making them down because I mean, are we gonna subsidize them forever? What is gonna happen? That's a good question. Of course if there's a price on carbon, then your non-sustainable alternative goes up in price. And so now you have a possibility of saying it's cost competitive, but we have to make sure that you are actually answering the right, I mean making the equation work. And so, yeah, and so now you've done all this, you have actually a business, I mean you're sure that if your technology is working, then the economic incentive will be aligned and then you have another trap that you can still fall into is that deep down, you know, you realize this technology won't scale, for example. So, you know, on the lab bench it's working and if everything scaled, then it would be working and it would be like viable. But actually it doesn't scale.

And then like, one of the problem is if you don't give up and if you keep going, and I think there's a cool citation quote from Phil Knight, the creator of Nike who says, "Sometimes you have to give up, sometimes knowing when to give up, when to try something else is genius." And I think it's true, especially in a climate tech where we really need people, I mean, we really need the talents to be funneled to the technologies at scale so that we meet our emission reduction goals. And so, you know, thinking about that, I've thought about like a sort of framework of what are the good reasons to quit and what are the bad, sorry, what are the good reasons to keep going with the tech or business idea and what are the bad reasons to keep going? So I think the good reasons to keep going are first this technology is fundamentally sound like, you know, like fusion. Like it's gonna be very hard, but you know, it can work and it's incredible what it can do and it just like can work fundamentally then the economics can work soonish or you know, or you have a plan to really back that up for a long time in terms of like funding. And finally you haven't tried everything, it's not working yet, but you haven't tried everything. And so there's still hope and perhaps, you know, you're one experiment away from nailing it down. So these are the good reasons. And now the bad reasons to keep going are probably like first in line, the sun cost. You've invested so much energy that you can't let it go. Like it's like five years of your life and you're like, oh my god, like if I stop doing that, what am I gonna do? And it's a terrible reason because like, I mean the the cost in the future are so much higher compared to the ones you've already paid for. Then you told the other it would work, so now you don't really wanna, you know, admit it won't work.

Or even worse, you told yourself it would work and you don't even admit to yourself it would work. So I think these are the thing with Dave early on, we've kind of made a promise that if, you know, one day we stopped believing that we could make this work, we would just stop and, you know, go work with a company that, you know, had a better idea like simply said and like, you know, that we would kind of watch out for one another egos getting in the way of actually doing something good in a reasonable timescale. So, okay, so you've passed all this, you still think it's gonna work and there's a final trap which is, you know, it can work, it's fundamentally sound, et cetera, but now you lose face because you're tired, you're really tired, you know, it's possible, but nothing is working in the lab and you don't know why. And yeah, and so there's a, I mean, a friend of my entrepreneur, Sebastian Boyer, gave me a good image to think about that, which is like the curse of complex systems. So, you know, you have to imagine your system when you're working on a complex technology as a sort of series of components and they're all in series. And as you know, from your electricity process, when one thing is not working, then the series line is not working. And so here on this graph, you basically represent the probability of a system comprising and component of working based on the probability of one component working. And so you see that when you have one component and equal one, it's very easy. I mean it's linear of course, but then as you increase the number of components, there are more and more probability that the series of components won't work at a given probability of one component working. And so you end up, when you have a lot of components you end up by having like a very long portion, you know, I mean a very long time where your system is not working, although you like incrementally optimizing each of your components and you have to really reach a threshold where, you know, above that threshold, above that like probability of working of one component, the series starts working.

And I think that's a very important thing and we had that a lot also at, I mean, at the beginning. I mean we still have systems that don't work and you know, you test one hypothesis, you think it's not like you think the result is negative, but it's actually kind of a false negative because there's still something else that is not working. And yeah, and that's really hard. And the answer to that is to keep pushing. And actually there's a second part to that quote of Phil Knight when it says, "Sometimes you have to give up, sometimes knowing when to give up, when to try something else is genius," which is "Giving up doesn't mean stopping, don't ever stop." And that's the answer to the last trap. Thank you. (audience applauds) Audience Member Hi, thank you so much for coming. 00:40:47,040 I'm curious, what are your thoughts on a public-private partnership and have you explored private partners like Generate Capital, which is a public benefit corporation that turns technology projects into infrastructure so customers don't have to take risks, they don't want to take or spend money they don't have to, for reference Generate Capital operates the electric batteries on Stanford's very own Marguerite buses circling campus right now. - Yeah, so sorry, I'm not familiar with Generate, 00:41:20,567 but well, I would say like public, I mean if you're mentioning a partly public funding, I think it's really important to bring in like both public and private capital, especially for like first of their kind pilots. I mean, for example, there's a, you know, a program Breakthrough Energy catalyst that fund first of their kind large plans.

And so it allows to de-risk a part of these plans for the industrial partner who is like co-funding the rest, I mean, it's not really public because it's a private institution, but it's like philanthropic money. So yeah, that would be my answer. I'm not sure. I'm replying, I'm sorry. Audience Member So for the audience, 00:41:59,670 I know a little bit, but if you were to frame your journey as you talked about starting in academia and where you are now in a pre-commercial, commercial on that spectrum of where are you on the journey of really generating revenue as a company? - Great question. So we are pre-commercial. 00:42:22,440 We do generate some revenues for like feasibility study and really early like customer engagement, but so the goal of our series A is to do our first industrial pilot. So that's happening now. Audience Member Hello Sarah, thank you so much 00:42:35,490 for your talk. I think it was very inspiring hearing kind of your journey and then all the traps that we can fall into as founders.

I had kind of two questions. What do you mean by being technical? Do you mean like pursuing a PhD in academia or spending like 20 years in industry? And then my other question, which you kind of touched on is do you believe that most people innovating in the climate tech space have to be coming from very like research heavy backgrounds or other ways in terms of like innovating business models or finding different paths to value? Yeah, - Yeah, great question. 00:43:16,500 So yeah, when I say technical, you know, I didn't say get scientific because I was actually on purpose try not to say like do PhD, that's the only way to get there. It's more like know your industry really well, like, you know, really understand like, I mean spend a lot of time in industry I think is a good idea. Like first, you know, especially on chemical engineering stuff, you know, you probably want to, I've done some process engineering somewhere, chemical engineering to understand how it works, which we didn't. But you know, so early on we were like, okay, we have to hire a process engineer, we have to hire someone who is very good at stacks, we have to do all these things. So I mean get technical in the sense that spend a lot of time really making sure you have all these skills in your team if you don't have them yourself. I would say though, like I think it's really hard to hire people who are very, very technical if you're not yourself like capable of really like pitching them something very strong. So yeah, any knowledge you can acquire is really good. Then you have other like version where, I mean other routes where you can start climate, I mean businesses which have a climate impact, which are a bit less technology heavy, but that's, you know, that's a different story and here it's more like you can start it if you have a great idea and that's easy.

I forgot your second question. I'm so sorry. Audience Member It was more, you kind of touched on it, 00:44:51,536 but are most like climate innovation based on like research and academia, like in terms of innovations or have you seen like successful climate tech startups where like the software space, like carbon markets or other like innovating like business models? - Yeah, I mean there's a lot of cool stuff to do 00:45:10,496 in the software industry as well then I mean carbon accounting, for example, is very crowded I think as a space. So yeah, I mean I've seen a lot of things that works very well, like watershed or things like these kind of companies, they're great. It's very different. I'm just saying you know like a lot of the things we need is also very, I mean very industrial unfortunately it represents a lot of like in terms of proportional of the emissions, it's a lot. So we probably need a lot of people to kind of sacrifice and go in there, you know. Presenter Thank you. 00:45:48,929 All right you guys, that is the end of today's session. Can we please give Sarah a round of applause.

(audience applauds) (soft music)..