Corn Saves America
Episode 7 – Over Promised, Under Delivered

Sarah Mock: This is Corn Saves America, a podcast exploring agriculture's environmental solutions, from ethanol to carbon markets. I'm Sarah Mock.

Happy Cellulosics Day! That's not a real holiday or anything (though admit it, it's believable that it would exist). Today is just the day that, after several episodes, of hinting at the topic of cellulosic fuel, we'll finally be digging into the other 16 billion gallons mandated by the RFS.

Let's get into it.

We have to start by understanding what exactly the cellulosic mandate was and how it came to be not just huge, but a billion gallons larger than the corn ethanol mandate, despite the fact that cellulosic technology was still nascent. Jeremy Martin, from the Union of Concerned Scientists suggests that this was a case of shrewd politicking particularly on the part of environmental interests.

Jeremy Martin: "Oh, 15 billion of corn ethanol? Oh, raise you, right, 16 billion of cellulosic biofuels, right." And so, I guess it's no accident that number was bigger. But that was, let's get to a billion gallons in the next few years, and then we'll really scale from there, right. And so, those two things were included in the same package, so, from my perspective in the environmental, kind of climate mitigation, there was a lot of focus on, "Okay, we're getting to E10, that's already baked into the system, but we need to get deeper emissions reductions, and we need to get these other feedstocks, the biomass feedstocks into the mix." So that we really can replace more oil and get deeper emissions reductions.

Sarah Mock: In other words, Jeremy, and many of our other experts saw the cellulosic mandate as the primary way that environmental groups planned to push the Renewable Fuel Standard forward, from what they saw as the unimpressive bridge technology that was corn ethanol to a future where cars and trucks ran on waste products.

So, what exactly is cellulosic ethanol? It's a biofuel produced from cellulose rather than from a plant's seeds or fruit. It can be produced from grasses, wood, algae, and lots of other plants. And though it's probably the most famous (or infamous) of the alternative fuels, the 2007 RFS actually identified two other categories of alternatives that are still mandated today - biomass-based biodiesel and advanced biofuels. We won't get much into these alternatives, but they're out there.

Though some RFS proponents saw corn ethanol as little more than the opening act to the main performance that would one day be cellulosic biofuels, not everyone shared that

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perspective. And according to Scott Irwin, ag economist at the University of Illinois, this - let's call it a misunderstanding - is not dissimilar from the disconnect between agriculture and refiners around the 10% blend level, and much of the controversy, between ag and environmentalists, today can be traced back to cellulosics.

Scott Irwin: I know for a fact that environmental groups think they're not going to get fooled again. They don't like the corn industry, the way we produce it here in the U S. mainly for what they see as big environmental problems caused by extensive modern corn production. And so, they really focused on, "Okay, we can accept these 50 billion gallons we're going to give to corn ethanol but the growth in that will fade real quickly and we're going to have this huge cellulosic ethanol industry built out of non-food, non-corn that will take over by now. And that's why they bought into it. I don't think the corn people ever thought that that was going to happen, but they were fine putting that in the legislation to bring those environmental groups along.

Sarah Mock: Whereas the ag industry was enthusiastic about corn ethanol, and refiners were relatively indifferent about what ethanol was made from (as long as it was cheap, of course), environmental groups have long been turned off by the idea of using corn starch, which is highly input and resource intensive to grow, to make fuel. On the other hand, alternative fuels made from waste had it all, less intensive, little pressure on land use, released fewer emissions, it was an environmental dream product that only grew in popularity as attention to global climate change escalated in the late-2000s and early-20-aughts. And cellulosics offered a promising narrative that there were other inputs besides corn, quote unquote wastes streams like corn stover or grasses, that could be used to make cleaner fuels. This vision was alive in the 2007 law, helping unite ag, refiners, and environmentalists under one banner. Here's UC Davis's Aaron Smith:

Aaron Smith: When you look at the Renewable Fuel Standard, what it mandates is that over the period up until 2022, that we'd have this increasing amount of biofuel that would be used in the fuel system. So, fuel system, including both replacing gasoline and diesel and effectively the corn ethanol component of this kind of topped out in about 2014 at 15 billion gallons per year. And then the overall mandate by now was supposed to be up over 30 billion gallons and that extra quantity, some of it was biodiesel, but most of it was supposed to come from a cellulosic or so-called second-generation ethanol, which is much, much cleaner, in the terms of carbon emissions, than ethanol.

Sarah Mock: But from the boots on the ground perspective, the picture was a lot more complicated than the glorious vision of high-tech fuels made from waste. Here's Kerry Rose, the farmer investor from Missouri:

Kerry Rose: It was kind of laughable because I was at that time, really involved in it and knew a lot about it. And I knew that there was nothing going on. And it wasn't even close. That the cost to build a cellulose plant was about double and the cost to process it was about double. So, it needed some huge technological breakthroughs, and everybody was working on it, but it was

going to take time to get done. I think just a few plants were running making literally, small batch batches of it, but that's where the excitement was. That's what, people wanted to talk about.

Sarah Mock: There is a lot of common knowledge about cellulosic like this out there in the agricultural ether - it doesn't work, it never worked, it only ever worked at a small scale in a lab, it was a pipe dream, it wasn't economical, farmers wouldn't switch crops, the material was too costly to move - the list goes on. But I wanted to know what the cellulosic story really looked like from the inside. So, I found an expert who was there at the time.

Vonnie Estes: Okay, I'm Vonnie Estes and I've spent my career in both - new technologies and agriculture, and also new technologies and biotechnologies in the biofuel space. And mostly in business development. I've worked for large companies and small companies and startups and trying to bring new technologies to market.

Sarah Mock: Vonnie and Kerry actually had some similar experiences in the ethanol space - both didn't get the timing quite right to be involved in corn ethanol.

Vonnie Estes: I remember in 2004, I was talking to someone I remember and that was when everyone was interested in corn ethanol. And I remember someone saying, "You know, it's as easy to make money in corn ethanol as it is to fall off the log," because like everybody was building corn ethanol plants. And that just became the big boom. And so, I actually went to work with a friend of mine that a group of us got together and we were trying to raise money to build corn ethanol plants.

Well, it turned out that was kind of like the end of the big corn ethanol, boom, and what started coming up is really talking about, you know, second-generation ethanol and what can we do, not from corn, but from other crops? Starting to look at second-generation ethanol was really exciting to me because one, it's different crops and two, it's really interesting technology of how you actually have to convert those crops into ethanol.

So, between 2004, or 2007 and 2015, I worked for four different companies trying to crack this. So, there were big things that had to be solved. One was what's the crop? What are you going to start with the feed stock? And a lot of what we looked at first was corn stover. That was one of the big things people looked at. And then we started looking at energy crops and growing crops specifically. And then you had to look at how do you break that down? and then how do you ferment it? And then how do you get the sugars out and produce alcohol? So, there was all these different steps, and nobody knew how to do any of it.

Sarah Mock: For a trained scientist, Vonnie said, this work had all the trappings of a new frontier, and there was such a broad mix of work to be done, and so many experts to involve, from agriculturalists to engineers to fermentation experts. It was a thrilling time, and even more attention was on its way.

Vonnie Estes: So, in 2007, Bush did his famous State of the Union address where he mentioned switchgrass. And it was, it was a very funny time because there's all these guys in the Midwest working on switchgrass in obscurity. Nobody knew what switchgrass was and suddenly their phones are ringing off the hook.

It's like, "Oh, it's switchgrass." So, that's kind of what got things going where Bush said that there would be 35 billion gallons of ethanol by 2017, which was 10 years away at the time. And that 20 billion of that was going to be cellulosic ethanol and so, people started trying to figure out like, how are we going to meet that goal? What was really interesting to me is kind of how the government went about it, which was they started writing checks to build these gigantic plants, like really big plants. But the technology was still on the lab bench.

And so, we hadn't figured out, like, what enzymes do we use? And what fermentation organisms do we use? And how do we do this? And so tons of money got spent to build these gigantic plants and so that was kind of the beginning of, I think some of the technical failures of cellulosic ethanol.

Sarah Mock: This intense attention, and the massive scale up and available resources that followed, would, in a relatively short period of time, exacerbate the limitations of ethanol in an extreme way.

But why did all that attention come so quickly and fiercely? There are a lot of reasons, but a big part of the equation was simply that in 2005, corn ethanol had been ready to go, and it was expanding rapidly. For the parties who felt like their priority was to support non-corn-based biofuels, they wanted to see cellulosics grow at a similar pace, so much of the same money and attention was directed towards cellulosic.
In other words, as Jeremy Martin at the Union of Concerned Scientists put it, the RFS used a one size fits all approach for both corn and cellulosic ethanols. But the problem was, as Vonnie pointed out, corn and cellulosic ethanol were at fundamentally different places in terms of technological development. Cellulosic was not ready for expansion. Scientists were still figuring out everything from the fermentation enzymes to the simple act of picking up corn stover off the ground.

Vonnie Estes: So, originally, I was working for DuPont, and we had some grant money and we're working on this, and we started a program with Deere trying to figure out how do you pick up corn stover?

And so, it, it was a huge project, we were figuring out like, how do we pick up corn stover off the ground? And how many passes on the tractor? And then where do you store it? And so, there was a lot of issues around corn stover, some of it needs to stay on the ground, they don't want to pick up all of it because you need some have to leave some of the organic matter. And there was a big problem on storage and there was a plant. It was, Abengoa [Bioenergy] had a huge fire because when you, when you bale that stuff, and you stack it up. It can combust. And so

suddenly we were having fires, and this stuff was burning and storing it took football fields, full of corn stover to like fuel a plant to run.

And so, where do you store that? And where do you store it so that it, it's not going to combust. And so, there was a lot of issues around that, and then just putting the machinery in the field, like when do you go up and pick out the corn stover and then you have to bale it. And so, there became like more complexity.

Sarah Mock: These turned out to be just a few of a myriad of complications that were unique and compounded with every new feed stock that was considered. This, to Kerry's point, is why cellulosic ethanol plants were so much more expensive to build and run. And these challenges with trying to use an existing waste product eventually led to exploration into completely new crops, and Vonnie ended up working on a project in Tennessee.

Vonnie Estes: And we started doing switchgrass projects. And what was exciting, in Tennessee is it had been - a lot of tobacco had been grown there and they were trying to grow corn and they just never could make, they could just barely break even on corn, on a good year.

So, the thing that was great about switchgrass is like, we've got land - it's marginal land - but we've got land and we've got people who want to farm it, so can, and instead of them trying to grow corn, can we grow switchgrass instead? And we built a plant down in Tennessee. A demonstration facility to see if switchgrass was going to work. And then other people started developing, sorghum was another crop that there was a lot of development work on, and miscanthus was another one. So, there was a bunch of different crops. It started being developed specifically for this purpose and if you looked at where they could grow, and if you weren't growing other things there, it was a good use of land. It was a good place to get jobs. And so that started making more sense than trying to pile up these gigantic piles of, of crop residue that are going to burn and fall over.

Sarah Mock: This is a really important part of the cellulosic story that is often missed - the industry was evolving and improving over time. Though even as some technical issues were getting solved, cultural issues emerged.

Vonnie Estes: We had a number of meetings with farmers in Tennessee about switchgrass and switchgrass, you have to grow it for two years before you really make money off of it. And it's a very small seed and it's hard to plant.

There's this - it's all doable but it's, it's not corn and it's not tobacco. And so, there was a huge educational proponent that had to happen, and we were willing to pay the farmers to transition, you know, so that they wouldn't lose money. And it was, it was not easy.

Sarah Mock: The brass tacks here is, there were just a lot of problems to solve. But even as the pure science and engineering were being refined, new environmental hurdles emerged

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constantly, in a Brazilian plant that Vonnie worked with, literal explosions were common, due to high levels of silica getting into the process - basically, the sugar cane that was being used as a feedstock just had too much sand on it.

But from Vonnie's perspective, perhaps counterintuitively, the real problem that would doom cellulosic ethanol, had little to do with the science or engineering, and everything to do with outside intervention.

Vonnie Estes The DOE was writing checks to build these gigantic plants. And what I learned about engineering is that that's not how you scale technology. You start at the lab bench, and then you go up a tiny bit and then you go up a tiny bit more than you go up a tiny bit more, and then you go up a tiny bit more. But the way that the government kind of supported the industry in the beginning was, "No, skip all those stages that are going to help you learn and go to the big thing."

And then of course, venture capital got involved, who always help, so a lot of money from people like Vinod Khosla started going into like, "Let's build these 250-million-gallon plants," when we haven't even built a 60,000-gallon-plant. And so, a lot of venture capital money started going in. And so, everything was like big, big, big, big, and we didn't know how to scale. And I think that's where a lot of the problems came in. A lot of those problems could have been solved by really good engineers had we gone the normal path of how you build new technology.

Sarah Mock: One of Vonnie's big takeaways is that, because of the way the RFS was set up, and the narrow time horizon on which these technologies were supposed to come online, government agencies were simply given too much power to pick winners and losers with enormous grants that funded private efforts, which, she says, is just not an effective way to set up innovative markets.

The points of overlap between the corn and cellulosic ethanol stories are fascinating, but where a huge amount of outside intervention and investment left the corn side of the equation growing at a breakneck pace, a similar amount of attention on the cellulosic side left the nascent sector in ruins. There are shades of Silicon Valley fraud stories here - where technologists and executives were promising that their process, which was just barely coming to life in highly controlled laboratories, could in short order be transformed into billions of gallons a year of production.

Part of the fervor that drove this overpromising, was the exact same national security motivation and the goal of curtailing dependence on foreign oil, that we've discussed as driving the growth of corn ethanol. Which, again, the energy sector understood and was largely onboard with. But and this is a big but, at the same time that the Department of Energy and Silicon Valley investors were overwhelming cellulosics with resources, the energy sector was being much more conservative and also having a problematic impact.

Vonnie Estes: We called on all the big oil companies, because they felt like, okay, they saw this in the beginning and they're like, "Okay, we really are going to have, you know, RFS and RFS 2 and there really is going to be 35 billion gallons and we better have our own, like we don't want someone else to be producing cellulosic ethanol." So, we called on Shell and Exxon and, you know, we called on everybody and there was, it was such an interesting dynamic is but they all kind of stayed on the fence, waiting to see like, where's this going to go? And if they felt like it was going to tip, like we better build our own plant and have our own technology, they were ready to do that.

But I think they sat on the fence long enough where then they didn't have to, but they all wanted their own cellulosic ethanol when they thought that was the direction it was going to go.

Sarah Mock: The slow and painful erosion of the cellulosic ethanol sector was not a victimless event either. Besides investors who wouldn't be made whole, and environmental groups whose hope for a waste-based fuel was dashed, there was also the very real impact on the people who had dedicated years to making cellulosic ethanol work.

Vonnie Estes: I can't think of a day where it kind of shut down, but for me personally, in my career, it was "Okay. I better pivot because there's no jobs here." And so, agriculture started looking really good again. So, I think, you know, and there was a lot of people, there was a lot of really smart people that we had kind of birthed this industry and we'd worked together for like 10 years and you know, I've still close friends from that time, but everyone was kind of suddenly, "Oh, I, this is over, this party's over now." A lot of people lost their careers – that was the end for them. Like when this died, people that had spent their, 20 years of their career or so trying to build this up and then it just kind of went away and, it was a lot of scars. I mean, a lot of people who went through that, that decade like there are so many scars on all the things that we tried, and it just didn't seem to work.

Sarah Mock: Though some of the advances made in cellulosic ethanol have, as Vonnie says, trickled into other technologies, even the very earliest, cutting edge cellulosic plants struggled just to break even, while others have been totally shuttered. Today, cellulosic has more or less disappeared.

Vonnie Estes: And there's no, as far as I know, there's no cellulosic ethanol or plant anywhere that that's running. And I, it's hard for me to say because some of those challenges were really big challenges. And if we spent the time to solve them, what would have come out of it? I'm not sure actually, but I think they were all solvable, but just not in the way we went about it. What, and now, given we have electrification, you know, that's going to happen. And I don't know that we need it. So, that, I don't think that would be money well spent to, to go back and say, "Let's solve cellulosic ethanol."

Sarah Mock: Electrification is part of the reason, Vonnie says, why cellulosic likely doesn't make sense today. But electric cars were far from the first outside factor to undermine the

sector. In fact, the same factors that started working against corn ethanol in the last decade, also helped to make cellulosic less attractive.

Vonnie Estes: I think fracking happened. I think that was one of the big things that happened it's like, when but when we modeled cellulosic ethanol and like, what, how if it made sense at DuPont to do this as a business and we were trying to figure out should we invest in cellulosic ethanol? We modeled at what was at the time, a low cost per barrel of oil.

So it was, we were modeling. $20 less than the current price of oil. That went way, way, way down then went down to half. And so suddenly it didn't make economic sense. And everyone's looking at how does this pencil out and with fracking and just having more oil? So now, it's no longer a national security issue. It's no longer a price issue. Even at the higher price, the technology was really trying to work, and electrification is going to be a big deal. And so, I think it was fracking and electrification and all the problems with the technologies and the companies that were developing the technologies. It all swirled around at one time.

Sarah Mock: I'll note here that alternative energy expert Scott Sklar does not have such a dower outlook on the present and future of cellulosic fuels. He grants that sure global economics have shifted, and perhaps the short-term viability of cellulosic was overpromised, but, he says, that it shouldn't be counted out yet.

Scott Sklar: Our national labs and we have about eight of them working feverishly with the private sector on a lot of different cellulosic and enzymatic conversion of biomass, along with other processes. And of course, looking at other feedstocks, other like algae, and switchgrass and all this other stuff, all is good. And actually, looking at - I've even seen, there are a couple of plants in the United States looking, working off of dead trees. One of the big reasons we have forest fires aside from climate changes, you have a lot of dead trees sitting in forests and as it gets hotter, guess what, they ignite the most. So, can we create a system that gently removes things that out and creates an economic industry based on that? Where those resources go become liquid fuels for our vehicles? Absolutely. And by the way, we are using hydrologists and enzymatic conversions in making chemicals from biomass now.

It's a big multi-billion-dollar industry, and we have very big companies on this planet, using the technologies that we are going to make fuels. Making chemicals and medicines from these processes and making a huge profit, frankly, they're just more profitable markets than getting into the fuel industry where you're competing against the oil industry. It just takes time, but are we going to be able to get there 100%? Is it going to be a significant contributor to our transportation industry? Yes. Is it going to be the only one? No. And we don't want it to be the only one.

Sarah Mock: But Brent points out that shifting economics and outside factors weren't the only things working against cellulosic ethanol. There was a significant political shift which worked, unintentionally, to undermine confidence in the sector. Here's Brent:

Brent Gloy: When they started waiving the requirements for cellulosic in the RFS, you knew it was probably not going to happen because the idea behind the requirement is, whatever the price it'll get produced because the price has to go high enough to get it. And if you were financing a cellulosic ethanol plant, you're sitting there going, "Well, as long as that mandate is binding, I can afford to produce this at really high costs because the market's going to have to buy it. Until more people can do it and we'll figure out how to get better over time." But once they take that requirement out, then all you've got is a super-high-cost ethanol plant that, you can't make any money. So, all of a sudden, the bankers wouldn't finance it and you're never going to get there.

Sarah Mock: From Brent's perspective - this waiving of the mandate is one of the most important decisive differences between corn ethanol's success and cellulosic's fall. And at its core, Brent argues this decision was pretty simply about how much we were willing to pay for something we professed to want.

Brent Gloy: If they would have left the cellulosic mandate in place. I don't know how many gallons of that stuff we'd have to be producing today, but it's a lot, and we'd have high prices on lots of commodities if that were actually being done.

It just has not come along as fast as people thought, or in other words, the incentives to get it to be a scalable technology had to be much higher than we were willing as a society to pay. So, if they would have left the mandate in place cellulosic ethanol prices would have went so high that we'd been doing it. We would have been doing it, but I don't think, there wasn't enough appetite on the part of consumers or policymakers to see those prices go that high. So that it actually got made and they ended up waiving the requirement because they were like "Oh my god, it's not going to work so we don't want to impose these high costs on people so we're not going to do it." I still contend that if they had stuck with it, we'd have it to some degree.
But nobody in their right mind was going to go out and spend millions and millions of dollars of their own money to like develop the feedstock handling system for a cellulosic ethanol plant that was probably never going to occur because without the market, the banks were never going to finance it, and the technology was not going to come along without the investment, which you need the banks to make the investment – without all three of those it was never going to work. And that just basically killed the cellulosic ethanol development.

Sarah Mock: But why was waiving the cellulosic mandate even an option? If policymakers and all of these stakeholders were so convinced in 2007 that cellulosic was about to be huge. I'll let Dr. Hanna Breetz from Arizona State explain:

Hanna Breetz: So, to go back to the history again, where we started off in the White House with this big goal that had an economic safety valve compliance option, then it gets into Congress and the Senate, which kind of crafted their version first, yanked the safety valve and it gets in the House and now, all of a sudden, now you've got this like huge and impossible to reach mandate with no alternative compliance options, no flexibility in it. And so, at the very, very last minute,

it was actually an ethanol lobbyist who kind of snuck in this piece, which it has to do with the EPA waivers to say, "Man, we know we can't reach those goals. How do we make sure that we are rewarded for partial success but our lack of production, isn't going to take down the entire policy?" Because if you had no flexibility and you didn't meet those goals, then you would end up with like a lot of pushback and the whole policy could end up being yanked.
So how do you build some flexibility in there? And that's where they came up with this annual EPA waiver. And it was not a good idea from a policy design perspective, very administratively complex, huge burden on the EPA but also, and this is the real problem with it. It basically rendered the entire cellulosic mandate, toothless. The whole benefit and all the innovation benefits that you get from a mandate is that it stands firm. And so, you have to find some way to meet that mandate and make the investments that are needed in order to innovate. And in order to build that thing. If you have a mandate and then you say, "Oh yeah, but if you don't reach it, no problem. We're going to issue a waiver." All of a sudden there's no power and no force behind that mandate anymore.

And so, what that ended up doing was basically gutting the entire cellulosic mandate. If you've had a firm mandate, maybe you would have had more investment, maybe you would have had more innovation in ways that could have solved some of the technology challenges, but with this weak mandate that was rendered toothless by the waiver, you didn't have any of those incentives. All these pieces have to come together, and they just couldn't.

Sarah Mock: A further piece of insight from Hanna– the waiver became a necessary part of the cellulosic discussion because of the very energy that brought the RFS to life in the first place. In short, the cellulosic mandate simply turned out to be too big a swing.

Hanna Breetz: I think there's this kind of sweet spot where, when I was doing interviews with different staffers and different lobbyists, and a lot of times people would say something about, "Your ambitions, define your achievements," something like that. Where it was this idea about like, you have to go as big as you possibly can. If you want to do something big.
And instead, what I felt like I was really observing when I was looking both at that kind of micro politics of how the policy instruments were designed, like the details of specific provisions, as well as the, kind of the larger politics that happened afterwards, is that by setting the goals too high, it really created a lot of incentive to undermine the policy and weaken it because when you set unachievable goals, you have to find some way that you can find a loophole or find a waiver or, you know, this sort of death by a million cuts of figuring out ways that you can weaken the mandate and that you might have actually had more progress with a more modest goal, but something that was actually a really tough policy instrument.

Sarah Mock: In addition to the over-ambitiousness that became toothlessness for the cellulosic mandate, however, Hanna also attributes the failings of cellulosic to policy to a much deeper misalignment between the technology and the farmers that would feed it.

Hanna Breetz: It was a policy that was really unfortunately designed without a lot of input and know-how from the agricultural sector. And I think that's a big part of why there was so much over-promising on the cellulosic. So, for example, when you would look at what actors in the sector saying, "Oh yeah, we're going to have switchgrass and miscanthus, and we're going to go with these perennial grasses, and we'll be able to grow so fast."

They weren't thinking all about what that meant in terms of on the ground land use practices and agricultural practices. If you're actually trying to get farmers to switch over from corn, or corn-soy rotation, but things that they have grown for generations, they know how to do it. They have all the equipment to do it. All the financial structures of the farms are built up around that model and asking them to switch over to perennial grasses where they're not going to have any income for two or three years, they have to buy all new equipment. Like that's a huge risk that you're asking farmers to take. And nobody really thought about how hard that is going to be in enabling a switch over to any kind of energy grass-based cellulosic biofuel.

I think it's no accident that the only kind of silos like ethanol that you've actually seen commercialized is corn stover, because you're able to build again on some existing expertise.

Sarah Mock: Hanna anticipates that had the cellulosic mandate also included support for research and transition, as well as other elements to ease the transition and minimize risks for farmers, it could have been much more successful.

But beyond that, the economics of cellulosic also work against it, because it's just more expensive, chemically, to convert cellulose, rather than starch, to ethanol. Physically, corn kernels are energy dense, corn leaves and stalks, grass stems, and many other cellulosic feedstocks, are not. And though this might seem odd to mention, it's important that no one got lucky. Perhaps there is a unique insight or formula or technology out there that would upend the technical realities of cellulosic fuel, but no one found it, and as Brent pointed out in one of our conversations - you tend to get luckier, the more money, and critically, time that you spend.

David and Brent had a different perspective on where the economics of cellulosic ended up failing, and it wasn't in the lab - it was in the field. Their arguments come back to the idea that Vonnie mentioned a few minutes ago, when she talked about her project in Tennessee, the idea that farmers were not only going to be able, not only to replace corn or tobacco with a cellulosic feedstock, but that it would be a valuable crop on all kinds of marginal land.
Here's David:

David Widmar: I think what's interesting on switchgrass. One of the initial sales pitches for this was that it was you're going to be able to take, land that just wasn't going to be good for raising corn?

We always want to put our good ground into corn, and this was an option for the farms that just didn't have great corn land. So, you're going to be able to raise this switchgrass and make good

returns on that switchgrass. And I think what's always in the back of producer's minds is, "Well, if I can make decent money on my bad ground, I bet I can make a bunch of money on my good corn ground." If this switchgrass thing is really going to be what it is. And so, the initial premise was that it was going to be the marginal acres, the acres that aren't very good. It's not going to compete with fuel. It's not going to compete with other uses of the resource. And I think that's a big misconception. I think anytime you hear this sort of marginal land, or you're going to make a lot of money on something that's not going to currently make you a lot of money. That's a heuristic that you should be aware of.

If switchgrass was going to be successful and profitable on the not so productive ground, it would be very, profitable on the good acres and it would start to compete for, resources just like soybeans or corn. So, it would start to take on some of the problems and have some of the same indirect land use issues that other uses of land would have.

Brent Gloy: Yeah. So that the whole idea that cellulosic ethanol was going to use the marginal land. Was, I think in part, a response to the food versus fuel debate. So, people were like, "Oh my gosh, we can't, we don't want to lose any of our food production." Cause at the time, we were in limited resources mode, peak oil, peak everything and we were worried that we weren't having a food. So, then the people like, "Wow, this will work on the marginal land?" Which, when you hear somebody say that that's a very good indication, they have a very limited understanding of economics. I mean, honestly, if my students would say that I think I would flunk them in an economics class because it's just absolutely wrong. I mean, the chances of cellulosic ethanol, like coming in it just profitable enough to work on like crappy land that has no other use, but not so profitable that it can like, not be really good on the really good land is like ludicrous. And, it wasn't, that was never going to be the way it worked.

Sarah Mock: The point David and Brent make here, about the fundamental mistake people make when thinking about marginal land, and land use incentives overall, is important not only when we think about the miscalculations inherent in cellulosic, but also when we think about the long-term effects of ethanol overall, a topic we'll get way into next episode.

But for now, let's talk lessons learned. As we switch our focus to carbon, there's a couple key ideas from the cellulosic experience we need to keep in mind.

1. It's important to recognize that when a policy or market is sold as having environmental benefits, and those benefits do not materialize, retribution can be swift and far reaching. Consider - early RFS boosters in the environmental community are now some of its loudest critics and have been effective in casting public doubt not only on the viability of cellulosic, but on the whole agricultural biofuels space.
2. Figuring out a new market from the basic science up is incredibly hard and expensive. It takes not only resources well-applied, but it also takes time and luck. Even once the science exists, scaling-up production to meet demand offers a whole new set of

challenges that could be so costly to solve that it makes the whole endeavor economically impractical.
3. When the enthusiasm of policymakers and outside investors is misaligned with the science, especially in a market where the technology is such a critical part of the equation, wild swings in confidence and ambition can be devastating to a market, whether the technology works or not.

In the conversations I had with experts for this season, there were many who felt that our experience with cellulosics offered the most relevant parallels and lessons to the possible future of ag carbon markets. Considering what we've learned, there could be a lot to worry about.

Where to start?
That's after the break.

[[COMMERCIAL]]

Sarah Mock: To kick off our ag carbon conversation today, I went back to Vonnie Estes who, when she looks around now at what's happening with carbon markets, can't help but hear echoes of her time working on cellulosic - the promising and over-promising, the outsized ambition, the manic energy. She mentioned the surprise she felt hearing President Joe Biden refer obliquely to ag carbon market in his annual State of the Union address in 2021.

Vonnie Estes: When he mentioned carbon markets, I was thrown back to Bush's 2007 remark. It's like, "Oh, now everyone's going to rush towards this and think that this is the answer and we're all going to make money here." And I think one of the biggest issues that I learned and that we need to keep in mind is that it's really a systems problem and it needs a system solution. So, it's not just, "Okay, let's find a way to dig better cores in the soil to figure out what carbon we have in," or "Let's use a cover crop," but generally look at the whole system of, from all the way, the end of, you know, who's buying that carbon credit?

What does that carbon credit mean? How are we going to bill up that carbon credit? How are we going to measure it? And either the government threw money or venture capitalists or whoever - don't just throw money at different pieces of it, but really think about it as a system solution of how this is going to work. Just throwing money at the issue to make big solutions without realizing that it's a whole system problem, I think is, is a mistake.

I think there's just, there's a lot of things along the way of how to measure and how many times can you sell that credit? And you know, who gets the money? And is it permanent? And there's just a lot of questions in that, that I'm not sure we have the answers to, and, not to say we shouldn't go ahead, but just kind of be wiser about, you know, money doesn't solve everything. And sometimes it actually creates problems.

Sarah Mock: And one of the key things that large quantities of money and short timelines doesn't solve, Vonnie warns, is good science, which as we've discussed, is a key outstanding concern for modern ag carbon markets.

Vonnie Estes: That creates weird activity and certainly does not create good science. And so, I I'd like to see like some kind of pre-competitive science. I think that's what would be great if the government would fund some university pre-competitive science where everyone could say, "Okay, this is the science, this is what it looks like. This is what permanents means. This is how we do these different things." Instead of having, you know, startups do that. That's not the best thing for startups to do. So have some pre-competitive work where we kind of all have a baseline of, this is what the science is, and this is what it needs to look like. And this is what a carbon credit is.

Sarah Mock: Vonnie, like so many of the experts we've heard from thinks that more thorough and rigorous science is critical for the future of carbon markets. In fact, it is still an open question today how rigorously we can measure carbon in soil over a meaningful length of time, which, to many, is the bare minimum to even be able to have an ag carbon market in the first place.

Mitchell Hora, the Iowa farmer and soil carbon company founder, is not quite so pessimistic about existing technology:

Mitchell Hora: We can measure it somewhat.

Sarah Mock: I'm going to spare you some science here, suffice it to say, Mitchell knows his stuff.

Mitchell Hora: So, at the lab, the utensil to be able to quantify that carbon is really expensive and the throughput is very low. So, it's very, it takes it's expensive at the lab and it's just not scalable from a lab side of things, especially for the hundreds of thousands, probably millions of samples that we need to run every single. Also, we have to do a lot of bulk density samples, the way that the assessment is today. And there is no way that we were getting a very accurate reading out in the field, in gathering that bulk density, I just don't see how it's been done, really with the certainty that, we are putting in behind it.

Sarah Mock: Let me sum it up - a technically possible technology that doesn't scale, that's terribly expensive and would need to operate at many times its current capacity to make the system we're already building operate effectively? Sound familiar? Yeah. Sounds like cellulosic ethanol to me.

And for good reason - like cellulosic, the technical challenges with ag carbon measurement are significant. Carbon cycles in and out of soil, the atmosphere, and living things constantly, at varying rates due to an almost infinite amount of variables. Carbon can be a solid, a liquid, or a gas, it can be attached to soil, part of plants, or suspended in water or air, but even high-quality

soil tests today, Mitchell says, are mostly just measuring dry combustion organic carbon, in other words, it may be missing a big part of the carbon picture.

Mitchell Hora: And again, that boils back to the models are not robust enough the way that they are today. and that's fine. We didn't create some of these carbon models to be able to build a massive multi-billion-dollar industry on top of these models, the way they were set up for academic purposes and whatnot.

Sarah Mock: But despite these challenges, Mitchell isn't discouraged. He thinks there's still time to figure out the science on ag carbon markets and is even optimistic that some of the essential pieces are already there.

Mitchell Hora: We just have to get a lot more data going into this. So, I think we just have to open this up again to make sure that these markets are based on calculating your actual carbon impact, your actual footprint. That's why I think farmers shouldn't be fully going in and doing this right now. Cause I really worry. I mean, the flywheel has to start somewhere. So, I hope that what we're doing today is good. I think it's starting to move the needle, but I think the key thing is going to be quantify where you're at today in the soil. And then hopefully we can build out more of these calculations to understand, what's your carbon footprint today? The data's got to be out there. There are solutions there. We understand the emissions coming off of your tractor. We understand the fuel utilization. We can calculate these footprints and we can calculate you know, what your real impact is. I just don't see it being done in a cohesive manner, but the data is all there. We just have got to pull it together and make it usable.

And then if you want to enter into a carbon market and you want to offset somebody else's footprint upon any of those environmental outcomes. Well, now you understand where you sit because you understand how to calculate your own impact. But that's where we need help and that's where we need more innovation and where we can where there's room for entrepreneurship and there's room for science and collaboration here.

Sarah Mock: All of this begs the question of course, what happens if the technology doesn't get figured out? When it comes to Dr. Aaron Smith from UC Davis - who has had a long career studying economics and policy in and around the energy and ag sectors with consideration to how both industries think about pollution and environmental impact, he thinks the challenges of measuring soil carbon levels at any given moment is just one small aspect of ag carbon's big thorny problem.

Aaron Smith: If our goal is to reduce the amount of carbon dioxide and greenhouse gases in the atmosphere then, you know, we need to be thinking about putting less of it up there or pulling some of it down. And the idea behind carbon farming is that you might, you know, you might till the soil less because that's going to cause less carbon to be admitted into the atmosphere. You might grow cover crops that are going to absorb some of that carbon and place it in the soil. But then the question, the first question for me is, well, then what? So, you know, what, if you go

then plow that field up next year and then that carbons up there anyway, and you haven't had had any effect.

And so, there's a permanence aspect to the extent that we're going to subsidize these activities. Then what we want is we want something that's going to be additional. What that means is by subsidizing, we actually get less carbon emission than we would have otherwise. And so, to the extent people were going to be doing planting cover crops are doing no till anyway then you're not gaining anything from, from that subsidy. And so, it's sort of, you're not doing anything to improve the climate over how it already would have been.

And I think the third thing is measurement, I think is really hard. So even if you were able to solve the additionality problem and you're able to solve this permanence problem, just measuring exactly how much carbon is being stored and being able to pay out for that is, is really expensive and maybe not even possible - I don't know. I mean, I'm certainly no scientist, but the science that I have seen seems kind not very conclusive about this. So, it's designing a big program that would have big potential administrative costs that might not actually really get much carbon benefit doesn't seem like a good path to me.

Sarah Mock: Aaron did a great job here outline three of the really significant technical challenges that proponents of ag carbon markets are grappling with today. One - measurement or ensuring that carbon is being sequestered. Two - permanence or ensuring that sequestered carbon stays in the soil over time, and additionality - ensuring that farmers are getting paid to sequester more carbon, not for doing work they would have already done, payment or no. All three of these come down to, in short, how do we make sure that we get what we pay for when we pay for carbon sequestration? From Aaron's perspective, today, there's no way to do it.

Aaron Smith: I don't really see how it can work, because, if we lived in a sort of an imaginary world where you could imagine capturing that ton of carbon and like taking it somewhere and like taking a big hole and dropping it down there then that's going to work. But, you know, to the extent that it's part of these sort of complex biophysical processes, and it's sitting in the soil and you're paying for it to stay there and then you're paying a bunch of money and then and maybe it doesn't stay there, either because of natural processes or because somebody comes back and farms that land in a while. So, I guess I don't see that being a program that is very helpful when set up that way.
And I think if there were a scientist to come and say, "No, actually, here's how we can measure this thing. And here's what it is. And here's where it's sitting and it's going to stay there, because we know for this reason it's going to stay there," then I'd change my mind. But nothing that I've seen in agriculture is remotely close to that.

Sarah Mock: In other words, Aaron is leaving open the possibility that someone might figure out this complicated technology, someone, somewhere might get lucky, but baring that, from his perspective, the outlook is bleak. And yet despite the many outstanding questions and the incomplete technical suite available to carbon marketeers today, companies are already selling ag

carbon credits. How? I asked Aldyen Donnelly, as the company she cofounded, Nori, Is among the existing ag carbon markets. She acknowledges the debate around permanence and additionality but is not overly concerned by them.

Aldyen Donnelly: Additionality is so stupid. What is the agriculture equivalent of the benchmark that we apply to a refiner, an oil producer, a petroleum product producer? So, the carbon intensity benchmark for the producer is greenhouse gases per barrel of oil. What's the equivalent benchmark for farmers that we can agree on carbon intensity per I don't know, pound of edible product or nutrient value, or energy value of the product? That would be equitable. Fair. That's how the rest of the carbon market works. Why are we going nuts over additionality tests for food and fiber producers?

So yes, there should be a form of additionality test. Let's agree on what the benchmark is and everybody who's beating it is earning credits whether or not they've been beating it for 25 years or four months. And everybody who's not beating it has to catch up.

Sarah Mock: Aldyen's argument makes sense and is worth thinking about given the criticism of existing carbon markets that farmers who have been using carbon sequestering practices for a while, who, we'd think, are the ones we'd want to support the most, often can't participate, because they're not doing anything different, they're not making additional efforts, because they're already made the change.

But remember, this "new practice" requirement exists, at least in part, because we're not very good at measuring soil carbon. So, because we can't say decisively "This farmer has sequestered x amount of soil carbon" existing markets are using the practice-as-a-proxy, assuming that going from no cover crops to cover crops or no conservation tillage to conservation tillage, is a monetizable carbon sequestering activity. In short, many of the current systems create credits when a farmer moves from 0 to 1, no practice to practice.
Aldyen here is arguing, reasonably I think, that rather than creating credits only from the 0 to 1 movement, we should just set a benchmark and reward everyone at or above it, whether they started the practice today or 50 years ago. But of course, to set a benchmark, the technology has to be there to measure whether people are hitting the benchmark or not. That technology, which can measure both the added carbon and its permanence, and at a reasonable price, doesn't exist today.

Brent offers another perspective on how we might set that benchmark and suggests that in the absence of the technology there's a simpler way than setting up a tradable credit market to achieve these goals.

Brent Gloy: Federal policy rules - are there practices we can agree on that are A, good for the environment and B, might somehow reduce carbon emissions, store carbon or something like that? At least not increase them. And are viewed as universally good practices - maybe we can incentivize those and not worry so much about the ultimate measure of it. Just say, "Well, this is

our environmental policies. These are things that we kind of universally agree are good and not worry as much about how to measure."

Sarah Mock: That's right, a simpler alternative to a complicated ag carbon market that requires rigorous and large-scale measurement technology is to simply take these universally agreed upon good practices - like cover cropping and conservation tillage - and make them required - in other words, create and enforce basic environmental regulations.

The benefits of this system are obvious, farmers who have been doing these good practices the longest would be advantaged over those who have to transition, which creates those early adopter rewards we want. But this could solve another problem too, which is that, in the long term, especially in the absence of highly confident soil carbon testing, the idea of getting paid in perpetuity for doing the same thing year after year is economically problematic to say the least.

SPEAKER: This idea that well, we're going to get paid for something else doing is nonsense. If you are someone who's buying a carbon offset, why in the heck would you ever pay somebody had to do, continue to do what they're already doing? It makes no sense. You're obviously not creating anything through your payment. You've incentivized, no change in behavior. You've paid them to do what they normally do? That's stupid. I mean, nobody who's buying a credit legitimately, would ever pay for one of those, unless they really just want to buy a really cheap credit, to convince their consumers that they're doing something green and hope that nobody ever figures out what they're doing.

If they're really committed to this, you would want to pay people to do something different. It's the idea of additionality and it's really important in terms of carbon markets, if you don't have additionality, you're not buying anything. And farmers don't like to hear that because they want to say, "Well, I'm already doing this and why should my neighbor, who's never done cover crops, get paid when I'm already doing it?" Well, yeah. Well, he probably shouldn't get paid for either – and no-till is the same way.

Like why should we incentive sell as a practice it's widely adopted? I mean, probably not something you should get paid to do. It's a pretty much a standard practice. And if the people who are buying the credits really care about what they're doing, they wouldn't buy those credits. I mean only people want to do that or people are greenwashing their stuff. They want to do it because they want to say that. And they're going to hope that nobody ever looks behind the curtain to see what they've really bought.

But the cynical side of me says that's what's happening, but I think I'm perhaps being too cynical there are people who are doing this because they really do want change and it's not all just about marketing, and it's not all just about, trying to sell more stuff at any cost and they think this will sell. They're actually doing it because they're true believers. They want it to happen. And those people, I think, are the ones who are going to look and say, "No, this is, I'm not going to pay for

that. That's stupid. I want a legitimate carbon offset." And that requires change of behavior and that's a tradeoff and people don't like trade-offs because they're costly.

Sarah Mock: And here we are again, stuck between something we profess to really want, carbon sequestration, and the cost of actually achieving it. Whether this price is called the cost of compliance in a mandatory market or simply the price of achieving our goals in a voluntary one, it comes to the same thing. It takes a lot of energy – in the form of resources, time, and attention, to actually create change. It will be costly, and a lot of people probably won't be that happy about it. It should serve as a warning than, that when people are enthusiastic to pay for something as many companies are currently enthralled with buying ag carbon credits, it's likely because they're low cost enough to not motivate much change. A better sign perhaps that change is actually occurring, is that prices are high, and people are mad because they're having to make tough choices.

But who are these people who are in and around ag carbon markets today? Environmental activists and Silicon Valley investors make up a major part of pro-ag carbon market cohort – that familiar team-up might be a little bit of a red flag. Policymakers, of course, are largely still on the sidelines, and many big companies, in the energy sector and beyond, are hovering around the periphery, participating at a small scale when it's convenient.

Within agriculture, farmers and their advocates who are participating in these markets must bring an economic advantage to growers first. And it seems that, for now at least, the priorities of the agriculture industry are triumphing, as money is already flowing to farmers, even in the absence of strong verification.
Here's David.

David Widmar: We know it's imperfect, but we're running quickly anyway. And so, we want to move as quickly as possible. And with ethanol, there was really, how can we create change in a very short period of time? And I think with the carbon markets, we're trying to run very quickly, and we don't actually really know how some of this technology works. I think we're still trying to answer some of the technology questions as we're putting the policies and the programs and the markets together for this. And in ethanol or renewable fuels, we saw cellulosic ethanol as a technology we were really excited about, and we were putting this into the mandates, and it never came to be. And I wonder if in the carbon, we're trying to specifically the ag, we're trying to put some stuff together that the technology just isn't 100% there yet.

Sarah Mock: So where does this leave us?
With a few key risks to watch for, I think.

1. Ag carbon markets could create some real environmental benefits, hypothetically, and are certainly being marketed as doing just that. But the way that too many markets are currently being set up does not involve rigorous, long-term, affordable proof that environmental improvements are being made. This is a huge red flag. As folks like

Mitchell Hora have pointed out, this not only could lead to ag carbon boosters turning on ag, but to ag carbon customers becoming ag industry critics in the future.
2. The rigorous science needed to prove delivery of the environmental benefits of ag carbon is not yet built, and even once it is, it'll take time and money to scale up. As we've talked about today and in previous episodes, this could significantly reduce the benefits for farmers of participating in ag carbon markets.
3. We should be cautious of the exuberance of outside investors and policymakers whose excitement at the possibilities of ag carbon may outpace the reality. The wild swings that come with overpromising and underdelivering on ambitious goals could kill ag carbon markets before the we even have a chance to make the science work.

In my mind, the one major question we have left to answer, is all about the long term. And in some ways, ethanol is not a good template for predicting the long-term effects of a policy, because the RFS is just not that old yet – it was signed a mere 15 years ago, which is a relatively short time in the scope of U.S ag history. But in other ways, it does offer really valuable insight into the longer-term carbon market future, a big part of those long-term effects revolves around land use and David, for one, thinks there's a real parallel there between ethanol and ag carbon.

David Widmar: I think if the carbon markets are going to be successful and it's going to be successful on sort of marginal activities if I can make a little bit of money using no till practices, if I can use a little bit of money planting cover crops, how much money could I get if I planted my farm to grass in perpetuity? Or how much could I make if I planted my farm to trees in perpetuity? What are some of these higher return or higher uses of my land for the carbon market?

Sarah Mock: When farming has to compete with not farming, Next time on Corn Saves America.

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