Scott Tinker (00:00):

Next on Energy Switch. One of the most popular topics in energy today, hydrogen.

Scott Tinker (00:06):

Why is there a climate driver on hydrogen?

Steve Hamburg (00:08):

Most of the conversation right now assumes that deployment of hydrogen is carbon neutral. It has no impact on the climate. That's simply factually wrong. It's how we use it that really matters.

Julio Friedmann (00:21):

Abatement potential in these sectors using hydrogen is very large, but that is just potential. It is like anything else. You have to realize that potential to be material.

Scott Tinker (00:31):

Coming up on Energy Switch, could hydrogen be our energy future?

Speaker (00:36):

Funding for Energy Switch was provided in part by Microsoft and by the University of Texas at Austin.

Scott Tinker (00:48):

I'm Scott Tinker, and I'm an energy scientist. I work in the field, lead research, speak around the world, write articles, and make films about energy.

Scott Tinker (01:00):

This show brings together leading experts on vital topics in energy and climate. They may have different perspectives, but my goal is to learn and illuminate and bring diverging views together towards solutions.

Scott Tinker (01:14):

Welcome to the Energy Switch.

Scott Tinker (01:18):

Fossil fuels are hydrocarbons, compounds of hydrogen and carbon. Natural gas is mostly hydrogen and it's what nearly all pure hydrogen is made from today. But there's a great deal of excitement around making hydrogen from lower carbon sources with the potential to replace fossil fuels in transportation, industry, and to generate electricity. Is this really promising or a pipe dream?

Scott Tinker (01:42):

Weighing in are Dr. Steve Hamburg. He's the Chief Scientist for the Environmental Defense Fund and a Lead Author for the Intergovernmental Panel on Climate Change. He's joined by Dr. Julio Friedmann. He's Chief Scientist at Carbon Direct, known as the Carbon Wrangler, hence the Western shirt. He served in the Obama administration's Department of Energy.

Scott Tinker (02:05):

On this episode of Energy Switch, could hydrogen be our energy future?

Scott Tinker (02:11):

Let's get started with hydrogen and the Hindenburg. When people think of hydrogen, they think of a big dirigible blowing up or catching on fire. Is it dangerous?

Steve Hamburg (02:22):

Well, yes, but at the same time we have an industry that's demonstrated you can use it safely, so I'm less concerned about the danger.

Julio Friedmann (02:29):

Yeah. We have in the United States over a thousand miles of hydrogen pipelines and they go through heavily populated areas and the incidence record has been zero. And it is no more dangerous than natural gas, which is also explosive, which we bring into our homes. Or gasoline, which we put into our cars. We know we can do it safely.

Scott Tinker (02:47):

Yeah, so hydrogen's got colors now. It's color coded.

Julio Friedmann (02:54):

Yeah. So to be clear, I'm not a fan of the hydrogen rainbow. I think that ends up confusing people. Really, it's pretty simple. If you start with something that has carbon in it, like biomass or fossil fuels, you go through one process that strips out the carbon and stores it, and that's generally called blue hydrogen. Then there's the part where you make it from water, where you just run zero carbon electricity into water and you get hydrogen and oxygen out, right? That's generally called green hydrogen. And today what we make is called gray, because we're just making it from carbonation stocks and putting that in the air.

Scott Tinker (03:30):

Okay.

Steve Hamburg (03:31):

And that's really the key is the fact that currently hydrogen is not a climate friendly energy source. And so the blue and the green are in the future, they really don't exist now. So we have to be careful because everybody's sort of thinking of hydrogen as now. Well, that's in the future.

Julio Friedmann (03:49):

So about 1% of hydrogen today is clean hydrogen, and that 1% is kind of evenly split between blue hydrogen and green hydrogen. So when we talk about hydrogen in the future, we're talking about a factor of 500 scale up and it means you need to keep your eye on the carbon footprint and issues like leakage or else we're going to create problems.

Steve Hamburg (04:06):

And we also have to worry about additionality because the point is the fact that you could do green and use renewables. What else would those renewables be applied to matters a lot because you would never want to displace the electrification with hydrogen if you have the choice because...

Scott Tinker (04:22):

Penalty absorption.

Steve Hamburg (04:23):

The energy penalty... I mean, thermodynamically, it's always going to be less efficient to produce the hydrogen than to use the electricity directly, and we need so much more renewable energy just simply to offset fossil fuels and carbon emissions. So we have to be careful in assuming that it will be there. We don't know how many places will have that excess, renewable energy to be able to produce hydrogen rather than assuming it will be there when we want it.

Scott Tinker (04:46):

I mean, H2, lightest element. Helium makes balloons float up, so it's lighter than that. It's hard to keep it contained.

Steve Hamburg (04:54):

Absolutely. So leakage is a big issue. And one of the things that none of the debate or thinking about hydrogen includes is exactly that fact. It does leak. It leaks... it's referred to as a small slippery molecule, right? It gets out, it's hard to hold onto. And because it's such a potent indirect greenhouse gas. It's very short lived in the atmosphere. So it's not going to stick around a long time, but over the next decade, two decades, three decades, that leakage can make a radical difference.

Steve Hamburg (05:22):

So if our goal is to try and stop climate change by 2050 and really stabilize the climate, hydrogen can be part of that solution only if we minimize leakage. And currently we have no idea how much hydrogen is leaking out of these systems. We focus that on safety, which we should, we want it to be safe, but there's a big gap between what's safe and minimal leakage.

Scott Tinker (05:45):

Sure.

Julio Friedmann (05:45):

So let's talk about where hydrogen can be used immediately and well, because like the reason we're having this conversation is because we think we need it, right?

Scott Tinker (05:55):

I'm starting to wonder, do we need it?

Julio Friedmann (05:57):

Well, we do. And here's why.

Scott Tinker (06:00):

Yeah. Okay.

Julio Friedmann (06:00):

So there's a lot of things that you can electrify, right? And if you can electrify a lot of things and you can green the grid, then you're a lot of the way there. There's a bunch of things that you really can't electrify or that are really hard to electrify. And a lot of those for me, the killer app is heavy industry. Steel, chemicals, these kinds of things, glass making, most people don't realize it, but about a quarter of global emissions come from that. Just the heat from heavy industry emits more than cars and planes combined.

Steve Hamburg (06:30):

Well, I think as we have talked about, using it for heavy industry is the logical place where we should really focus a lot of our energy, because those are places where we don't have alternatives, like steel production where we need to use coal now. And so we know that hydrogen can offer real positive benefits for the climate.

Scott Tinker (06:51):

What makes coal and hydrogen unique? And steel? I mean, we can use anything.

Steve Hamburg (06:54):

I'm going to let Julio answer that. He's more...

Scott Tinker (06:57):

Why can't I use wood or...?

Steve Hamburg (06:58):

You need high temperatures is the main thing.

Julio Friedmann (07:00):

Okay. There's two things you need to make steel. And really when we're talking about steel, we're talking about iron and steel, because you've got to make the pig iron too. One of the things you need is heat, and you don't get that with wood chips and electric resistance heaters. So 1,200 Celsius, that's like 2,400 Fahrenheit.

Scott Tinker (07:17):

Okay.

Julio Friedmann (07:17):

The other thing is when you make iron, you actually have to strip the oxides out of the iron ore, and the coal and the coke, specifically the metallurgical coke, does that chemistry. So today, when you put coal in a steel mill, you get carbon dioxide as a byproduct. If you put in hydrogen into a steel mill in the future, you get water as a byproduct, which would be nice.

Scott Tinker (07:39):

Yeah.

Julio Friedmann (07:39):

Okay. And that's, again, 7%, 8% of global emissions. It's where you want to end up.

Scott Tinker (07:45):

Okay. 7% or 8%.

Julio Friedmann (07:47):

And we make 2 billion tons of steel a year. Same thing with chemicals. The good news is the chemical industry, making things like fertilizer and methanol and ethylene and plastics and stuff like that. Everything that goes into those plants is typically a gas. Methane goes into those. That means that you could put hydrogen into those systems a lot easier. You still need some carbon in there because methanol's got carbon in it, ethylene's got carbon in it, but you could actually provide a feed stock of hydrogen in, you could provide some heat with hydrogen that actually can go in pretty fast and pretty easy.

Julio Friedmann (08:20):

So, a second place where I think we're going to use a lot of hydrogen is in heavy duty transportation. And by heavy duty transportation, my favorite is shipping. Okay? To get a container ship from Shanghai to Los Angeles, it's really tough to do with batteries, right? It's just really tough.

Scott Tinker (08:36):

It's a lot of diesel and that's a lot of CO2.

Julio Friedmann (08:39):

And not a lot of only a lot of CO2, a lot of pollutants, a lot of sulfur, all these other things. And we know that we could run that ship on ammonia, okay? And if we ran it through a fuel cell, you wouldn't burn it, so that we...

Scott Tinker (08:50):

We can't do it on batteries to state the obvious because they weigh a lot.

Julio Friedmann (08:53):

They weigh a lot and they take a lot of space, right? And so there's some applications where we look at and we go, we think hydrogen's going to be the go-to for that.

Scott Tinker (09:01):

Let me draw an analogy here then, because I think what I'm hearing you both say is for hydrogen; big things, big steel manufacturing, big boats, is that the same for cars?

Steve Hamburg (09:14):

You bet.

Scott Tinker (09:14):

Let's go to fuel cells. I mean, why not fuel cells in cars? Where do fuel cells make sense?

Steve Hamburg (09:21):

You have alternatives. Why would we go to putting it in individual vehicles where a battery in a car works really well. We've demonstrated that. And the large auto industry is building them en masse. We'll have that option, so why would we then open that up when we have so many questions.

Scott Tinker (09:39):

What's a fuel cell?

Julio Friedmann (09:42):

Basically, you can think about a fuel cell as basically the opposite of an electrolyzer. So an electrolyzer you put electricity into water and out comes hydrogen and oxygen. In a fuel cell, the opposite happens, you put hydrogen and oxygen into a fuel cell and what comes out is electricity. Okay? And they're actually very efficient now for the most part, you can get 70%, 80% efficiency out of a really good fuel cell. So what's nice about that is it doesn't burn. There's no combustion, so there's no combustion related pollution associated with it. So you don't get nitrous oxides and [inaudible 00:10:14] and all these other sort of things.

Scott Tinker (10:14):

Or CO2?

Julio Friedmann (10:15):

Or CO2. Right. Instead, hydrogen and air go in, out comes electricity. And that's pretty slick. So if you look at something like a battery in a car. Battery costs $5,000 or $6,000, okay? For a car, that's not that much though. On a grand scale, that's not that much. To put it in a truck costs $90,000. That is a completely different value proposition. And it could take 20%, sometimes 40%, of the cargo holding the battery, right? So a long haul truck is a pretty different value proposition than a car in terms of cost, in terms of efficiency, in terms of charge time, in terms of all these things.

Steve Hamburg (10:53):

But it's important to note that a lot of trucks are hub-based trucks, and that is a large portion of the market. And that is going towards electricity for obvious reasons, right? The duty cycles are very accommodating of electrification.

Julio Friedmann (11:09):

A short haul truck like the vans that Amazon uses are basically going electric pretty well. Maybe that's the right answer for those kinds of medium haul trucks. But for the long haul trucks, I don't see it yet. I'm still betting on hydrogen to win.

Scott Tinker (11:22):

How else might we use hydrogen in the future?

Julio Friedmann (11:24):

Let's talk about the best case. Let's say we're in a 2050 world. We will have like 500 to 1000 times more clean hydrogen. Okay? Clean hydrogen, meaning really, really low carbon footprint. In that world, all of heavy industry, chemicals, cement concrete as best we can do it, steel, aluminum, glass, all that stuff is run on hydrogen. Our ships are run on hydrogen-based fuels. Our planes are run on synthetic fuels made from hydrogen.

Scott Tinker (11:51):

And we're burning it to make the heat. When you say run on it, what does that mean?

Julio Friedmann (11:55):

So a combination of burning it here, fuel cells there, and chemistry there. So the less we can burn the better off we are. We'll be using hydrogen storage, huge salt caverns, and very large tanks to balance the grid for the really hard stuff.

Scott Tinker (12:11):

You can store it for longer periods of time, potentially months or even seasonally, and you can release a lot of energy from it. So as a big battery, for some things, not a bad idea?

Steve Hamburg (12:24):

Conceptually it's fabulous, and it helps us. I mean, we looked at how to decarbonize the electric grid in California with a comparative model, set of models, really went in depth. Renewables are phenomenal, but they don't get you all the way there. At least certainly not cost effectively and with land use constraints.

Steve Hamburg (12:41):

So if hydrogen can be generated and stored with minimal impact on the environment at a cost effective way, it's fabulous. But that's an if right now. We shouldn't put all our money on that bet, right?

Scott Tinker (12:57):

Right.

Steve Hamburg (12:57):

There are others horses in that race. We need to put money on all of them to place to win. And if hydrogen proves out to be good at it, great. But if something else does and you're having it on your show, right? Lots of different options. That's okay too.

Scott Tinker (13:13):

So there's a lot of folks in the world, and I talked to quite of them, are just skeptical about hydrogen. Never going to happen. Never going to happen. Why is that? Why do they think this? What's the first bet?

Steve Hamburg (13:25):

Well, I think that part of it is that... I heard about the hydrogen solution for climate change in 1975. So when a idea's been kicking around for many decades and never materialized, some people look over and say, yeah, here we go again, right?

Julio Friedmann (13:39):

I would echo Steve's words in one important way. The thing that's really changed in this instantiation is climate, because when we were talking about hydrogen in the 70s, we were talking about the oil embargo. We were not talking about climate.

Scott Tinker (13:50):

Hydrogen economy. Jesse Ausubel.

Julio Friedmann (13:52):

We were talking about it in the 2000s. People were really talking about getting hydrogen for cars and for power plants. And that's not really what people are talking about these days. You're looking at a different market, serving a different set of needs. And that's the basis on which I'm thinking differently about hydrogen this go around. I was pretty skeptical in 2002. I'm not skeptical now.

Scott Tinker (14:14):

How does hydrogen reduce CO2 emissions? What's the driver here? Why is there a climate driver on hydrogen?

Steve Hamburg (14:21):

Well, there's just the basics. If we can replace hydrogen for fossil fuels that emit CO2, when it's either burned or used as an energy source, then that's a big advantage. But we have to not think of it as dichotomous because hydrogen is a greenhouse gas as well. So it's really about the amounts. So how much hydrogen is emitted to the atmosphere from deploying hydrogen energy systems and how much is CO2 is emitted from deploying fossil fuels?

Scott Tinker (14:47):

So it's a net? Netting things out.

Steve Hamburg (14:50):

Absolutely. And in the case of blue hydrogen, we got to add methane to it as well because we're using natural gases as a feed stock. And that's composed of methane, which is again, another potent greenhouse gas.

Scott Tinker (15:02):

Right.

Julio Friedmann (15:02):

What we really want, somewhere along the line, is someone to come along and say, you have to be this tall to go on this ride. And this tall means you cannot admit more than this amount. And if you do, then you're not allowed in the clean energy hydrogen game.

Julio Friedmann (15:15):

So right now China makes 22 kilograms of CO2 for every kilogram of hydrogen they make. That is a huge carbon footprint and they make boatloads of hydrogen. So if they push their hydrogen economy through their whole economy, we'd be in a world of hurt.

Julio Friedmann (15:33):

And so hydrogen is a great substitute for fossil fuels if it's made clean, and that's where these standards, this thou shall not exceed this limit becomes an essential work. And you have to include the upstream life cycle stuff, as well as the use case, you got to do the whole bit or else we could be making a new problem for ourselves.

Scott Tinker (15:51):

Right. But on the CO2 emissions and climate, scale matters.

Julio Friedmann (15:57):

Yeah.

Scott Tinker (15:57):

Hydrogen's only one of the levers or wedges or whatever we want to call them. But it is one, it's scalable, so it could be when used correctly.

Julio Friedmann (16:06):

Hydrogen could be one of those things if we do it right, because the abatement potential in these sectors using hydrogen is very large, but that is just potential. It is like anything else, you have to realize that potential to be material.

Scott Tinker (16:19):

Right. When you get down to that list of these things that are actually scalable, there aren't that many on it really.

Steve Hamburg (16:27):

But I think the key is... I just want to go back to Julio's point is the difference between theoretical potential and realizable potential, and in that, we have to really double and triple down on collecting the information we need to figure that out. I think there are many permutations of energy systems that we're going to need to deploy, and we need to understand how to deploy them effectively. And to do that, we just don't have enough data.

Scott Tinker (16:53):

The world's emitting 35 gigatons, 40 gigatons a year of CO2. If we were to get hydrogen by 2050 to where it potentially could be in the right sectors at the right places, what are we looking at? Is it a 5% reduction, 10%?

Julio Friedmann (17:07):

So the energy service that hydrogen could provide in terms of running a steel mill or moving a turbine or going through a fuel cell, whatever it is. It could be as much as 20% or 30% of the economy, so it's a big chunk. And when people look at say, getting to zero by 2050, the amount of...

Scott Tinker (17:25):

28 years.

Julio Friedmann (17:26):

28 years from now. Exactly. Five Senate cycles from now. We need to go up to something like 730 million tons of hydrogen a year, which is about a factor of 9 or 10 more than we got today. And it's got to be all zero emissions, all clean. That is a hugely difficult thing to do, but the prize is just as big.

Steve Hamburg (17:48):

And again, I think we have to be careful here, because this is crystal ball gazing and this is sort of potential, theoretical, and this creates the hype that leads to poor decision making. So while I won't argue with Julio on that number, what I will say is the reality of what we're likely to realize is much smaller than that.

Scott Tinker (18:10):

Sure.

Steve Hamburg (18:11):

So if we have to be careful of not putting it out there and then everyone doubles and triples and quadruples down on it, and we make a whole lot of bad decisions, and we're going to regret those.

Scott Tinker (18:23):

And then it gets pitched.

Scott Tinker (18:23):

Well, its get pitched.

Julio Friedmann (18:23):

People get skeptical.

Scott Tinker (18:25):

And we just don't get to the real goal here, which is to decarbonize the economy, do it equitably, give better access to energy across the globe.

Scott Tinker (18:34):

In 28 years, if we could knock 3 billion tons a year out of the emission stream with hydrogen; that'd be a pretty good thing, wouldn't it?

Steve Hamburg (18:43):

It would be, and it may be bigger, it may be smaller. The point is that what we need to do is as we are doing in many places is doubling down on getting those answers and figuring out what the realistic potential with integrity. When that's where Julio and I agree, it has to have integrity.

Scott Tinker (18:58):

How important is a carbon price for hydrogen? How vital is it or what are the options to a carbon price?

Julio Friedmann (19:05):

Well, a carbon price would be the most efficient way to drive change around the world. It is also inversely proportional to the political ease in which you do that. One of the things we can do is we can do incentives. And right now we're seeing in Europe and in North America, we're seeing incentives coming forward for clean hydrogen. Something like a production tax credit. In the U.S., a contract for difference in the United Kingdom, where they basically say, if you make hydrogen that is this clean, we will give you this much of a tax break.

Julio Friedmann (19:33):

And they're also adding grants. They're saying here's a bag of cash. Go try something, learn something, build a hub, build some infrastructure, train some people, and then we'll have some answers, right? Those are good policies. And those policies help.

Scott Tinker (19:46):

Incentives typically work.

Julio Friedmann (19:47):

Incentives work. Sticks work too. Sometimes you want to use a carrot. Sometimes you want to use a stick. So in the case of sticks, a lot of countries just said, we're not going to emit more than this amount. Everybody get your ducks in a row and you all got to pay. Like that's a pretty strong driver too.

Julio Friedmann (20:03):

The last thing that I'll put on, and this is one of my favorite ones, this is a sleeper, but I think it's an important one is government procurement. Okay? It's an unused policy lever. Governments buy 60% of the concrete in the world. Governments buy 20% of the steel in the world. If they wanted low carbon versions of that, you could create some market pull with some government procurement and set the standards for hydrogen in the process.

Scott Tinker (20:26):

Interesting. Where are you on the carbon tax thing, Steve?

Steve Hamburg (20:29):

Well, I mean putting a price on carbon is an integral part of it. And I'm a scientist, I'm not an economist.

Scott Tinker (20:36):

Right. Economists seem to love the carbon tax mostly.

Steve Hamburg (20:37):

Yeah. Well we need to put a price on carbon. There are multiple mechanisms, ways that you can do it. And the really issue is how do we ensure that those who are producing energy or products and take those externalities, the emissions of greenhouse gases and price them into their products, because historically we have never done that. And then you start to create the level playing field so that in fact you can compare A to B. But again, we need these incentives and we need to just have absolute mandates in a lot of these cases because the climate crisis requires early, early action. If you can say, you may not sell product A, unless it has attribute B, a certain greenhouse gas emissions, that works too. That's not a price, that's just you can't do it.

Scott Tinker (21:21):

Why are oil and gas companies interested in hydrogen? Because they are.

Steve Hamburg (21:25):

Well, I mean, there's a potential market, a very large market for the products they currently sell, particularly the gas. And so because gas can be used to produce hydrogen, it is now used to produce hydrogen, and it can be used to produce blue hydrogen, which is going to be a much cleaner hydrogen. I think that's fine, as long as it isn't become the raison d'etre of the whole hydrogen system. And rather we're using it in the appropriate places. I think where we have to be really careful is not to substitute hydrogen for gas without thinking, because in a lot of those substitutions, there's not a good use.

Julio Friedmann (22:03):

Yeah. But I would add there's a couple of other reasons why oil and gas companies are interested in hydrogen. The best oil and gas companies in my experience know they have to do an energy transition. Like they know they're going to zero, that's the case.

Scott Tinker (22:16):

Zero emissions.

Julio Friedmann (22:17):

Yes. They are also in the fuel business, and the fuel business is a pretty good business. If they can sell zero carbon fuel, they like that. And hydrogen is a zero carbon fuel. Right? So it's not just that they can use the assets that they have, but it is also a business model that looks interesting to them because it's a business model they understand.

Scott Tinker (22:35):

And it makes use of some of the existing infrastructure.

Julio Friedmann (22:38):

Yes.

Scott Tinker (22:38):

Potentially as well.

Julio Friedmann (22:39):

Potentially. If you were to start with hubs and say like where in the United States would be great places to do it, there's actually quite a lot. I mention the Gulf of Mexico, but the Gulf of Mexico ain't one thing. It's actually lots of things. So you could imagine something in Houston and Port Arthur and near New Orleans, like you get a couple of these things, right?

Scott Tinker (22:57):

Yeah. Yeah.

Steve Hamburg (22:58):

But we have to think about, again, the larger system here, so just take an example. If you say New York and New Jersey, well, there's a real dearth of renewable energy in that part of the country. So if you build a hub to do green hydrogen there, you are continuing the use of fossil fuels. And if you use Hydro Quebec power, it has a lot of associated greenhouse gas emissions with it. And so you have to think about what are the system characteristics. And if we go down to the Gulf coast, there are a whole suite of communities who've been really heavily impacted by the existing infrastructure. And then you say to them, oh, by the way, we're going to bring some more stuff here. There's real equity issues there.

Julio Friedmann (23:38):

The big challenge is we have to be as ambitious and as urgent as we can possibly be. And at the same time, we got to be humble about how hard it is and what we don't know. I'm not really a markets expert. I'm not really a politician. I'm not a social scientist. I don't live in a disadvantaged community. We got to be humble about the fact that all these people have a voice and they have a say, and that will take longer, and we don't have longer. That will make it harder, and harder will cost money. And we have to be clear-eyed about these trade offs. It's part of the reason why we keep going back to something so simple as can we please run some pilots and get some data, because if we do that, we could make better choices.

Steve Hamburg (24:23):

We need more than a little though. [inaudible 00:24:25]

Scott Tinker (24:24):

Yeah. Get started.

Steve Hamburg (24:26):

We got to get started and we've got to build on it. And we can deploy relatively quickly if we have concerted efforts to understand the systems, whether that be leakage, whether that be the effectiveness of storage, whether it's the price points on electrolyzers. As we get more data on all those things and we start bringing them together in a systematic way, we start to get clarity on where we need to go, and that's what we're lacking. And we have to be resistant to the shiny bauble that's out there that everybody's looking at, and say, look, there it is, because then what we do is we get distracted and we really have to do the hard work.

Scott Tinker (25:03):

Wow. Great deep conversations from two, obviously, extremely well-versed and intellectual people here.

Scott Tinker (25:11):

We talked about different ways to make hydrogen, 99% of it today is gray produced from methane natural gas, but that also produces carbon emissions. Blue is the same process, just capturing the carbon. Green uses solar or wind. And pink uses nuclear to split hydrogen from water. To realize hydrogen's full CO2 reduction potential, we'd have to grow blue, pink, and green as much as a thousand times. And shrink gray to near zero. We also talked about hydrogen's potential uses for heat in industry, as feedstock in chemistry, and as fuel in heavy transport. To begin, we could build hubs in existing industrial areas. And we need to get started to see what works and what may not.

Speaker 1 (26:36):

Funding for Energy Switch was provided in part by Microsoft and by the University of Texas at Austin.