SCIENTIFIC AMERICAN FRONTIERS PROGRAM #1506 "Hydrogen Hopes"

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HYDROGEN HOPES

Hello and welcome to Scientific American Frontiers. I'm Alan Alda.

What will today's kids be putting into the tanks of their cars when they start driving in ten or fifteen years time? Chances are it'll still be gasoline —— but the price they'll be paying could be steep, not just in dollars and even lives as the international competition for oil escalates, but in the consequences of continuing to pour global warming gases into the atmosphere.

Which is why in this program we're visiting some of the people who are planning for a future when oil will begin to be replaced by a fuel that can be made in unlimited quantities and produces zero pollution — hydrogen.

We'll meet a husband and wife team who've been working toward a hydrogen-powered economy for over 40 years...

We're checking in with a brand new start-up company that plans to harvest hydrogen-producing algae from smokestacks and sunlight ...

And we're visiting a country that plans to be the first in the world to achieve energy independence through hydrogen

That's all coming up in tonight's episode, Hydrogen Hopes.

HYDROGEN SPONGE

ALAN ALDA (NARRATION) In Germany recently we checked out a car that's powered by a fuel cell and runs on hydrogen. Much of the auto industry is betting that cars like this are the future, reducing dependency on oil and — by putting out only water from their exhausts — reducing the emission of carbon dioxide, linked to global warming.

ALAN ALDA It smells good, you know? Really, it smells like a laundry room.

BOB NATKIN Fresh laundry is what we call it.

ALAN ALDA Moist air, yeah, really nice. That'll turn out to be like a thing that people do, you know, smelling each other's tail pipes.

ALAN ALDA (NARRATION) The car I was sniffing is also powered by hydrogen, but it doesn't employ a fuel cell. This is a Ford Focus, modified so that it's internal combustion engine runs on hydrogen instead of gasoline. It's also a hybrid, employing an electric motor to supplement its engine.

ALAN ALDA You've got hybrids on the road now that use gasoline and electricity. But here, electricity and hydrogen, that seems like, it seems like we're standing next to a car of way in the future. I mean, how far in the future is this car?

BOB NATKIN The technology here is all conventional technology utilizing a new fuel. If we had fuel available this car would be out in a very short period of time.

ALAN ALDA (NARRATION) And here is the big roadblock to replacing gasoline with hydrogen — actually, two big roadblocks: first, getting the hydrogen; and second, distributing and storing it. We're going to tackle the storage issue first. Like most experimental hydrogen-powered vehicles being tested today, this one runs on compressed hydrogen gas stored in a high-pressure tank. But hydrogen gas takes up much more room than the equivalent amount of gasoline — as well as raising concerns about safety. Last year, we met a husband and wife team who've been thinking about hydrogen for over forty years, and believe they already know the best way to store it— as a solid.

STANFORD OVSHINSKY ... and you have an all hydrogen car with solid hydrogen.

ALAN ALDA Now what's Iris getting?

IRIS OVSHINSKY I brought a piece of your solid...

ALAN ALDA (NARRATION) The sample Iris Ovshinsky has brought over is a proprietary metal alloy that soaks up hydrogen gas like a sponge soaks up water.

ALAN ALDA How do you get the hydrogen out of this and into the car?

STANFORD OVSHINSKY Very easily, because we put it into a tank back here...

ALAN ALDA (NARRATION) Stan and Iris claim their Ovonics tank can store twice as much hydrogen as a typical high-pressure tank containing hydrogen gas.

ALAN ALDA What's keeping us from having these either in our cars or at the gas station to produce hydrogen? What's the roadblock?

STANFORD OVSHINSKY Ah, we're the best-kept secret. Now that we're on television, maybe that will change!

ALAN ALDA (NARRATION) We were so intrigued by Stan and Iris Ovshinsky that we decided we'd go visit them. So here we are, a year after I drove off in their solid-hydrogen-powered Prius in California, arriving in the same car — borrowed for the occasion — at Stan and Iris's corporate headquarters in suburban Detroit.

STANFORD OVSHINSKY Nice to see you again.

ALAN ALDA (NARRATION) We're starting at the place that's the heart of the Ovshinskys' now far-flung empire — and an alchemist's dream. Here, a mix of metals are brewed into unique alloys that have in common a passion for hydrogen surpassed only by Stan and Iris's. When these alloys encounter hydrogen they embrace it to form metal hydrides. The best known is the nickel metal hydride in the rechargeable battery of your cell phone or camera. Stan Ovshinsky has spent decades tweaking the formula of these alloys, allowing hydrogen to slip into and out of their embrace in different ways.

STANFORD OVSHINSKY The hydrogen economy started right here years ago when we started building nickel metal hydride batteries. Before us no one had ever built them before. They tried to do it but they failed.

ALAN ALDA It's kind of fascinating that the same stuff you make a battery out of you can store hydrogen in to run the car off of pure hydrogen.

STANFORD OVSHINSKY That's exactly right.

ALAN ALDA Wow. Just by changing the recipe of this block of stuff.

STANFORD OVSHINSKY That's what we're about, we invent the materials, we invent the products and we invent the production technologies.

ALAN ALDA (NARRATION) At the foundry they told me that the production technology in this case involves soaking the alloy block in hydrogen to make it brittle.

SCIENTIST After we got the big chunk...

ALAN ALDA Yeah, then you broke it up with hydrogen, and you ground it up into a powder and that's what you've got here?

SCIENTIST You're the expert, Alan!

ALAN ALDA How many elements do you have in each...?

SCIENTIST Seven or eight.

ALAN ALDA Seven or eight elements. And every particle of powder has these elements.

ALAN ALDA (NARRATION) Stan wanted us to get a close-up view of how the hydrogen-absorbing powder can be loaded into a fuel tank.

ALAN ALDA They're wearing gas masks.

ALAN ALDA (NARRATION) The next step is a reminder that this is a project still in the process of invention.

STANFORD OVSHINSKY We wanted you to see how realistic everything is so there's no hidden things there. Obviously in production you would not be doing it that way.

ALAN ALDA When you mass produce these, you don't have two guys pouring into a measuring cup.

STANFORD OVSHINSKY That's what I'd like to make sure the public understands. This is not a science fair.

ALAN ALDA What's amazing to me about this is that it is all done in a fairly simple way, and up here is where all the work was done. That's where the magic is.

ALAN ALDA (NARRATION) This little canister is already filled with Stan's magic powder.

NED This canister we're going to charge with hydrogen. And you can actually hold this. You can actually feel the hydrogen go in.

ALAN ALDA Now it's getting warm. This is because the hydrogen is mixing with those particles.

NED It's reacting with the metal and it's forming the metal hydride which is exothermic, it generates heat. So you can see the temperature gradually climbing.

ALAN ALDA Now you could fry an egg on my hand. OK, thank you very much.

ALAN ALDA (NARRATION) To avoid melting your fuel tank ever time you fill it with hydrogen this heat has to be gotten rid of — and of course Stan has a solution for that, too.

STANFORD OVSHINSKY We'll go out and show it to you.

ALAN ALDA Yeah, but what about this? They're liable to be watching.

STANFORD OVSHINSKY No cameras!

ALAN ALDA (NARRATION) The secret that Stan doesn't want competitors seeing is that inside each fuel tank is an elaborate heat exchanger — these shiny things you can just see from back where you are — a heat exchanger that when you fuel up with hydrogen will have water pumped through it.

ALAN ALDA Ok, now you need the water so that when you put that in, it doesn't overheat, when you put the hydrogen in.

JOHN Right.

ALAN ALDA Should I stand back?

JOHN No. You want to do it?

ALAN ALDA Is this alright?

STANFORD OVSHINSKY Sure.

ALAN ALDA Just jam it in here? JOHN Just push it on.

ALAN ALDA (NARRATION) A real hydrogen filling station would have to have pumps that combined cooling water and hydrogen. But once you fueled up...

ALAN ALDA How far can I drive on that tank?

STANFORD OVSHINSKY Well that one tank there is about 140 miles, right now with that present alloy that we're using. However, I'm working on other alloys and other things that will . . .

ALAN ALDA When you say you're working on other alloys, you must have a list of things that you'd like to figure out.

IRIS OSHINSKY Stan always says he likes to use the materials from the mind rather than from the mines.

ALAN ALDA And you do.

ALAN ALDA (NARRATION) We'll be back later in the show to see how Stan plans to make hydrogen as well as store it. Meanwhile, we're visiting a country that's perfectly placed to become the world's first to run itself entirely on hydrogen.

FIRE AND ICE

ALAN ALDA (NARRATION) Nowhere is the dream of hydrogen's becoming the fuel of the future more alive than here — perhaps one of the last spots on earth you'd expect such a revolution to unfold. We're in Iceland, whose tiny population of less than 300,000 is entirely dependent on imported oil — oil that provides the fuel for its large fishing fleet as well as its cars, trucks and buses. But if Iceland has no oil of its own, it does possess another underground resource -- hot magma from the earth's mantle welling up beneath a surface that is itself the product of volcanic oozings in the not-too distant past. In many places the magma comes close enough to the surface to heat the groundwater to well above its boiling point. We're walking in one of those spots now, where a borehole was recently drilled to test the potential of the geothermal energy just under our feet.

ALAN ALDA This is just one of many boreholes in the country?

JON BJORN SKULASON Yup.

ALAN ALDA And you could make many more, you could put one pretty much anyplace?

JON BJORN SKULASON Well I wouldn't say anyplace. It's more or less around the crack where the Atlantic Ridge goes through the island. It's remote control. You can open the borehole from far away. Just push the red button and you will see.

ALAN ALDA (NARRATION) The noise is shattering — and a dramatic reflection of the power Iceland is sitting on — power in the last 50 years it has increasingly tapped, first to provide hot water for heating homes, more recently to produce

electricity. In fact, one of the country's major tourist attractions — the Blue Lagoon, packed year-round with bathers — is actually the waste pond for one of a half-dozen or so geothermal power plants in Iceland.

JON BJORN SKULASON And this is more or less 100 percent renewable power and then we can actually use that to make hydrogen. So we have a big resource to make a lot of hydrogen to power our own vehicles and our own ships and then in the future maybe vehicles and ships in some other countries.

ALAN ALDA You'll be able to transport the hydrogen, which is a way of transporting...

JON BJORN SKULASON Electricity.

ALAN ALDA Electricity, and in turn that's a way of transporting your geothermal resource.

ALAN ALDA (NARRATION) In the last few years, Iceland as a nation has committed itself to this vision of becoming the world's first hydrogen economy, freeing itself entirely from imported oil. Jon Bjorn Skulason heads a venture jointly owned by the government and several major companies with an interest in hydrogen. It has as its symbolic beginning a rather lonely fuel station on the outskirts of the country's capital, Reykjavik. ALAN ALDA It looks like you are all set up for a car to pull up and fill up.

JON BJORN SKULASON It's actually ready. We can actually... the station is full of hydrogen and if we had vehicles here we could actually fill up vehicles right now. So it's ready for use.

ALAN ALDA Watch where you point that thing!

ALAN ALDA Now where is this coming from when it comes out of here?

JON BJORN SKULASON Well we've got to go inside and show you where all the machinery is. So inside here you have all the major components of the electrolyzer, actually the mother of the station as we can call it.

ALAN ALDA (NARRATION) The electrolyzer is actually simply a reverse fuel cell stack, producing hydrogen from electricity and water instead of electricity and water from hydrogen.

ALAN ALDA This is right next to or part of a regular filling station where they sell gasoline, right? And you can add a little building like this and produce hydrogen at a filling station and sell it.

JON BJORN SKULASON Yup. That's what we think actually will be part of the future is actually on-site production of hydrogen. You can see all these oil tankers driving around all over the world. If we designed the future like this we don't need oil tankers driving around anymore. We still need the wires in the air with the electricity, and of course, the water system or pipeline system for the water system, but the distribution is on site.

ALAN ALDA (NARRATION) A few weeks after our visit to Reykjavik's hydrogen filling station, it had a customer — a delivery van, loaned for the ceremonial opening of the station by one of the partners in the venture, DaimlerChrysler. But while Iceland is bullish on becoming a hydrogen economy, it does have unique advantages most of the rest of the world lacks — a small, politically cohesive population, and above all of course, an abundant, cheap, clean and renewable source of electricity that can be made into hydrogen on site in stations like this one. In the United States, hydrogen is made today from fossil fuels like oil, natural gas and coal. But in the future, the hope is — as in Iceland — to make it from renewable sources, and so eliminate the climate-warming gases generated by fossil fuels. And the ultimate renewable resource, of course, is the sun — as we'll see next.

SUNSHINE HYDROGEN

ALAN ALDA (NARRATION) The sun gets its energy from hydrogen, squeezing its atoms until they fuse. So there's an appeal to the idea of using the sun's energy to make hydrogen here on earth. The idea caught Stan Ovshinsky's imagination in the early 1960s, when he sketched it out on a blackboard for his wife and business partner Iris — and began experimenting in his storefront laboratory. His plan was to capture solar power to make electricity, then use the electricity to split apart water into its component elements, oxygen and hydrogen.

STANFORD OVSHINSKY So we went to the first solar meetings that we could, and I'll never forget, they gathered together, had a big magnifying glass, and burned pieces of wood and saw smoke coming out, and thought they were using wood.

IRIS OVSHINSKY And sold solar cigarette lighters.

STANFORD OVSHINSKY And things like that. So I said, "well, that doesn't make much sense." And I thought that we would approach it much differently. And I started then the idea of the hydrogen loop, the complete loop. Where do you get your hydrogen? Start with solar energy from the very beginning.

ALAN ALDA (NARRATION) Today the solar energy business is booming, with billions of dollars being spent on solar panels to make electricity. Almost all these so-called photovoltaic systems employ cells made from delicate and expensive crystals of silicon. But from the very beginning, Stan and Iris Ovshinsky had a radically different kind of solar device in mind. Here in a huge factory filled with machines Stan mostly invented himself, photovoltaic panels are made not from silicon crystals but multiple layers of the exotic metallic alloys the Ovshinsky's use in all their creations. Turned out literally by the mile, these solar panels soak up more sunlight than conventional cells — and are far more forgiving.

ALAN ALDA So these holes you've put I here to show that it doesn't damage easily?

STANFORD OVSHINSKY Yeah, for example... why don't you bring that here... this is conventional crystalline, very heavy and...

ALAN ALDA Very heavy, yeah...

STANFORD OVSHINSKY And breakable.

ALAN ALDA Now does this produce the same energy as this?

STANFORD OVSHINSKY No. Through the day you get more energy out of this that you do for that.

ALAN ALDA And if you damage one little part of this, the whole panel is out, right? Now here you've damaged a dozen places. So now, this is hooked up to this radio? And that's your only source of light?

STANFORD OVSHINSKY Yeah.

ALAN ALDA The radio goes right on. And you can actually take this out in the rain?

STANFORD OVSHINSKY I do it all the time. I get my clothes all wet. Because everybody says that and then when we get back to the office and it's raining I rush out, and I meet them with rain coming down, playing the music.

ALAN ALDA (NARRATION) Several large structures all over the world are now clad in Ovshinsky's solar panels. While they are less efficient in bright sunlight than conventional solar cells, their ability to go on making electricity even in dim daylight — for instance, in the early morning and late evening, as well as while it's cloudy or raining — makes them an attractive alternative. Stan's latest invention is an extraordinary machine, longer than a football field, that's able to

make six strips of his solar panels at a time, each a mile and a half long. His goal is to make solar electricity as cheap as that made from coal, then use the electricity to make hydrogen.

ALAN ALDA When you first proposed to your people that you wanted to make something a mile long, what did they say?

ALAN ALDA They thought he was crazy.

STANFORD OVSHINSKY I don't ask for, when I introduce a brand new thing, I never ask for taking a vote. We offer solutions here to what people think are the most serious problems right now -- pollution, climate change, and wars over oil. As well as building new industries. So I think if you want to change the world, this is a better way than making political speeches.

ALAN ALDA (NARRATION) Stan Ovshinsky's dream is to make hydrogen from the sun via solar-generated electricity. But there are other ways the sun could create hydrogen. Here on the roof of the power station for the Massachusetts Institute of Technology is the test of a plan to make hydrogen from sunlight using the everyday miracle of photosynthesis. The gas making the bubbles in these green tubes comes from the power plant's smokestack — and the green stuff is algae. Ancestors of the algae here once grew in the ocean, but now the microscopic plants are feeding on the flue gases and growing in the sunlight.

ISAAC BERZIN Imagine a black box, and fuel gases are coming into this box, and what's coming out of this box is renewable energy, and clean gases. OK? So instead of a black box, it's a green triangle. That's the only difference, OK?

ALAN ALDA (NARRATION) The algae in Isaac Berzin's green triangle absorb most of the pollutants in the flue gases, leaving them some 80 percent cleaner. Every day, the tubes are drained to collect the last 24 hours of growth.

ALAN ALDA They're harvesting the algae in there? How do they. . .

ISAAC BERZIN They just drain ALAN ALDA They just drain it out.

ISAAC BERZIN Like a cow, they take a little milk from the cow, and you leave enough there for the new generation to catch up.

ALAN ALDA (NARRATION) The algae in the buckets have done a job power plant operators usually have to install expensive pollution control equipment to do — remove the nitrogen oxides from their stack gases. The algae have also consumed most of the carbon dioxide, or CO2.

ALAN ALDA So this has a lot of bad stuff in it, you wouldn't want to . . .

ISAAC BERZIN No, actually not. Once the carbon, once the CO2 is turning into organic carbon, there's nothing bad in it.

ALAN ALDA You mean a person could eat this?

ISAAC BERZIN Actually we start every . . .

ALAN ALDA I'm shocked, that the producers haven't made me eat this.

ISAAC BERZIN Listen, I want to tell you something. We start every morning with a glass of algae drink.

ALAN ALDA Get out of here. I don't believe that. No, come on.

ISAAC BERZIN You can get it in Whole Foods, it's called a green machine, there are all kinds of generic names for it. It's basically algae drink. It's good for you. It's a health product.

ALAN ALDA So after the algae eats all that bad stuff, it's just a nice piece of algae.

ISAAC BERZIN It's because the chemistry changes.

ALAN ALDA You're not making this to see it in a health food store. What do you do with it that makes it profitable to the company that uses this machine?

ISAAC BERZIN Very simple. You can take this and use it as a renewable energy source. First thing you have to do is dry it. How do you dry it? Well, the flu gases are very hot, we touched it. You saw that. So use this excess heat to dry this goo stuff into something that looks like a powder. So you feel now in your hand the transfer of CO2 from a gas that no one knows what to do with, to a viable product, you feel it in your hand now.

ALAN ALDA Yeah, yeah, yeah.

ISAAC BERZIN OK? So that's the miracle.

ALAN ALDA (NARRATION) Today, power plant operators pay money to get rid of nitrogen oxides from their stack gases — and one day in the future they may pay to get rid of carbon dioxide, too, as evidence continues to mount that carbon dioxide from burning fossil fuels like coal is contributing to global warming. Isaac's idea is that power plants will install large arrays of his green triangles,

earning money by cleaning the gases and also providing the raw material for what's called bio-gasification, a process for turning waste plant material into hydrogen. Making hydrogen from the algae ends up putting carbon dioxide back into the air, but...

ALAN ALDA In a way, you've used the carbon twice, so you get two hits at it.

ISAAC BERZIN Correct.

ALAN ALDA You get twice the use of the same amount of carbon. So this doesn't prevent carbon from going into the atmosphere, but it makes more efficient use of it.

ISAAC BERZIN Exactly, so that's one of the reasons we think it's going to catch. Because if you want to make an environmental revolution, you have two ways. OK, one way is take stones and throw stones on the bad guys. Another way is, look guys, let's make more money. Yes, it's environmental, but let's make money. So it's making a more efficient use of the current infrastructure of power production in this country.

ALAN ALDA (NARRATION) So in Isaac's vision, a by-product of burning fossil fuels would be hydrogen, created from waste gases and sunlight captured by his algae.

ALAN ALDA Let me see you go first.

ISAAC BERZIN OK, cheers guys.

ALAN ALDA (NARRATION) And that seems a vision well worth a toast.

ALAN ALDA You can turn this into hydrogen?

ISAAC BERZIN Yeah.

ALAN ALDA Alright, I'll drink to that.