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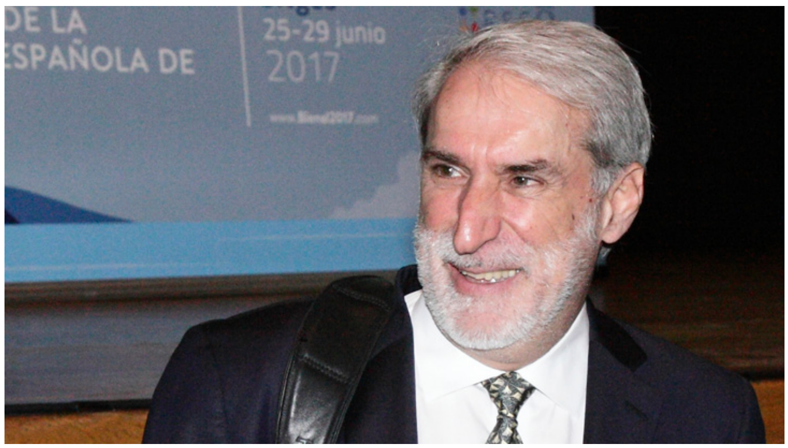
“Bionic leaf could provide starch, drugs,... anything in a renewable way”



Interview with Daniel Nocera, Professor of Energy at Harvard University. He has been working since he was 25 for creating an artificial leaf that mimics plant photosyntesis. He has already developed it to get a bionic leaf that provides hydrogen, liquid fuel and fertilizers using sunlight, water and bacteria. Nocera has participated on the XXXVI Reunión Bienal de la Sociedad Española de Química, organised by the UAB in Sitges at the end of June.

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What is the advantage of producing hydrogen from your artificial leaf compared to other methods like electrolysis or from carbon compounds?

In the artificial leaf there is an electrolysis splitting water into hydrogen and oxygen, but we do it directly (vs. indirectly). Indirectly you take a solar pannel, and then you have wires, to catalyse, and then you do electrolysis. In the artificial leaf, the catalysts coats the silicon on the solar cell

and there are no wires. So an advantage of the artificial leaf is that it is much more simpler to fabricate, because it’s just coatings and silicon. You can think on a glass, and then you have coatings on a glass. You have silicon with just coatings, so that’s easier to manufacture, because we know how to do coatings really easily.
With regard to the other part of the question, wich is carbon, the problem there allways is that you make CO2. Whenever you try to get hydrogen out of anything that contains carbon, inavitably you will get CO2. If people are worried about climate change you will have to avoid that.

Is it better to obtain hydrogen this way than to get electricity with photovoltaic panels?

Yes. When you have solar pannels, thats fine, but you can only get the electricity when the sun is on. When the sun goes down you don’t have it anymore. The water splitting gives you a mechanism to store the solar energy because when the sun is heating the solar panel you are generating electricity and you can store it in hydrogen and oxygen. Then, later at night, when the sun goes down, you could recombine the hydrogen and oxygen in a fuel cell and get the electricity back on demand.

The artificial leaf gives you a method for storing. Without that, you can only use a solar panel when the sunlight is on.

You’ve also developed a leaf that produces fertilizers. How does it work?

We did two things. With one of them we can make fertilizers, and with the other version we can make liquid fuel. They both work the same way, just details are different. We use the artificial leaf that splits water to hydrogen and oxygen, and you could use hydrogen as a fuel in a fuel cell. But the infrastructure isn’t set up tu use hydrogen. So what we do is we take bacteria and we genetically engineer them to bread the hydrogen in, from the artificial leaf. One bacteria can bread nitrogen in from the air, it takes the hydrogen from the artificial leaf, and inside the bacteria it combines the hydrogen with nitrogen to make ammonia or solid nitrogen biomass, and you can use that for direct fertilisation of crops. So it’s totally renewable. You are just using sunlight + water. That makes renewable hydrogen. And then it takes nitrogen from the air + the hydrogen, and makes fertilizer.

In another version, we do the same thing, but it doesn’t take nitrogen, it takes carbon dioxide from the atmosphere. Combines it with hydrogen and makes liquid fuel. We call this combination a hybrid of putting biology and interfacing it with inorganic energy chemistry. And these hybrid systems have a lot of power associated with them.

Let’s talk about the discovery process. Were you looking for these results from the beginning or were you searching for anything else?

I started this research at 25 years old, to just split water into hydrogen and oxygen. That took a long time because we had to invent different fields of science. We needed to figure out how what is called “proton coupled electron transfer” -how electrons and protons couple to each other-. It took many many years to figure out this dance between electrons and protons. Once we figured that out, we then set out to make catalysts to take advantage of everything we learnt about electrons and protons, that was, to make a catalyst to split water into hydrogen and oxygen.

Then it was logical to make the artificial leaf interface with silicon and, then, only a few years ago, we said how could we get the hydrogen into a bigger product, so that's when we came with bacteria. That has been a sort of life goal since I started at 25 years old doing science.

You founded a *start-up* to develop this research and bring it to the market, in India...

I have two start-ups. We have a company called SunCatalytix that developed the *Flow Battery*. It is a big battery you could have at the power company, then the solar pannels on your roof generate electriciy that you could send back over the grid to the power company, they could store it for you and, at night, give it back to you. To do that, you need this thing called the flow battery wich we invented. Lockheed Martin bought that and they are commercialyzing it.

With the artificial leaf, in its newer version, wich we call bionic leaf, I'm going to do it in a different way. I'm going to develop them in India. So I'm not going to do a start-up in America and then try to sell it in India. We are passing all of our knowledge over to India and I'm working with an institute there, the Institute of Chemical Technology, in Mumbai. And they are going to do the scale up and prototyping, and then, indian investors work with those indian scientists and engineers to develop it and then roll it out.

I won't start a formal company to do that. I'm going to let the indians do that. I'm going to give them the knowledge we have to help them do that.

What's the aim of this?

The aim is a little different. In the developed world, like in Spain, you have a big infrastructure already. You can do fertilization, you have big chemical industry to do fuels for you, but if you're in the developing world they haven't built that infrastructure yet. Rather than have them build that infrastructure, the question is, would they choose a different path and go this more delocalized infrastructure? The goal is to make it affordable, but it's an easier price target to hit [than in the developed countries]. In Spain you've already paid off the infrastructures. In India, rural China, Africa..., they have to build that infrastructure, wich is going to cost lots of money. The question is, rather than do that, use the money to do this more distributed renevable energy. That's what I am hoping will be able to be competitive in that market, with these discoveries, and make it affordable for people.

Do you have any partners for the project here, in Europe?

I don't have any partners in Europe that I've been working with, but I have a lot of friends. As scientists we allways play off of each other's research. But in terms of commercialization strategies, no, that's all being done just in India. I'm not even doing it in America, actually.

What are your future plans, are you working on any other technology?

With the bionic leaf we have renewable hydrogen, that powers bacteria, and we make fertilizer and liquid fuel. But genetically, I could encode the bacteria to make anything. They could make starch, or they could make drugs. In a more general way, this is a way to do the chemical industry renewably, using sunlight and water. We would like to generalise this to just being a renewable chemical platform, because depending on what genetics I put into the bug, it eats the hydrogen, and I can in principle have it make anything. That’s what we are thinking about right now.

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