The Oil Drum: Canada
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

Weekend Energy Listening: The H2 Economy vs the Electron Economy

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This week's installment of the podcast is a conversation that I had with Ulf Bossel, organizer of the Lucerne Fuel Cell Forum, one of the biggest scientific fuel cell conferences going. This conference used to flip every year between a focus on low temperature PEM fuel cells and a focus on high temperature solid oxide fuel cells. A couple of conferences ago, the PEM cycle was dropped on "sustainability" grounds and now the conference is flipped between the SOFC program and a general fuel cell program.

You can listen to the conversation by clicking play in the built in mp3 player or by downloading the show directly by clicking on the link. A transcript is available for this conversation below the fold.

or download the link directly: Ulf Bossel on the H2 economy vs the electron economy (12MB, 35min)

Here are some reports that may be of interest as well.

The concept of the H2 economy has fizzled from its peak along with many stock options but it still seems to creep up every once in a while. Every car manufacturer has a PEM fuel cell program and occasionally I see an ad on TV promoting a fuel cell car which is "right around the corner". Here's a tricky ad for Honda's fuel cell car that was recently brought to my attention.

Now, the technology works, no doubt about it. If you live in the Southern California area, for $600/month you can lease Honda's fuel cell car. Last year I took a test drive in a Ford Focus with a Ballard PEM fuel cell and a compressed H2 tank stuffed into the trunk. They couldn't tell me how much it cost but I was told it was insured for $250,000. Also no mention of the lifetime, but the last person I spoke to about this who works in the business (it was a Japanese maker) tells me that they're at the 5 year mark before problems arise and the target is to double that. I have confidence that they'll be able to double it, just like they've been able to fix the sub zero freezing start issue.

The problem with the H2 economy isn't in the technology, it's in the thermodynamics when compared against battery cars (note, batteries do have their own problems). Making H2 is extremely hard to justify when you can keep electricity on the grid and charge up a battery instead. This isn't to say that H2 as a fuel is a goner all together, it just means it will have a much smaller impact than previously thought. It's the so called hydrogen economy which is a goner, and the market knows it. This smaller impact is largely reflective of the correction in Ballard's stock price that happened about 8 years ago now when they first decided to investigate PEM fuel cells

for stationary power generation, a much smaller market than the transportation sector.

Transcript
Disclaimer: This transcript was provided by a 3rd party and may not be 100% accurate. Please refer to the audio as well.

Ben : Joining me from Lucerne, Switzerland is Dr. Ulf Bossel who is the organizer of the European Fuel Cell Forum in Lucerne, which for me at least is one of the conferences to go to, although Switzerland's Big Macs are a little more expensive than they are in Canada. Ulf has been around fuel cells and renewable energy for a long time now, but Ulf, I think, one of your best credentials is that your great, great grandfather back in the 1830s, Christian Friedrich Schoenbein, was the first to figure out how fuel cells work.

Ulf Bossel: Yes, he is the discoverer of the fuel cell effect.

Ben : So, fuel cells obviously run in your blood.

Ulf Bossel: Because of genes.

Ben : In your genes, yes.

Ulf Bossel: Fuel cell genes.

Ben : I have one of your books that you wrote about the history of fuel cells and it was dedicated to your great, great grandfather. So, thanks for coming on the show by the way. It is great to have you.

Ulf Bossel: Oh, thank you.

Ben : So, the topic...

Ulf Bossel: It's a pleasure to have a show across the Atlantic.

Ben : So, the topic today is about sustainability and where our energy will come from for the rest of the earth's lifetime. But before we get into that, you made a really significant announcement at the most recent European Fuel Cell Forum, which was the week of July 3rd and the announcement was that any discussion of hydrogen and PEM fuel cells will not be continued. So, why did you make this announcement?

Ulf Bossel: Well, the overriding issue is the creation and establishment of a sustainable energy future. Sustainability, let me say that, it is a term which was coined by the Prussian Forest Administration back in 1790 or so and it means that one should never take more wood out of the forest than can re-grow between two harvesting periods. That means we leave nature intact and just live from nature's interest rates. We take from nature what nature can provide without harming nature. Now, in the energy field, we interact with nature in two ways. We first interact when we draw energy from nature and then we interact again when we release the products of the energy use into nature. Clearly, all fossil fuels are finite and therefore we cannot live off the fossil fuels forever. This is also true for uranium, that is also depletive in whatever time this may be, but Uranium deposits will not last forever. On the other hand, after energy use, we leave CO_2 or radioactive waste behind which nature cannot absorb. Therefore sustained energy can only come from renewable sources, i.e. solar, wind, biomass, hydropower, geothermal. It means that a sustainable energy future will be based on energy from renewable sources used with the highest energy efficiency we can afford or we can accomplish between source and service, i.e. between energy harvest and energy use.

Ben : So, basically hydrogen fuel cells just...

Ulf Bossel: Hydrogen is an artificial, synthetic fuel. It has to be made from other energy. If you look at renewable energy, most of it is harvested as electricity, some as biomass and some as solar heat, but basically most of the renewable energy is harvested as electricity. Hydrogen has to be made artificially by splitting water by electrolysis. This requires more energy than you will ever recover from the hydrogen. However, hydrogen has to be compressed or liquefied for handling, it has to be distributed, and then reconverted back to, guess what, electricity. That means electricity derived from hydrogen has to compete with its original energy source, electricity. If you go through a hydrogen chain, you find that after the fuel cell only 25% of the original electricity is available for use by consumers. A hydrogen economy is a gigantic energy waste. We cannot afford this in the future. Therefore, three of four renewable energy power plants are needed to balance the losses within a hydrogen economy luxury. Because of the losses, electricity derived from fuel cells and hydrogen must be four times more expensive than power from the grid.

Ben : So, you might as well just keep it in grid form.

Ulf Bossel: Sure. People will not choose the hydrogen roots to make their own electricity, but they will take it from the grid. That means we have to extend the grid, of course. We have to develop renewable electricity generation and electricity storage systems. People talk about a hydrogen infrastructure. We have to adjust the electricity infrastructure to meet the challenges of the future.

Ben : So, why did you make this announcement now? I mean we have known about this problem for a while now.

Ulf Bossel: There is no future to a hydrogen economy because it is much too wasteful. We cannot solve the energy problem by energy waste. The energy losses are all caused by laws of physics. If you go through the entire hydrogen chain starting with AC-DC conversion, electrolysis, compression, or liquefaction, transportation, storage, re-conversion the electricity by fuel cells with subsequent DC-AC, there are additional losses in every process stage. These are all related to physical processes. This is physics, not poor handling, and as the laws of physics are eternal, there was no past, there is no present, and there will be no future for a hydrogen economy. Hydrogen economy is a structure of mind, which has no backing by physics.

Ben : Actually, I just want to clarify. When people generally say hydrogen economy, what they overwhelmingly mean is hydrogen-fuelled vehicles, right?

Ulf Bossel: Right. This is part of the game, the hydrogen-fuelled vehicles, but electric vehicles will be four times less costly to drive.

Ben : Yeah.

Ulf Bossel: So, who wants to buy a hydrogen vehicle? Today, the plug-in hybrid is the proper development goal. We will have plug-in hybrids in the sustainable energy world because 80% of the driving is done for rides of less than 50 kilometers, or 50 miles. 80% of the miles are driven in short-range commuting traffic. Such short rides can all be handled with electric cars. So, a plug-in hybrid means you fill up the batteries at home, you fill them up again at work and you commute between work and home with electricity. When you take your car on longer rides or go on vacation you may fill up the tank with gasoline as long as it lasts, but with methanol or some fuel derived from biomass in the sustainable future. This is the most likely picture of the future.

Ben : I totally agree that hydrogen is much less efficient than batteries. Just from quick back of the envelope calculations, if somebody drove a hydrogen-fuelled cell car, say 35 kilometers everyday, then the amount of extra electricity that you have to use to make that hydrogen is pretty much the same amount of electricity as the per capita electricity consumption in Germany.

Ulf Bossel: Yes, this sounds right.

Ben : Quite a bit. If you went to battery cars, then you would be using the same amount of electricity as the per capita consumption of Poland.

Ulf Bossel: Yes, exactly. There are a number of studies confirming this. With the same amount of electricity, original electricity, be it from wind solar energy, with the same amount of electricity you can drive an electric car three times farther than a hydrogen car. On 100 kWh of electricity you can drive an electric car 120 kilometers while a hydrogen fuel cell car of similar size can do only about 40 km. If we want to have mobility and a sustainable future, we have to go for electric cars and not for hydrogen cars because we electric cars are less costly to operate. It is not the vehicle technology, but a question of energy cost of the fuel. Hydrogen must always be much more expensive than electricity needed to split water by electrolysis etc. That is a very clear picture. I have analyzed the situation to illustrate how much water and electricity is needed for certain hydrogen jobs. If you take the Frankfurt Airport and Frankfurt Airport is perhaps comparable to the airport at Montreal. About 50 jumbo jets leave Frankfurt every day, each charged with 130 tons of kerosene. If you replace kerosene by hydrogen on a one-to-one energy base, each plane needs 50 tons of hydrogen. As a side remark: 50 tons of liquid hydrogen occupy 720 cubic meters of space, while 130 tons of kerosene take only 160 cubic meters. We need totally different airplanes for hydrogen. But that is another story. To fill the 50 jumbo jets one needs 2,500 tons of liquid hydrogen every day. 22,500 cubic meters of water, the water consumption of a city of 100,000, must be split by electrolysis. For this one the continuous electricity output of about eight nuclear power plants is needed. Now, if the entire traffic at Frankfurt Airport was all done with hydrogen, one would need the water consumption of the City of Frankfurt plus about 25 nuclear power plants. Using hydrogen for all public air and road transport in Germany, it would take the power output of about 400 nuclear power plants plus enormous amounts of water. You need nine kilograms of water to make one kilogram of hydrogen. The Rhine river and all other rivers would be dry in the summer because the water is used to make hydrogen. So, we are really approaching limits and we have to talk about these limits before we talk about a hydrogen economy.

Ben : So, while we are on the topic of flying, what can replace kerosene though?

Ulf Bossel: Well, in my vision, the long distance transport by air, ships and also transcontinental trucks, some railroads that is not electrified will continue to run on diesel or diesel-like fuels.

Ben : Okay.

Ulf Bossel: Or kerosene. That means we have to reserve the last drop of fossil fuels of oil for these kinds of applications and we have to also reserve the diesel-like fuels we derived from biomass for these kinds of application. We should not use biomass fuels for the local transport where we can use electricity, but airplanes cannot run on batteries or solar energy. They cannot on hydrogen either because hydrogen is simply impractical for long distances. We need different planes which are so bulky that they cannot fly at high speeds, but have to fly at low speed and still, their drag is so high that the fuel consumption is up. So, the last drops of oil plus biomass fuels must remain reserved for long distance transportation by air sea and surface.

Ben : Okay. So, let us just get back to my original question, which is why did you make this announcement now? I mean why not five years ago?

Ulf Bossel: Well, the European Fuel Cell Forum is a completely independent body. We are not receiving money. We are not accepting money or asking for money from governments and other organizations because that would imply, that we cannot be critical about energy policies. But we are free to articulate our concerns. Five years ago things were not that clear, but today the facts are on the table. A hydrogen economy is in conflict with a sustainable energy future. Even the promoter of hydrogen say, "Well, it will come in 30 years or so." Patents have a lifetime of 20 years.

Ben : Yeah.

Ulf Bossel: That means all the research and development we do now will not be put to commercial use in the foreseeable future. Why spend money for a technology, which may become useful in 30 years if we are not even 100% sure that a hydrogen economy will ever come?

Ben : But is not there a risk though if you stop researching, say PEM fuel cells outright, then we might miss out on some accidental discoveries or spin-off technologies from the research?

Ulf Bossel: Well, the research can go on. I am not stopping the research. I just think that it is much more urgent to talk about the establishment of sustainable energy future. That includes implementation of wind energy, solar energy, plus all measures to improve the energy efficiency, i.e. technical advances, infrastructure and whatever else we need. All these issues have to be discussed in a broad sense by an international audience. That is much more important than talking about the details of a particular energy conversion technology and one type of energy conversion device.

Ben : Yeah.

Ulf Bossel: We have many different energy conversion devices. Fuel cells have to compete with the internal combustion engine, with gas turbines and so on. The problem with fuel cell that needs pure hydrogen, it is link to the hydrogen economy. The decision is not against fuel cells. Fuel cells are efficient energy conversion devices, but no new sources of energy. We just had a successful solid oxide fuel cell congress and we will continue this conference series two years from now. Next year we will feature the congress "Fuel Cells for a Sustainable World". We will discuss molten carbonate fuel cells, phosphoric acid fuel cells and solid oxide fuel cells Some of these fuel cells have already run 60,000 hours and more and doing well and we should continue to support these successful technologies. However, we should not push solid polymer fuel cells because they have fundamental problem which apparently that cannot be solved. Even if these problems are overcome, it will remain a standalone technology, which cannot be put into the market because there is no hydrogen fuel.

Ben : Okay, so let us start talking about the sustainable energy path for us then. I know early in the discussion you were talking about the electron economy and I know that you have written papers talking about how today about 80% of our energy is derived from chemical energy and 20% from physical sources and the future will be pretty much exactly the opposite, so can you explain that a bit? What is chemical energy?

Ulf Bossel: Yes. What people need is physical energy. We need motion of vehicles, we need light, we need heat, and we need communication. These are all physical energy. People need chemical energy only for eating and drinking. Okay, that is what the people's needs are. Now, to satisfy these needs, engineers of the 18th, 19th or 20th century have developed a fantastic technology for the conversion of chemical energy of fossil origin into physical energy needed by people: steam engines, gas turbines, internal combustion engines and so on. All these inventions are fantastic. It is a fantastic technology, but in the future this technology will run out of fuel because there is not

enough of oil, gas and coal left to drive our economy. Also, we may have political issues restricting access to fossil resources. The use of fossil fuels may further be restricted to stop global warming. Anyway, the renewable energy from wind, solar and so on is mainly harvested as electricity. Therefore, as fossil resources become depleted, the chemical energy base vanishes. Electricity from wind, water, waves, solar and ground heat will become the new energy base. Once electricity has become our source energy, we should not make the mistake to convert it into chemical energy like hydrogen in order to continue with energy technologies which were developed to convert natural gas or fossil fuels to electricity or motion, but we should find the courage to say, "Goodbye steam engines. Goodbye Carnot cycles. Here we are with electricity. We don't need you any longer."

Ben : Yeah.

Ulf Bossel: This is what we should drive for. We have to accept that our energy base is being changed from chemical today to physical tomorrow and conceptually, we have to be prepared to make this change and not replace the dwindling resources of fossil fuels by synthetic chemical fuels. The worst you can think of is that hydrogen is made from natural gas, which it is supposed to replace.

Ben : Yeah.

Ulf Bossel: It is really strange to hear people say that they make hydrogen by reforming fossil fuels in order to replace fossil fuels. That does not make sense at all.

Ben : So, the future of the 80% of our energy will come from physical sources, wind, solar, geothermal type things, right?

Ulf Bossel: Well, the 80% is a number, which I think is practical. Wherever people live, we can recover up to 20% of the energy needs from organic waste produced by human and animal society. It could also be residues from farming and food industry, or agriculture-produced biomass. 20% is a realistic figure, but rest has to come from physical sources. We have to install wind generators, solar power plants, photovoltaic arrays, small hydropower installations etc. to make up the rest and the difference could be about 80% of the total energy needs.

Ben : Do you think that this will provide us enough energy for our future?

Ulf Bossel: Yes, it will because the efficiency of an all electric system is about three times higher than it is today. That means we can do the same, provide the same comfort, the same quality of life, the same living standard and the same energy services with one-third of today's primary energy consumption.

Ben : Yeah, that is a good point.

Ulf Bossel: Today we derive most of our comfort from primary fossil energy with is converted to electricity or motion at fairly low efficiency. If the primary energy comes from sun, wind & Co., the efficiency is 90% between the renewable power source and people. The electricity has to pass through a number of transformers, but it is never converted across the physical-chemical boundary

Ben : And we will have to find a way to store electrons in an electron economy.

Ulf Bossel: Yes, this is right. Exactly.

Ben : And that will probably be done by, I mean it could be done by plugging vehicles, right? Just

battery cars?

Ulf Bossel: Yeah. It is basically electricity has to be stored as physical energy. That can be easily done with batteries, but physical energy can also be stored with flywheels, compressed air, pumped hydro storage etc. The worst energy storage would be if we convert the physical energy "electricity" to the chemical energy "hydrogen" and then convert it back to electricity. This has a roundtrip efficiency of about 35-45% while compressed air has 75%, flywheels perhaps 80% and Lithium-ion batteries about 90%. Now, it seems to be best to store electrical energy in the form it will later be used. For instance, in a 48 Volt battery for a 48 Volt electric car. You could also run a refrigerator at night to make enough ice to keep the appliance cold for the entire next day. There are many things we can do. Electric cars will have the wonderful lithium ion batteries for high density electricity storage at low volume and weight. Roundtrip efficiency is above 90%. The batteries can be charged in very short time, i.e. in 10 minutes from 15-85% capacity given the needed power, of course. The expected lifetime is 10 years and one million cycles may be obtained. The final word has not been spoken because these batteries have not been around for 10 years. We now use them in cell phones and laptops. Five years ago it took hours to recharge the cell phone and one charge lasted only a few days. Now the batteries are recharged in a few minutes and last for a week.

Ben : Actually, the lifecycle of batteries is something that I am pretty interested in because I personally do not think that they can compete with a diesel engine, for instance, in terms of the lifetime.

Ulf Bossel: Well, they may have to last a lifetime of a car. We are used to replace car batteries every five years.

Ben : Yeah.

Ulf Bossel: And a car, you might say, is sitting there, on four wheels for 10 years, but it is actually driven for about only two hours a day. 3000 hours is the typical lifetime of a car. The question is do batteries deteriorate when the car is not driven? With the lead acid batteries, this was the case. It is no longer the case with lithium-ion batteries. Anyway, I can see that the energy storage problem can be solved by keeping electric cars grid-connected when they are not driven. Now, that sounds strange, but a car is normally driven two hours a day, so it is parked for 22 hours at home, at work or somewhere else. What we need is at home and at work are inductive power transfer platforms. While the car is parked, the battery is recharged. The meter is in the car. At the end of the month, the meter is read and you pay for electricity received from the grid. Such system would create a huge electricity storage capacity. Batteries are filled with surplus power at night, during windy days, on weekends etc. If the wind is not blowing strong, then batteries are charged to only 80%, but every car remains in a drivable condition at any time. You do not have to go to a gas station to fill up a battery. You park your car at home, turn off the key and then the batteries are charged automatically. Of all I have said, this is the only vision I have. All the rest is derived from physics, but this is a vision, is doable even today. It can be a bit more sophisticated in that the power company automatically recognize the car and does the bookkeeping for you. You do not have read a meter, but the power company is controlling the charging of your car and at the end of the month will send you a bill for the kilowatt-hours transferred to your car.

Ben : So, basically in conclusion then we are going to have to use a variety of renewable energy sources in the future because we are running out of fossil fuels. Fossil fuels will not be available in the quantities that they are today, so we are going to have to be using renewable energy sources. The organic fuels that are available will not be available in very large quantities and so we better find the most efficient way to use them.

Ulf Bossel: Yes.

Ben : And one of the most efficient ways of using the organic resources is actually through a fuel cell, like a high-temperature fuel cell.

Ulf Bossel: Yes. Right, right. Organic fuels derived from biomass or the last natural gas or oil flowing through pipelines, have to be converted with highest efficiency into electricity and heat by co-generation. For that, solid oxide fuel cells, high-temperature fuel cells, are the best because they can convert hydrocarbons directly without the need of a reformer. Because solid oxide fuel cells are always superior to PEM fuel cell and reformer. This is another reason why we should discontinued to push the hydrogen technology, because PEM fuel cells run on hydrocarbon fuels cannot beat solid oxide fuel cells with respect to overall system efficiency. Most of the waste heat from PEM fuel cells is too cold for practical use. So, I cannot see that the polymer fuel cell have a great future in today's energy system. It makes sense in a hydrogen economy, but because of the physics a hydrogen economy may never be established. The future has to be built on renewable energy and energy efficiency.

Ben : Let me just read from one of the paragraphs of one of your papers in the conclusion. You wrote, "The key points is the transition from a chemical energy base built on fossil fuels to a physical energy base built mainly on electricity from renewable sources. The transition is predetermined by the laws of physics. It could not be avoided or significantly delayed by politics. However, the transition will proceed more smoothly if all players agreed to move in to the same direction."

Ulf Bossel: It is my intent now, to provide some insight into the physics so that people can recognize the "light at the end of the tunnel." Only then can we join forces and go together into one direction rather than trying find solutions by trail and error. At the moment, time and money is wastes, because the solutions are know and the technologies are available. We do not have to invest in research on technologies which cannot provide sustainable solutions to the energy problem. If one considers the overall mass and energy balances, ideas like "clean coal", "nuclear fusion", "oil from tar sands" etc. sound like bad jokes. One cannot solve the energy problem with processes whose energy input exceeds the energy output. The energy problem has to be solved soon by energy efficiency and energy from renewable sources. We have not much time to waste.

Ben: Just one last question. What type of responses have you been getting to your announcement?

Ulf Bossel: Positive. Very, very positive. People have told me that they will come to Lucerne next summer, because we are now talking about energy politics. Of course, there are some others who would like to present their good PEM solutions. Indeed, the advances in the PEM area are fantastic. I have highest respect for my fuel cell colleagues. But it does not make sense to develop fuel cells for which the fuel is not available and will not be available in the near future. I fear that all the wonderful PEM fuel cells and the PEM fuel cell vehicles will all end up in technical museums.

Ben : Okay, well, thank you so much Ulf for coming on the show. It is great to talk to you.

Ulf Bossel: Okay. Thank you and it was a pleasure.

Ben : Bye-bye.

Ulf Bossel: Thank you. Bye-bye