The Oil Drum: Canada
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

Weekend Energy Listening: Ethanol's Energy Balance with Tad Patzek

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For a bit of weekend energy listening, here's a conversation that I had with Tad Patzek (who should need no introduction around here), talking about ethanol's energy balance. This was recorded 2 years ago now, but it still remains quite timely today. You can listen to the mp3 either by downloading the link or clicking play in the built in audio player.

or download mp3: Conversation with Tad Patzek (52min, 21MB)

A long transcript of this conversation is available below the fold.

This discussion is especially relevant in Canada now because of Bill C-33 which amends the Canadian Environmental Protection Act and is supposed to be debated in the House of Commons around May 28th, 2008:

> Amendments to the Canadian Environmental Protection Act, 1999 proposed in this bill allow the federal government to implement regulations requiring 5% average renewable content in gasoline by 2010. Subsequent regulations will also require 2% average renewable content in diesel and heating oil by 2012 on successful demonstration of renewable diesel fuel use under the range of Canadian environmental conditions.

Here are some links that I mention in the mp3:

Thermodynamics of the corn-ethanol biofuel cycle, Tad W. Patzek, Critical Reviews in Plant Sciences 23(6), 519-567, 2004 and The Real Biofuel Cycles

Transcript
Disclaimer: This conversation was transcribed by a third party and may not be 100% accurate.

Ben: Tad Patzek joins me over Skype to talk about the very important issue of the ethanol energy balance. Tad is a professor in the Civil and Environmental Engineering Department at the University of California, Berkeley and he is well known in the bio-fuels industry because he offers the viewpoints that ethanol and in particular ethanol from corn requires more fossil fuel energy to make than the energy that ethanol offers us in return by burning it and using it to fuel our cars. So, one pretty big consequence of this is that ethanol made from corn produces more CO2 than gasoline does. So Tad, thanks so much for taking the time to come on the show and talk to me today.

Tad Patzek: Thank you for having me.

Ben: The first thing that I want to do is direct everybody or all the listeners to your website so that they can read your reports, titled Thermodynamics of the Corn Ethanol Biofuel Cycle, because that goes into some pretty good detail about what is included in energy balances and what your reasoning was to include or exclude some things from the energy balance. So everybody listening, please I put up a link from thewattpodcast.com website so that you can read through Tad's documents and I especially like the idea of having a document like that, which is continuously refined. Are those refinements based on reader comments, Tad?

Tad Patzek: Yes. I got a feedback from several people and I accounted for them but also some of them reflect my changing in thinking, for example, switching from the low heating value to the high heating value of fuels reflects the point of view that if you want to look at sustainability of an energy scheme, you want to account for the most you can get out of this regardless of how much you get in a given implementation, so that is just one example. The second example that was a big discussion about how much energy goes into steel making process, so I have added [02:19 unintelligible] on that and so it goes on, but I stopped updating this document. I think the version that is on the web was stopped in February. I wrote now a simpler and shorter document which is called The Real Biofuel Cycles, which is also on the web on my website and it does not go into the second law of thermodynamics which probably is sort of discouraging for some of the readers, although it makes most sense to use it. So, in the second document I just used the first law of thermodynamics, the energy balance and the mass balance to show the overall energy efficiency of the corn ethanol cycle.

Ben: Okay. Can you explain why the overall energy balance of ethanol is so important and what would be the impact to our society if we somehow manage to replace the 380 million gallons of gasoline that the US uses everyday with the biofuel like corn ethanol?

Tad Patzek: Okay. I think that we need to step back a little bit here.

Ben: Okay.

Tad Patzek: We need to talk about a somewhat different issue. You and I, as human beings continuously develop the power, that is, work over unit time of 100 watts. So you and I continuously are about equivalent to 1, 100 watt bulb switched on continuously. That is what we need. During the night we need less during the day we need more but on average it is about 100 watts. Okay? So, that is us as human beings. That is how are body is designed. If you are Lance Armstrong a super, a strong human being, you in fact can develop the power of 300 or a little bit more watts for some time and it bursts of 600 watts and that makes him the best cyclist ever, but we are not as strong so 100 watts is a good number and in fact in order for us to develop this power, we need to eat about 2025 kilocalories per day and so that is our diet. Of course we eat more in the United States, so that is why we become flabby and fat.

Ben: Yeah.

Tad Patzek: So, if you look at this a consumption for 300 million people living in the United States over one year, all of us consume about 1 exajoule of energy, that is what we eat. That is 1 followed by 18 zeros, okay? Now, as a country, as a society, we form a super organism of all of us together and then we become different beings and we use 105 exajoules per year of energy. In other words, we use 105 times more energy as a society than we need to live. So, if you compare a human heart as an individual you have to imagine let us say a V-Tec Honda engine, a 6 cylinder engine, as a member of our society so we are two different beings, one a biological human being and another one an industrialized member of a very large society that consumes a lot of energy at a very high rate. Okay? That is the most fundamental point that I would really like people to think of that you use 100 watts as a human being, but you use 11,000 watts continuously as an American.

Ben: Even Americans per capita use them most energy in the world. Well...

Tad Patzek: That is right.

Ben: Yeah. Well, actually Canadians use more energy than Americans.

Tad Patzek: Right, right, but it is very comparable. We are at the top there. The Canadians use a little bit more, but there is very few of them and they have huge landmass so they are not as dangerous to the earth as we are.

Ben: Yeah. One of the reasons why we do that is because we drive so much.

Tad Patzek: Right.

Ben: That is why we have to consume 380 million gallons of gasoline, so I guess that is why everybody is concerned right now about switching from gasoline or trying to find an alternative of gasoline.

Tad Patzek: Yes, right. I know I need to focus on that, but let me just add one more comment. So, in order for us to live the lifestyles we do, we need immense amounts of energy. This includes also the energy as you said correctly required for us to drive. So, now let us go back to nature. The energy we use comes from reservoirs from stock of ancient solar energy, crude oil, natural gas, coal which have been accumulated over the last 300 million years or so. They are accumulated at an incredibly low rate over an incredibly unimaginably long time. We are using them now at the rate we need to be users of 11,000 watts per person per year continuously, but now we are running out of some of them, well not so soon, but we are, okay. There is no doubt about it. So, become scared because we have gotten used to our lifestyles and now we are saying, “Okay, well if this resource is gone we’re going to replace them with biofuels.” That is the big issue of our times right now in the United States and also worldwide. The problem with this is that Mother Nature is absolutely unable to produce the fuels at the rate we want to use them. There is a fundamental incompatibility between us as biological beings using 100 watts and us as mechanized beings using 11 kilowatts. So, the whole question of replacing fossil fuels with biofuels is in fact ill-posed. You cannot do that. You cannot absolutely do that. That is the first lesson here.

Ben: Without some amount of conservation.

Tad Patzek: No. That is right.

Ben: Yeah.

Tad Patzek: Some is actually understatement, so let me just immediately jump to Brazil.

Ben: Okay.

Tad Patzek: Brazil is given as an example to us of a country that is successfully using bio fuels, right?

Ben: Uh-huh.

Tad Patzek: In fact, we are told that if we just behave like the Brazilians we will be okay, we will be supplying more than half of our fuel from biofuels. Well, there is a problem with this argument. There are 182 million Brazilians or so, there are 300 million Americans. The Brazilians use 6½ billion gallons of gasoline per year and the Americans use 140 billion gallons of gasoline per year.

You do the ratios of the populations and the fuel used and it turns out that if you and I drive only once in two weeks, once in 14 days, so one day we drive, 13 days we walk or bike, then we become equivalent to the Brazilians. So, I just want listeners to understand that in order for us to talk about biofuels playing an important role we would have to very, very dramatically change our lifestyles and that is actually not something that any of the listeners I presume is ready to do.

Ben: We might be forced to do it one day.

Tad Patzek: Oh, yes. In fact, that forcing is coming and much of it actually can be achieved with relatively little pain if we just pay a little bit of attention. Let me give you another example. We now use 21 million barrels of oil per day, 21 million barrels of oil per day.

Ben: In the US, yes.

Tad Patzek: In the US. The transportation uses about 2/3 of it. Our cars, trucks, trains and planes use about 2/3 of it. So, if we were to double the efficiency of our transportation system, that is, double the mileage of the cars, put more trains and fewer trucks, drive fewer things around, and increase the efficiency of our planes, we would be saving 7 million barrels of oil per day. That is 7 million barrels of oil per day. Now, without introducing anything radically novel or ravaging the environment with these huge monocultures that we now use to fool ourselves into believing that biofuels will solve our problems, but that requires discipline and that also requires political leadership from our government, which simply does not exist.

Ben: Also just to bring you back to I guess ethanol in some fashion, ethanol is only 2/3 the energy density of gasoline.

Tad Patzek: Correct.

Ben: And so you are actually going to be reducing your fuel efficiency if you move to ethanol.

Tad Patzek: Well, right. I mean you will have to essentially burn more of it to achieve the same distance. That is correct, but again the main point I would like to sort of pass on to the listeners is this. The volume of fuel regardless of its calorific content, for ethanol it is less, that is being supplied from biofuels stands in no proportion to the volume we need to sustain our lifestyles. Okay?

Ben: Yeah.

Tad Patzek: That is sort of the crucial argument here, which we simply lost over because it is very difficult for us to understand the scale of the problem.

Ben: Well, that is why some people are looking at ethanol because I know that there has been some disagreement as to whether or not ethanol does in fact use more fossil fuel energy than what it does in return.

Tad Patzek: Right. Yes. Well, we are stuck on this little argument and it basically boils down to throwing numbers across fences that is how I call it. The listeners have to realize that in fact there is a little simplistic model of reality, which is called this net energy balance, which is not a balance at all, by the way. It is a manipulation of certain inputs and outputs to the corn ethanol cycle from which there comes a number called the net energy ratio. If you do sort of a more thorough job of balancing things and you could read this in this real biofuel cycles paper that is on the web on my website, you will find out that in fact it is not only the fossil fuels, but it is also the environment that we consume while we are producing these biofuels. Let us start from the agriculture because that is the first link here. The agriculture in Midwest is basically a desert paved with monocultures of greedy plants, which we bred to be standing in great crowds, very close to each other, and which need to survive. They need lots of fertilizer and lots of human intervention. Then these plants produce a lot of an industrial commodity, which is the #2 yellow corns while using the soil and polluting one-half of the area of the United States and the coastal waters and the rivers and what have you, okay? So, the whole notion of that agriculture is in fact completely unsustainable. That is a completely unsustainable transient state of agriculture supported by fossil fuels.

Ben: It is completely unsustainable because of the fact that you are actually removing the nutrients from the soil without replacing them right? Is that how…

Tad Patzek: Right. Well, in fact you have to replace them with fundamentally fossil fuels.

Ben: Yeah. Yeah.

Tad Patzek: The soil nitrogen, for example, cannot sustain these plants so you have to put a lot of fertilizers, let us say 200 kg of nitrogen per hectare of a cornfield. This nitrogen is actually methane pure and simple with added energy. You do that and you obtain your corn grain. Then that corn grain has inside starch. Starch is nowhere close to the desired product, which is ethanol, which chemically means you need to put a lot of energy to get from one to the other. If you look again what you can do to that starch, you can liquefy it with enzymes, then you can ferment it with yeast, and then you distill the beer that you obtain to obtain 96% spirit containing 96% of ethanol and then you exclude the last 4% with molecular sieves and then you add gasoline to it as a denaturant and that is your final product.

Ben: Yeah.

Tad Patzek: The problem with this is that if you as you go through this process you in fact use on average seven times more energy per unit input energy, which is your corn grain, than you would in a normal petroleum refinery and the reason actually is very simple, corn is not ethanol. Crude oil is very close to gasoline and diesel fuel. It takes in fact much less energy to transform crude oil into gasoline and diesel than corn into ethanol.

Ben: In converting corn into ethanol what is the most energy intensive step? I know that from reading your reports that the actually industrial process is more energy intensive than actually growing the corn, the agricultural step. Is that true?

Tad Patzek: Correct. Yes, correct. The single largest fossil fuel expenditure is in the distilleries, in the bio refineries.

Ben: And would that be natural gas required to…

Tad Patzek: Now, you are asking an interesting question, right? So, almost all of these bio refineries have been designed to work on natural gas and they use huge quantities of natural gas. In fact, they should be designed next to a major trunk not just a little pipeline, but a major pipeline, a gas pipeline. Natural gas, as we all know, kind of increase in price a couple of times. Three or four folds depending on where you started counting. It becomes increasingly difficult to run these factories on natural gas; therefore, they will be switching to coal and in fact they are.

Ben: Yeah. That has already started.

Tad Patzek: Yes. Now, think about this. All of these plants have designed to burn clean natural gas. They have no facilities to scrub and to flue gases from coal to dispose of coal ash and in fact they are also ill-designed to transport into them 300-400 tons of coal per day to each one of them. Remember because the corn raw material is low density, these factories in fact are relatively small and dispersed, right?

Ben: Yeah.

Tad Patzek: There is some 30 of them in Iowa and they are dispersed on a grid sort of circles of 30 mile radius so they collect corn from a circle around them, which is around 30 miles in radius, which means that if you want to deliver coal to them you are going to have some logistical problems.

Ben: I know that they are struggling right now just to produce 2% ethanol and gasoline so that they can be replaced with MTBE. I know that they are going to have be building a lot more ethanol refineries. Are those new ethanol refineries going to be easier on the environment? I mean...

Tad Patzek: No.

Ben: They are not going to be any better.

Tad Patzek: No. In fact, you remember that there is yet another bit of the story, which is not being told widely, the water used by these plants. A 40 million gallon per year plant uses about 750,000 gallons of water per day. That is so astronomical that I would like to encourage the users to compare this to their daily, I mean the listeners, to compare it to their daily water use. Some of this water is recycled, but a significant portion of it is evaporated and also they need very fresh and soft water for the boilers, so you have to redo chemical treatment of the water and you need to take fresh water. We are running out of water and especially in the western part of Midwest, there is a tremendous water shortage. In fact these plants will have to move out from Midwest. There is not enough environment for them to exist there anymore. So they will have to go to the coasts, to the east and the west coast, and that is the plan, right? People are trying to build these plants in Pennsylvania, New Jersey, Colorado, Oregon, Washington State, etc. So now, we are going to be faced with the problem of transporting gigantic quantities of corn from Midwest to the coast.

Ben: Yes.

Tad Patzek: Also the west of course does not have too much water as well, as we all know, and in particular in California, building ethanol plants in the Central Valley, let us say in Fresno, it is sort of an idea of adding another major source of pollution and water use to the already most polluted environment in the United States. That is kind of cute, but not for the people who live there.

Ben: Are there any technological improvements that can make a significant improvement to the production of ethanol?

Tad Patzek: Well, okay, again I would like to warn you, yes there are, but no they are not going to resolve our major problem of incompatibility of the energy flux from the system and the energy flux that we need in order to sustain our lifestyles. That cannot be removed. That is a law of nature. We can actually tweak sort of at the edges of the system and we have, make no mistake about it. The dry grind plant today to produce ethanol is much more efficient than the one that was in operation let us say 10 years ago. People have done several things. First of all, they try to buy to upgrade corn in a sense that they try to buy corn with the highest starch content.

Ben: Okay.

Tad Patzek: Still they use about 15% of the corn that is produced in the United States. They can upgrade the corn that they buy for the refineries vis-à-vis the starch content. The second thing they do, they try to in fact digest a higher percentage of the starch that is available there, not all starch is fermentable, so they try to increase that percentage. The next thing they want to do and they do it successfully is they increase the percent of ethanol in the beer. It used to be 8% now it is 10-12% and people say you can go as high as 14%, although I have my doubts because at that stage, fermentation really slows down and bacteria catching up and producing other byproduct, by the way which are incorporated into ethanol. So when you buy ethanol in fact it will also contain the butyl alcohol and isopropyl alcohol and probably some other substances that you do not know about, it is no longer pure ethanol. That is okay, you can burn butanol and isopropyl alcohol, your engine will not know. Your engine will know about other substances that may find their way. Improvements have been made, but again it does not change that the premise of the whole energy production system, an incredibly low-density, low-efficiency and low-yield energy supply scheme and this cannot be changed. This is how Mother Nature has designed it.

Ben: So, we have identified that the largest energy input is the actual industrial process. People are moving away from natural gas to coal power now because the price of natural gas is too volatile. What if we started burning biomass instead of coal because biomass, some types of biomass such as pelletized switchgrass for instance has a fairly good energy balance, does it not, when you burn it.

Tad Patzek: Right. So here we are running into another problem. The thing about agricultural production is that it requires a substrate. Plants need soil to grow on and that soil needs to be protected from the elements, wind and rain being the most important ones. So a prairie system with switchgrass let us say protects the soil very well because the soil is covered with plants all the time. Prairie in fact is a very good example of a system, which is enormously efficient and whose net productivity, that is, net mass production is zero. That is, everything that the prairie produces is recycled in it. The bison, the buffalo eat the grass. The coyotes and the lions, mountain lions, eat the buffalo, and the wolves and everybody dies on the prairie and their bodies are recycled and so it goes on, the nutrients, and in fact the prairie gets flooded every now and then from the rivers, which bring other nutrients and so it goes on, the nutrients are resupplited. Now we come, we the humans come into that system and we say, “Okay, grass, we are going to cut you every year, year after year. Remove everything that we cut and burn it elsewhere.” Unfortunately, when you do so not only do you remove carbon, but you remove nutrients with the grass and these nutrients are gradually depleted from the soil and of course the whole system stops producing. There is a fundamental problem with removing all biomass from an ecosystem because that ecosystem stops functioning and in order for you to make it function, you have to resupply it back with the nutrients and that of course takes an enormous amount of fossil fuels. So we are back to square one.

Ben: Okay. I am so interested in the overall energy balance though. Why is there so much confusion over the energy balance? Is there not some type of standards organization that says this is how you do an energy balance and this is how it should be done?

Tad Patzek: Yes. That is actually a very interesting question. Yes, there are standards and in fact these standards were arrived at a long time ago in 1975 and in 1976. There was then a great interest in energy prices caused by the first problems that we had and there was the International Federation of Institutes for Advanced Study, which in fact gathered twice in Sweden, in Stockholm, and that organization provided guidelines for how energy balance should be done. Of course these recommendations have all been forgotten by now. In fact, there are some simple things that can be done. Define your system clearly. Corn ethanol system is an open system in which mass can flow through the boundaries and it does flow, which takes inputs from the environment and excretes output into the environment and so it is kind of difficult to do the balance. First, we define the system and you can define the cornfields, the bio refineries and the machines that burn the ethanol, this can be done. You can then define the system boundaries to go as deeply into the society as you please and there are guidelines as to how to do it. This has not been followed by the studies, by most of the studies. Now, the second thing you do is once you have defined the system boundaries now you can define the fluxes, the flows that go across these boundaries. So, now you can balance mass which is #1 requirement in science and then once you have balanced the mass you can balance energy, that is #2 requirement. None of these requirements were fulfilled in this net energy balance, that is, this net energy balance do not close mass or energy balances. They violate both. Depending on how you violated the mass or energy balance of your system, you can come up with different numbers and that is fundamentally what has been happening here.

Ben: Is this also being done for gasoline as well because presumably it would be a good idea to compare the overall energy balance of corn ethanol for instance with gasoline?

Tad Patzek: Well, it has been done sort of, well sort of I would say more than sort of, there was a big study out of NREL, National Renewable Energy Lab, several years ago in 1997, which attempted to do such a study for the crude oil diesel system and gasoline and diesel are in fact within a couple of percent the same thing in terms of energy consumption. If you do this for the mixture of crude oil that comes here from the Middle East and as well on local supplies and you look at the mixture of refineries and the pipelines and what have you, you use on average 17% of the energy in the crude oil to get from the crude oil under the ground in the reservoir to gasoline in your pump, that is 17%. So 83% is left as the gasoline product on average.

Ben: Presumably that is dropping I mean in Canada.

Tad Patzek: Oh, yes.

Ben: In Canada we are big on the Alberta in tar sands and that requires a lot of natural gas right now.

Tad Patzek: Yes. In fact this is a very, very good point. As we go on depleting this very rich and energy dense oil reservoirs in the Middle East and elsewhere, we are now turning towards more and more difficult oil, which takes more and more energy to not only recover it but also to convert it into a usable product, gasoline or something else, and that oil is increasingly more difficult on the environment. Your Canadian example is a very good one. That tar sands will require in the end all the natural gas that Canada has and it will also require all the water that Alberta has. In the meantime, we are going to generate a lot of [32:42 unintelligible] to upgrading that oil. So the oil energy supply system becomes less and less environmentally friendly. Of course, it never was friendly. It was more and more unfriendly towards the environment. However, as we are on this sort of efficiency, so the overall efficiency going from crude oil in the ground to gasoline, let us say, is 83%, okay?

Ben: Okay.

Tad Patzek: If you want to go all the way from a corn seed to ethanol, the efficiency of that process, overall efficiency, is 20%.

Ben: Okay.

Tad Patzek: Well, plus-minus, that is 20 or 23 depending on how you do the calculation. Now the big increase in the efficiency of that process comes from accounting for the coproduct, okay?

Ben: Yes.

Tad Patzek: If you do the following reasoning, because from corn grain we not only produce ethanol, but we also produce what is called DDGS or Dried Distillers Grain and Soluble, that is basically a mash of everything that is left from the corn grain other than starch.

Ben: That is mostly used for feed, right, for the cattle feed?

Tad Patzek: Right. That is right. Then you can play games as to how you apportion fossil energy you have used in the refinery to that portion of the corn grain. This is kind of again a paper accounting because the fossil energy you expend on distillation is the energy you have expended, it is gone. You have burned the coal; you have burned the natural gas. In fact, if you look at the refinery, the stage at which you separate starch from the rest of the corn grain does not require much energy at all. You basically grind the corn grain and then you steep it in water and you put enzymes, Barley and alpha-amylase enzyme, to hydrolyze, to liquefy the starch. You could separate the rest of the corn grain at that stage and expend almost no energy on it.

Ben: Okay.

Tad Patzek: But you choose to in fact keep the two parts together and run them through the entire refinery, in the end you have to separate the solids from the distillation columns and you also have to dry them up and that takes an enormous amount of energy and then you say because I get a product out of this, I will apportion 30% to 50% of the fossil energy spent in the refinery to the coproduct and therefore my process looks better.

Ben: Yeah. I also have to wonder if this co-product is made at any larger scale? Can we actually use it?

Tad Patzek: No. That is another problem.

Ben: Yeah.

Tad Patzek: Now, we are going back to a larger societal problem; that is, because our farms produce so much of this industrial commodity, the #2 yellow corn, as I said, we cannot simply use it up. We have decided to do three things with it, right? The first thing is to feed, not this, but white corn to the people as cornflakes, cereals and what-not, but that takes care of only 2% of the corn. The second thing that we decided to do is to basically run the corn through wet milling process and split it into the simple chemicals. So, we get the snow white starch and we get dextrose, which is basically your cellulose and we can convert it into other sugars and we then produce the famous high fructose corn syrup and other chemicals, which show up on labels of almost any processed food product in the United States, that is the second use, but that takes care of about let us say 20% of the corn, okay? But then we are left with the remainder and so we feed the remainder to the animals that are not eaten by people and in fact every animal in the United States eats corn these days including salmon, but then we are left with yet another overflow of corn in the fields, right? So we burn it, we feed our cars. So now we have managed to feed people, animals and cars with corn. That is a huge victory for the corn. Nevertheless, some of the animals do not take kindly to that corn especially cows because cows have been designed to eat grass, cellulose, and in fact ferment the cellulose using bacteria in the rumen. When they eat starch, they become sick. Starch acidifies their stomachs. It makes them fat. It also destroys their livers. In order to avoid being killed too early in the process, they have to be fed antibiotics.

Ben: Okay, so that is even more energy intensive.

Tad Patzek: Right, but not only that, it is just that there are limits to how much corn you can sort of pass through all the societal systems without destroying some of it.

Ben: Okay, so that is corn ethanol. So, in summary, even if the overall energy balance looked okay, in summary, corn is an unsustainable crop because it depletes soil from all the nutrients. Is that right?

Tad Patzek: Right, but the overall energy balance does not look okay. It is 20%

Ben: Yeah. True.

Tad Patzek: Yes.

Ben: Okay. Now let us now move on to sugarcane for instance because sugarcane is sugar, sugar juices so it must be easier to produce ethanol from sugarcane than it is from corn grain.

Tad Patzek: Yes. In fact, both corn and sugarcane are grasses, are seafloor plants. Sugarcane is designed or by nature to live in moist and warm climate, which Brazil provides in large quantities. Sugarcane grows around the year so all year long and it is being harvested twice a year in different parts of Brazil, in fact, much of it is still harvested by hand employing about one million people. Now that is going away because these plantations are being mechanized right now.

Ben: So they are becoming less organic farming? Is that what you are saying?

Tad Patzek: Sugarcane has another feature that differentiates it from corn. It actually coexists with a bacterium, Rhizobium bacterium, to some extent, which sequestered nitrogen. So sugarcane needs less nitrogen fertilizer than corn. Also, it grows year around not 100 days per year as corn does in the United States. There are differences in the yield. Also, sugarcane in the past centuries was grown organically with no fertilizers and basically what was taken out of the plantation in the end was the sugar juice, the carbon, in terms of sugar, but the rest of it and some fiber from the bagasse, but the rest of it would be returned back to the plantation as malt and as fertilizer and that would actually allow these plantations to go on for three centuries in some places.

Ben: Okay.

Tad Patzek: In Asia and in South America, so very good so far. Now, we are now doing it slightly differently. Now, in order for us to drive the process with sugarcane only, we need to use the entire plant, that is, the bagasse, the leaves and everything else and essentially bury them in the ethanol plants. So now we are removing all biomass from the fields. Of course, that puts us in the quandary that no we will have to be replacing the nutrients just as we do with corn. In Brazil, this is not being done to the same extent yet. So they are essentially depleting the soil and unfortunately they will have to do more and more fertilization as they go on with the system.

Ben: Okay.

Tad Patzek: Sugarcane has two things going for it, higher yield than corn and of course what is inside the sugarcane, the stem, is essentially juice that contains the sugar so you avoid a couple of steps and then you burn the bagasse, the rest of the plant, as fossil fuel and you get your ethanol relatively cheaply. However, again, you are depleting the environment and the whole system, in the long run it has to be unsustainable.

Ben: But it is a much longer run for Brazil.

Tad Patzek: It is a longer run. Yes.

Ben: Okay. Now the last type of ethanol that I want to discuss just quickly is cellulose ethanol. Hilary Clinton and all the politicians seem to want to produce cellulose ethanol instead of corn ethanol. Why do they want to do that? Should they be focusing on cellulose ethanol at all?

Tad Patzek: Well, it is sort of like the next best thing in the horizon, right?

Ben: Yeah.

Tad Patzek: Remember you still forgot about the algae.

Ben: Algae, yes.

Tad Patzek: We will come back to it later on in some other program. So cellulose in ethanol is the next best thing. Now what I would like the listeners to understand is that all of these systems no matter what they are, sugarcane, corn, algae, and cellulose in ethanol, have about the same overall efficiency. In fact, one I might argue that cellulose in ethanol would have a lower efficiency if we have the technology to produce it. Let me sort of discuss this a little bit more. The problem with cellulose is that cellulose is about the most sturdy and chemically inert compound that nature has produced over the last 2 billion years or so to protect plants from the attacks by animals, by elements, by fungi, bacteria, and what-not. It is basically the substance that makes the plants last together with lignin, which provides it mechanical strength. So by the very nature of it, cellulose is very difficult to decompose chemically and we can do that, of course, and we have been doing it very efficiently for many years, it is called the paper craft process right?

Ben: Actually, there is a company in Canada just pretty close to me, Iogen, and they use a steam explosion method.

Tad Patzek: Right.

Ben: Sounds pretty energy intensive to me, steam explosion.

Tad Patzek: Yes. That is right. You put your finger right where it should be. In order for us to get to cellulose, we need two things, we need lots of energy and thermal energy and mechanical energy, and we need time. If we are very impatient then we need to put a lot of energy so what we do basically, we explode the plants by immersing them in steam or blowing steam through them.

Ben: But you can create that steam using the lignin, right?

Tad Patzek: Correct. That is what you do.

Ben: Yes.

Tad Patzek: But that is not the end of it. So, now basically you have achieved a sort of smaller particles by exploding the cells, right? Now you need to digest these particles and you can this, for example, by attacking them with strong acid like sulfuric acid or strong hydroxide like sodium hydroxide, but then again takes a lot of energy and in fact the overall process would take more energy than you get out of it as ethanol or you can be more patient and at that stage you can in fact try to use enzymes, but enzymes have a very difficult task at hand, they have to attack this inert particles, which are now more exposed by exploding them, but they are still very inert, so it takes time. When you spend enough time digesting cellulose, unfortunately the bacteria that exist on the biomass, you cannot disinfect the biomass altogether. Start recovering and start competing for the biomass. In the end you would produce methane and if you have access to air acids, but not sugar and ethanol. The problem with all of these schemes is the are very low efficiency, that is, the yield of ethanol per ton of biomass is in fact quite low and very high energy requirement so if you care to ask Iogen what is their yield efficiency, I have asked them by E-mail and I have also forwarded my E-mail to their Shell sponsors and I got no answer to that. That is one of the deeply held secrets as to how many tons of biomass do I need to put in to get the ethanol that I get out of such a plant?

Ben: I was always led to believe that cellulose ethanol has a quite good energy balance.

Tad Patzek: Well, again, it depends on how you do the balance, right?

Ben: Yes.

Tad Patzek: Again, one has to be very careful to define the system boundaries. The way it is done right now is that basically you get your biomass for free, you call it trash, which is okay, but then remember that the trash also has nutrients, which will remove from the parent ecosystem and at some point you will start to have to put them back into the ecosystem. That is one. The second one that people do is sort of this naïve scaling, that is, if I have a small plot of switch grass and I cut it once or twice and I get 10 tons per year, I will from that conclude that therefore I will obtain 10 tons of biomass from each hectare of switchgrass anywhere for any number of years and that is of course not true. As you go on, your yield in fact can decline from 10 to 2 tons or the switchgrass can die as they do very often in a couple of years. The question of yield is #1, the question of putting the nutrients back is #2, and the question of having a technology that would actually yield the ethanol from the biomass at certain efficiency without using too much energy is #3, and I do not think we have answered any of these questions with cellulose in ethanol.

Ben: Okay. Yeah, this is running a bit long now so you must be getting tired, but how can we make the world more sustainable? Of course, conservation is important, but what is the solution, then?

Tad Patzek: Well, there are not any solutions. Let me be very blunt about this. There are two fundamental solutions, one is to limit the human population, there is just too many of us. Again, many people will raise their eyes, but again talking about energy solutions without talking about the population problems is just like mopping the floor with the faucets running on. So that is #1 problem. The second problem is that we will have to start using much less energy per capita, but that will bring us way towards the societies from which we have differentiated ourselves, that is, to rule out Indian-ruled China, let us say, and that is not a very pleasant perspective. However, having said that, the earth is finite and the same rule of populations in China and India look at us, watch our TV, and want to live like us. The problem is that there is not enough of the world for all of us. Somehow we will either have to adjust to it or something really bad will happen to all of us.

Ben: But I know that you are a proponent of photovoltaic, right?

Tad Patzek: Yes.

Ben: Because they can capture much more of the sunlight.

Tad Patzek: That is right.

Ben: Okay.

Tad Patzek: That is right. Photovoltaic, again, do not get me wrong, within the confines of using less energy and modifying our lifestyles, there are things that we can do better, one of them would be to use photovoltaic to a much larger extent that we do now and a photocell is 200 times more efficient in terms of producing work than biomass. So, you have [50:28 unintelligible] of magnitude of advantage. We are not producing these solar cells in large enough quantities that is because of manufacturing problems, but that is a separate story. We need to go a lot more toward solar cells, but again if we do we will have to sleep at night, work during the day, take time off when it is cloudy, and just live different lifestyles.

Ben: Okay. Well, thank you so much, Tad, for coming on the show.

Tad Patzek: Alrighty.

Ben: Thanks a lot.

Tad Patzek: Bye-bye.

Ben: Bye.