The Oil Drum
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

The Energy Balance of Ethanol versus Gasoline

Posted by Robert Rapier on August 28, 2006 - 1:04am
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Just when I thought I was out, they pull me back in.

I am trying to spend more time writing on topics other than ethanol. But I get a lot of e-mails on that subject, and often have 3 or 4 mini-debates going on at a time via e-mail. I just finished a debate involving a government official and some big names over the energy balance of gasoline versus ethanol. There still seems to be a lot of confusion surrounding this issue, so I asked for permission to publish the exchanges. I was reluctantly given permission, provided I deleted the personal information from the government official (name and government agency). The exchange involved myself, a government official that I will refer to as "Tom", Michael Wang from Argonne, and Vinod Khosla.

It all started when I got an e-mail from Tom. It wasn't clear to me which specific essay he had read that prompted his e-mail, but he wrote:

> Mr. Rapier,
>
> If your assessment of the ethanol fuel cycle energy balance (and its comparison with the petroleum fuel cycle energy balance) is right, then not only is Vinod Khosla wrong, but many others of us in the energy community -- including the U.S. Department of Energy and Argonne National Laboratory (see attached summary) must also be wrong.

Attached was a summary of an Argonne National Lab report written by Michael Wang, who initiated the following claim (from the report):

> As you can see, the fossil energy input per unit of ethanol is lower--0.74 million Btu fossil energy consumed for each 1 million Btu of ethanol delivered, compared to 1.23 million Btu of fossil energy consumed for each million Btu of gasoline delivered.

I must admit that appeals to authority don't impress me much, especially when I know the person making the argument is completely wrong. Remember, this is coming from a government official involved in alternative energy. So, I responded:

> Tom,

> They are wrong. I have read all of the Argonne studies. I have exchanged e-mails with Wang at Argonne and Shapouri at the USDA. They know they are being misleading in these claims, but most people don't dig into the details to see their sleight of hand.
>
> Here is a very simple test that will demonstrate they are wrong. After people work through this, they always see the problem. Let's say my goal is to make 1 BTU of liquid fuel. Will I consume more energy if I produce ethanol, or will I consume more energy if I produce gasoline? The implication from the Argonne et al. would imply that it should take more energy to produce the gasoline. However, that is not remotely the case. If I presume an energy balance for ethanol of 1.3, then I will consume 1/1.3, or 0.77 BTUs to make 1 BTU. My net is a mere 0.23.
>
> If, however, I make gasoline, the efficiency is 80%. That is where the 0.8 number comes from. In this case, I only consumed 20% of the BTUs to make 1 BTU of gasoline. My net is 0.8 BTUs. What they have done is convolute energy return and efficiency, and act like 1.3 for ethanol is the same metric as 0.8 for gasoline, when they are actually 2 different metrics.
>
> As I like to say, there may be some legitimate reasons for using ethanol. Efficiency of production is one of the most misleading arguments out there. It just isn't true. And I will gladly debate Wang or anyone at the DOE in print regarding these misleading claims.

Tom responded, copying Michael Wang at Argonne and Vinod Khosla (they were copied on all messages from this point).

> Robert,
>
> As I see it, the fallacy of your reasoning (similar to that of Pimentel's and Patzek's) originates, at least in part, from an "all Btus of energy are created equal" viewpoint. If continued /expanded use of petroleum was indeed feasible, sustainable, environmentally and politically acceptable, etc., then perhaps your conclusion, that petroleum is a more "efficient" energy option than ethanol, would be more valid -- i.e., just keep burning the petroleum Btus and continue to accept the bottom-line energy result (albeit a continually worsening one in any petroleum-depletion scenario) that the luxury of stored fossil fuel deposits afford us: by reinvesting a fraction (1/5 today but steadily increasing) of the recovered petroleum energy, we can continue to harvest what's left.
>
> But the production of ethanol and other biofuels (which, by the way, should include a broader focus, encompassing other forms of pure and mixed alcohols, biodiesel-type fuels, bio-crude type fuels, etc.), along with other kinds of bioenergy, offers a means of harvesting Btus of solar energy and incorporating this contribution from solar energy into today's transportation energy supply -- an achievement that has thus far proved elusive via other means, such as electric vehicles or hydrogen.
>
> The fact that today's investment of 1 Btu of fossil energy in the ethanol fuel cycle delivers "ONLY" 1.3 Btus of ethanol to the vehicle fuel tank (the added 0.3 Btu being solar energy incorporated into the fuel cycle) is actually a very beneficial energy result,

> especially given that this result only gets better with technology advances, potentially including production from cellulosic biomass. Meanwhile, the energy reinvestment necessary to capture remaining petroleum resources promises only to become greater. Ask yourself this question: If producing and operating hybrid electric vehicles (which I suspect have their own underestimated trade-offs besides the obvious higher cost factor), in order to make petroleum Btus go about one-third further, makes good sense in today's energy world, then why doesn't achieving essentially the same result via ethanol production and use (with at least incrementally, if not fundamentally better results in store) offer at least as attractive an option?
>
> While I don't think I would personally try to argue that the ethanol fuel cycle is twice as efficent as the petroleum fuel cycle (i.e., by comparing a 1.3-1.6:1 ratio to a 0.8:1 ratio), neither do I find your analysis compelling from an energy standpoint; in fact, it appears even more misleading. I believe that most of us in the transportation energy community -- along with many in the automotive industry, the oil and other energy industries, the environmental and global climate change communities, etc -- have come to accept the results of Argonne National Laboratory (as summarized in the U.S. DOE webpage document I forwarded to you earlier) as the most authoritative and fair assessement thus far of ethanol's net energy (and greenhouse gas) implications.

Michael Wang also weighed in, to say he wasn't getting involved:

> Dear Mr. Rapier,
>
> Instead of wasting everyone's time, let me just simply pointing out that I do not recall that I have extensive communication with you and I do not intend to do so, because of your statement "I have exchanged e-mails with Wang at Argonne and Shapouri at the USDA. They know they are being misleading in these claims, but most people don't dig into the details to see their sleight of hand."
>
> You are entitled to have your opinion, but do not imply personal attack on my professional work.
>
> Michael Wang

I answered both with my next response:

> Tom,
>
> There is no fallacy in my reasoning, and my arguments have nothing to do with Pimentel's and Patzek's. To suggest they do indicates that perhaps you still don't understand my argument.
>
> Unlike Pimentel and Patzek, I am using Argonne's numbers to make my point. Your argument, "If continued /expanded use of petroleum was indeed feasible, sustainable, environmentally and politically acceptable...." is a different argument than the one you originally started off with. You are suggesting that there are other reasons for using

> ethanol. Fine. But you are not addressing the point of my argument, which is simply that ethanol is far less efficient to produce than gasoline, despite the proponent's claims to the contrary. Argue the sustainability issues. Argue the environmental issues. But don't mislead people by suggesting that it takes more energy to produce gasoline than to produce ethanol. That is an incredibly ludicrous claim.
>
> My argument is not misleading at all. It does not convolute efficiency and energy return. It is a measure of the amount of energy that must be consumed to produce two different fuels: gasoline or ethanol. That is a very simple metric, and is not in any way misleading. Wang's metric is misleading, and I am sure that he is well aware that people are misusing it. When people say "ethanol is 1.2, but gasoline is worse at 0.8", they have compared two different metrics. When you write that you accept the authority of Argonne/DOE with respect to the net energy and greenhouse implications of ethanol, you are once again addressing a different argument. Please do not address Red Herrings, since I have accepted their net energy results for ethanol in my analysis.
>
> Regarding Wang's communication with me, I still have it if he would like for me to refresh his memory. I pointed out the same thing I have pointed out here, and his response was essentially "Yeah, but you are looking at the total energy inputs, and there are many different ways to look at this problem." I do not regard the debunking of misleading claims as a waste of anyone's time. I would think that Wang would want to defend his work against critics like myself, especially given that most of it has not been subjected to scientific peer review. Again, I will debate Wang, Shapouri, or anyone else who wishes to argue that it is more efficient to produce ethanol than gasoline. If you want to argue about something else, then you aren't addressing the argument I am making. Yet this is exactly what you did in your second response.
>
> Finally, I want to make it clear that my comments are not meant to defend the status quo. I want to see us move away from fossil fuels as quickly as we can. I am merely using the gasoline versus ethanol issue to show why these claims of higher efficiency of ethanol production are fallacious.

This response covers my biggest gripe about people who want to debate this issue. If I rebut a specific claim, they gallop off to a different claim. That is exactly what Tom did.

At this point, I also asked if they minded me publishing the exchange:

> Incidentally, do you have any problems with me publishing this exchange? I will publish it without changing a word, and will include Wang's statement that he doesn't recall having extensive communication with me. I think the public can benefit from these exchanges. I understand your position quite well, however I hope it is clear that you didn't actually address my arguments, but instead addressed other reasons for supporting ethanol.
>
> I am confident that my argument as written is completely accurate and not in any way misleading, and I have no problem being judged by public opinion on its merits. I am a strong supporter of publicly debating these technical issues, and I have no interest in misleading anyone. But I also have no interest in allowing people to be misled.

Vinod Khosla weighed in next:

> Robert's argument would make solar cells a horrible source of energy at an efficiency of 0.15! And why would we ever use electricity?
>
> Most modern ethanol plants being built have an energy balance of around 1.5 -1.6 as they try and minimize their energy use for cost reasons. That coupled with the higher use efficiency of ethanol energy than petroleum energy (25% less mileage even with 33% less energy is the accepted EPA rating for most flex-fuel cars - the SAAB 9-5 Biopower with Turbo is only 18% less mileage) gives an ethanol "fossil fuel efficiency" of about 2X per mile driven. The current California plants we are building don't especially ship corn (they are built around cattle feedlots where the corn has been shipped in for years) and they don't dry the distillers grain since they use it locally at the feedlot, does better than the 2X number. The E3 Biofuels plant in Mead Nebraska achieves an "energy balance" of five for CORN ethanol according to a report I saw from the National Commission ion Energy Policy.
>
> It is time to stop asking the wrong question of "energy balance" or even the somewhat less wrong question of "energy balance relative to petroleum" but rather ask the two right questions (a) how much petroleum use can we displace per gallon of an alternative liquid fuel and (b) what is the green house gas reduction per mile driven.
>
> For nuance we might add (c) at what cost of production per mile driven (to take away the short term price manipulation going on and (d) in what vintage of plant? Modern, average, old, coal fired, gas fired, with and without dry distillers grain, all the way to the E3 Biofuels model. Today the economics of reducing energy cost work.

I responded to Mr. Khosla's argument:

> The solar cell argument is not valid, as several people pointed out on The Oil Drum, because it confuses efficiency with energy return. The instantaneous efficiency may be 15%, but you can get that day after day. The total energy returned from a solar cell far exceeds the energy that went into creating it.
>
> The reason we use electricity is because we convert coal, something not especially useful for doing work in its natural form, into a form in which it can do useful work. That is not the case with most of the fossil fuels that go into making ethanol. We turn natural gas, gasoline, and diesel, all perfectly good transportation fuels, into ethanol. We capture a bit of solar energy in the process, but grain ethanol is primarily recycled fossil fuel. And while this argument has focused on the marginal energy return, not included in those assessments (as Wang can attest to) are the secondary inputs, nor effects from soil erosion from growing corn, or herbicide and pesticide runoff into our waterways.
>
> For the record, I fully support, and have advocated the E3 Biofuels model. In fact, I spoke with their project manager this week for an hour on the phone. I was also recently quoted in National Geographic endorsing the E3 process:

> New Ethanol Plants to Be Fueled by Cow Manure
>
> However, a couple of things need to be clarified. Their plant has not yet started up, so claims of energy return from this process are premature. It is definitely a step in the right direction, and I would prefer to see all new ethanol plants built around a similar model.
>
> Regarding "wrong questions" and "right questions", that misses the entire point of my arguments, which are quite simple. There is a horrendous level of misinformation out there surrounding ethanol. When someone claims that Brazil farmed their way to energy independence, or that it is more energy efficient to produce ethanol than gasoline, or that ethanol produces no greenhouse gases - those are claims that must be addressed. Ethanol policy should not be made based on misinformation like this. My agenda is simple, and that is truth in advertising. I am a skeptical scientist by nature, and I feel like these claims deserve critical technical scrutiny. It is not my goal to kill grain ethanol, unless it deserves to die. But we won't know that without an honest debate, and too little of that is taking place. My goal is to separate hype from what the science actually indicates, and pursue those solutions that make the most long-term sense. Corn ethanol, which has been the primary target of my criticism, is not a very efficient use of our resources as it is currently produced. On this, I know that Mr. Khosla agrees with me, because we have spoken at length about this.

Tom indicated that he really didn't want to have this debate in public:

> I'm inclined toward Dr. Wang's (and Mr. Khosla's) viewpoints that it is somewhat of a distraction and probably unproductive to pursue this debate with you further or participate in your forum -- especially in light of your unfortunate characterizations of individuals' and organizations' work ("sleight of hand"?). In any case, since you say you accept Argonne's basic analytical results, then this entire debate is all about the interpretation and implications of these results (and who is "right" trying to answer the academic question "Which is the more "efficient" fuel, ethanol or gasoline"), which I don't foresee being resolved in this forum.

I once again tried to convince Tom to take this debate into the public arena:

> How else do you characterize the comparison of an EROI for ethanol to an efficiency of gasoline, other than sleight of hand? A straightforward assessment would be to consider either EROI to EROI, or efficiency to efficiency. Perhaps it wasn't Dr. Wang's intention to have this issue so thoroughly muddled, but the public has certainly muddled it. I have lost count of how many times someone claimed that it is twice as efficient to produce ethanol as to produce gasoline.
>
> My impression then is that you do not want this exchange made public? If we posted this at The Oil Drum, it would be read by a tremendous number of people, and would have advocates on both sides. If your argument is correct, then you should have no concerns given that I will post this exchange verbatim. I think these are the kinds of open exchanges that need to take place so people can sort out hype from truth. My main

objective is education, and I think it would certainly suit that purpose.

We exchanged 1 last pair of e-mails that I won't entirely reproduce (because I told Tom I wouldn't). Suffice to say that Tom agreed to publication, provided I removed some information on him and his organization. In his final response to me, Tom accused me of rancor (passion is not the same as rancor!), questioned whether my rancor explains my e-mail identity (tenaciousdna), and once again invoked the argument from authority, suggesting that my argument was subjective and merely my opinion, and he and all those other authorities couldn't be wrong. Needless to say, my reply was "pointed", but I offered to take up the matter with him at any time.

This exchange may help explain why I haven't been posting as much lately, which some have asked about. These things take up a bit of my time every day, so I decided to kill two birds with one stone and make a post out of this debate. Let this also serve as a warning to those who want to bang heads with me. :-) If you want to win a debate with me, make sure you are arguing from a factual position.