The Oil Drum
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

Renewable Fuel Contenders

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Introduction

I got quite a few interesting e-mails and comments following my previous essay: Biofuel Pretenders. I probably should have mentioned - but I thought it went without saying - that pretenders usually don't think they are pretenders and will therefore protest mightily at the characterization. A number of people who e-mailed assured me that they have really cracked the code to affordable biofuels, and that we would be hearing more about them soon. Another person who wrote to me about algae said that he has been following algae since 1973, and he wrote *"In spite of all the hype and non-stop press releases, no one to my knowledge is producing algae on a commercial basis for biofuel production."** Ultimately, I would be happy to be proven wrong on this, but I am just calling it as I see it.

On the other hand, there are some renewable fuel options that have either proven themselves as solid contenders, or have not yet demonstrated fatal flaws that would disqualify them at this point. In this essay I will cover some of those. First, I will cover a pair of first generation biofuels that have proven that they can compete with oil on a cost basis, and then a pair of next generation biofuels that I believe will be competitive.

Caveats

There are some other things that I need to point out, but if history is any guide these caveats will be completely ignored by some. First, I am discussing liquid fuels here, even though I am hopeful that electric cars become a real contender.

Second, calling something a contender is not an endorsement – particularly of the first generation contenders. Palm oil can compete with petroleum on price to some extent. The wisdom of using palm oil for fuel is a different matter. So please do not confuse how I see it with how I would prefer to see it.

Third, I am fully aware that there are limits to the biomass that can be removed from the soil. I want to be sure that biomass that is grown and used responsibly. One of the things I am involved in right now concerns farmed biomass that removes few nutrients from the soil. There are even ways to produce biomass that can improve the quality of the soil. Imagine a tree that sends down deep roots, brings nutrients up from the subsoil, and concentrates them in the leaves which then fall off and add to the soil. It is not science fiction, and my new group has people working on these types of biomass.

Finally, for those who go on an anti-car rant any time there is a discussion of liquid fuels: I personally would like to see a big reduction in motorized transport. The basis of our future energy strategy has to start with conservation. But I believe we will need liquid fuels for applications like long haul trucking, airline transport, and marine applications. There will likely be a liquid fuel need for emergency vehicles. So while I am under no illusions that bio-derived fuels can replace our petroleum usage, I believe they can make a contribution for critical applications.

The First Generation Contenders

Sugarcane Ethanol

Ethanol that is produced in conjunction with sugar production, especially from tropical regions like Brazil, has some unique attributes that have enabled it to compete on a head to head basis with gasoline pricing. Specifically, during the production of sugar, the bagasse (sugarcane residue) is pulverized and washed many times. Many soluble inorganic constituents that may normally pose an ash problem for a boiler are washed out in the process. What remains after processing is a pretty clean biomass feed for the boilers. The normally vexing logistical issues aren't present because the biomass is already at the plant as a result of the sugarcane processing. So they essentially have free boiler fuel, which minimizes the fossil fuel inputs into the process. That enables ethanol production that is relatively cheap, and that is largely decoupled from the impact of volatile fossil fuel prices.

There are several reasons we don't this in the United States. Last year I made a visit to the largest sugar producer in Louisiana, and they explained the reasons to me. Ethanol can be produced from sugar (but sugar subsidies discourage this), or from the molasses that is produced as a co-product. (The latter was the basis of the plant I visited in India). For sugar producers in the U.S., the economics of the by-product molasses generally favor using it as an additive to animal feed. If the U.S. had a year-round growing season as they do in the tropics, it is more likely that the animal feed market would start to become saturated, and conversion into ethanol might be more attractive. Further, a bagasse boiler is a major capital expense, so there needs to be a high level of confidence that in the future ethanol will consistently be a more economical outlet than animal feed. For Brazil, this is certainly the case.

The ultimate downside of sugarcane ethanol will come about if the U.S. and Europe begin to rely heavily on tropical countries for their fuel needs - thus encouraging a massive scale-up. First, trading oil imports for ethanol imports doesn't do much for domestic energy security. More importantly, it may encourage irresponsible usage of the land in an effort to feed our insatiable appetite for fuel. I think the ideal situation would be to produce the sugarcane ethanol and use it locally, rather than try to scale it up and supply the world. In this way, sugarcane ethanol could be a long-term contender for providing fuel for the tropics, but not a long-term contender for major fossil fuel displacement outside of the tropics.

Palm Oil

The other major first generation contender is palm oil - which also comes with a lot of environmental risk. Palm oil is derived from the African Oil Palm. The oil palm is a prolific producer of oil, which can be used as fuel (and food). This is also a plant that thrives in the tropics, and is capable of annually producing upwards of 500 gallons of oil per acre. To my knowledge there is no other oil crop that consistently demonstrates these sorts of yields (acknowledging that algae could *theoretically* produce more).

The price of palm oil over the past 5 years or so has traded in a range comparable to that of crude oil; $50-$75 a barrel for the most part (although like petroleum, prices shot up to around $150/bbl in mid-2008). Palm oil can be used unmodified in a diesel engine, although some precautions are in order (and I don't recommend it). It can also be processed to biodiesel, or hydrocracked to green diesel. The extra processing will generally make the final product somewhat more expensive than petroleum, but demand has still been strong due to biofuel mandates.

The risks with palm oil are significant, though. Palm oil presents an excellent case illustrating both the promise and the peril of biofuels. Driven by demand from the U.S. and the European Union (EU) due to mandated biofuel requirements, palm oil has provided a valuable cash crop for farmers in tropical regions like Malaysia, Indonesia, and Thailand. The high productivity of palm oil has led to a dramatic expansion in most tropical countries around the equator. This has the potential for alleviating poverty in these regions.

But in certain locations, expansion of palm oil cultivation has resulted in serious environmental damage as rain forest has been cleared and peat bogs drained to make room for new palm oil plantations. Deforestation in some countries has been severe, which negatively impacts sustainability criteria, because these tropical forests absorb carbon dioxide and help mitigate greenhouse gas emissions. Destruction of peat land in Indonesia for palm oil plantations has reportedly caused the country to become the world’s third highest emitter of greenhouse gases.

Because palm oil is capable of competing on price, it was originally viewed as a very attractive source of biofuels. In recent years, countries have begun to rethink their policies as the environmental implications of scaling up palm oil production began to unfold. As is so often the case, the biofuel mandates that politicians thought were a good idea have had some pretty serious unintended consequences.

Next Generation Biofuel Contenders

Here is how I would define a next generation **Biofuel Contender:** *A technology that is capable of supplying 20% of our present liquid fossil fuel consumption on a net energy basis.*

Yes, 20% is somewhat arbitrary, but it weeds out a lot arguments over many potential small contributors. If you set the bar too low - say 5% - all kinds of things come out of the woodwork and make claims. Too much to discuss or debunk. Set the bar too high - say 50% of our current usage - and in my opinion no renewable fuel can meet that target via biomass. Although the pretenders will insist that they can.

I will focus in this essay on the United States, because I am most familiar with our energy usage and biomass availability, but these arguments should be applicable in many places around the world.

Consider for a moment the amount of energy locked up inside the 1.3 billion tons of dry biomass that the Department of Energy and the USDA suggest can be sustainably produced each year. (Current biomass usage is 190 million tons/year). Woody biomass and crop residues - the kind of biomass covered in the 1.3 billion ton study - contains an energy content of approximately 7,000 BTUs per pound (bone dry basis). The energy content of a barrel of oil is approximately 5.8 million BTUs. Thus the raw energy contained in 1.3 billion tons of dry biomass is equivalent to the energy content of 3.1 billion barrels of oil, which is equal to 42% of the 7.32 billion barrels the United States consumed in 2008.

This calculation tells you a couple of things. First, the 42% represents an upper limit on the amount of oil that could be displaced by 1.3 billion tons of biomass – presuming we could really produce that much sustainably. The actual amount of oil displaced would be much lower because energy is required to get the biomass to the biorefinery and then to process it. So replacing oil with biomass isn't going to be a trivial task, and a process must be capable of turning a respectable percentage of those biomass BTUs into liquid fuel if it is to be a contender. But it is unlikely that we are going to replace anything approaching our current level of energy usage with biomass.

Imagine a process that only captures 25% of the starting BTUs as liquid fuel. The liquid fuel production of 1.3 billion tons would then be 10.5% of our oil usage instead of 42% - and that's before we consider the energy requirements from the logistical operations (like getting that wood to the biorefinery). This is the realm of the pretenders; they waste a lot of BTUs during the production of the liquid fuel. What we really need is a process that can capture >50% of the BTUs as liquid fuels. That's what it will take to be a contender, and quite frankly I don't believe cellulosic ethanol has a chance of pulling this off on a large scale.

However, there are at least two technologies that can achieve net liquid fuel yields in excess of 50% of the BTU value of dry biomass. These technologies are flash pyrolysis and gasification. I will talk about each below. (Hydrocracked oils – green diesel - might get close as well, but the most consistent oil producers are generally also foods).

Flash Pyrolysis

Flash pyrolysis involves rapidly heating up biomass to around 500°C. The reaction takes place in about 2 seconds, and the products are pyrolysis oil (also called bio-oil) and char. The process can handle a wide variety of feedstocks, the oil yield is approximately 70% by weight, and the energy content per pound of oil is similar to the starting material. Thus, approximately 70% of the initial BTUs are captured in the oil before we have to start subtracting out energy inputs.

Char is frequently mentioned as a great soil amendment (as terra preta, for instance), but I don't really know if there is a market for it. As someone recently said to me, it may be like biodiesel and glycerin. In theory there are all kinds of uses for glycerin, but the market was quickly saturated as biodiesel production ramped up. Glycerin suddenly became a disposal problem. Terra preta does in fact appear to be a great soil amendment, but people are going to have to show that they will buy it. It seems to me that the ideal solution would be to use the char to help heat the biomass, unless the ash properties are problematic for the process.

There are definite downsides to flash pyrolysis. Heating up to 500°C will subtract from the net energy production, and while heat integration is possible, it would be more difficult to achieve in a hypothetical mobile unit (which I think could finally provide an outlet for the millions of acres of trees destroyed by the Mountain pine beetle). The properties of the raw oil are such that it isn't suitable for transport fuel as produced. It is not a hydrocarbon and is very acidic. Without upgrading, it can't be blended with conventional diesel. There are various issues around reproducibility and stability, especially if the biomass quality varies. The oil is suitable for power generation or gasification, and can be upgraded to transportation fuel, albeit at greater expense and lower overall energy efficiency.

With those caveats, it is still a contender. It could be knocked out of contention as a viable transportation fuel if the upgrading process is too expensive or energy intensive, but at present no fatal flaw has emerged. There are a number of companies involved in pyrolysis research. Dynamotive Energy Systems has been working on this for a while (I first wrote about them in 2007). UOP - a company that specializes in product upgrading for refineries - has teamed with Ensyn to form a joint venture called Envergent Technologies. The company intends to make pyrolysis oils from biomass for power generation, heat, and transport fuel (this is where UOP's skills will come into play).

Gasification: Biomass to Liquids

The following example is just one reason I think gasification is going to play a big part in our future. During World War II, the Germans were cut off from liquid fuel supplies. In order to keep the war machine running, they turned to coal to liquids, or CTL (coal gasification followed by Fischer-Tropsch to liquids) for their liquid fuel needs. At peak production, the Germans were producing over five million gallons of synthetic fuel a day. To put that into perspective, five million gallons probably exceeds the historical sum of all the cellulosic ethanol or synthetic algal biofuel ever produced. Without a doubt, one week's production from Germany's WWII CTL plants dwarfs the combined historical output of two technologies upon which the U.S. government and many venture capitalists are placing very large bets.

South Africa during Apartheid had a similar experience. With sanctions restricting their petroleum supplies, they turned to their large coal reserves and once again used CTL. Sasol (South African Coal, Oil and Gas Corporation) - out of necessity - has been a pioneer in gasification technology. Today, they have a number of gasification facilities, including the 160,000 bbl/day Secunda CTL facility, which has been highly profitable for the company (but very expensive relative to oil prices when constructed). In total, Sasol today synthetically produces about 40% of South Africa's liquid fuel.

While we can speculate on the source of future fuel supplies in a petroleum constrained world, we do know that two countries that already found themselves in that position turned to gasification as a solution. The technology has a track record, is scalable, and today commercially produces synthetic fuel in volumes cellulosic ethanol or algal fuel can only dream about. We *hope* various other technologies scale and that technical breakthroughs allow them to compete. But gasification has already proven itself as a viable go-to option. There are presently a number of operating CTL and GTL plants around the world. Shell has been running their Bintulu GTL plant for 15 years, and is currently building the world's largest GTL plant with a capacity of 140,000 barrels/day.

The biomass to liquid fuel efficiency for gasification is around 70% (See Section 1.2.2: Second-Generation Biofuels), a number cellulosic ethanol will never approach. In short, no other technology to my knowledge can convert a higher percentage of the embedded energy in biomass into liquid fuels.**

Of course there's always a catch. Despite large reserves of coal, the United States has not turned to gasification as a solution. Why? High capital costs. At the end of the day the desire to keep fuel prices low consistently overrides our desire for energy security. (There are also greenhouse gas concerns over using coal gasification which should not be an issue for waste biomass gasification).

But biomass is more difficult to handle, so there are added costs above those of coal gasification. So you have a process that is more capital intensive than a conventional oil refinery, or even a cellulosic ethanol plant. But what you save on the cellulosic ethanol plant ultimately costs a lot in overall energy efficiency. Until someone actually scales up and runs a cellulosic ethanol plant, we can only speculate as to whether cellulosic ethanol is even a net energy producer at scale.

Interestingly, one of the "cellulosic ethanol" hopefuls that we often hear so much about - Range Fuels - is actually a gasification plant. (Ditto Coskata). The front end of their process is intended to produce syngas in a process derived from that of World War II Germany. For their back end they intend to produce ethanol, which in my opinion is an odd choice that was driven purely by ethanol subsidies. But this is definitely not the optimal end product of a gasification process. They are going to lose a lot of efficiency to byproducts like methanol (which is actually a good end product for a gasification plant) - and that's assuming they get their gasification process right. They are then going to expend some of their net energy trying to purify the ethanol from the mixed alcohols their process will produce.

The question for me is not whether BTL can displace 20% of our petroleum usage. I believe it can. The question is whether we are prepared to accept domestic fuel that will cost double (or more) what we pay today. In the long run - if oil prices continue to rise - then BTL plants that are built today will become profitable. The risk is that a sustained period of oil prices in the $50-$70 range will retard BTL development. But I don't expect that to happen.

Conclusions

In my opinion, the question of which next generation biofuels can compete comes down to fossil fuel prices. If oil prices are at $50 for the next 10 years, it will be difficult for next generation renewable fuels to compete. Despite the many promises of technologies that will deliver fuel for $1 a gallon, I think that target is likely to be reached only on paper. My view on which technologies will be competitive is based on 1). An expectation of an average oil price over the next 10 years that exceeds $100/bbl; 2). An expectation that we will need to efficiently convert the available biomass. 3). Knowledge of what many of the major players are doing. I expect biomass prices to rise as well, and inefficient technologies that may be competitive if the biomass is free and fossil fuel inputs like natural gas are low-priced will not survive as the prices of both rise.

I am certainly interested in helping promote promising next generation technologies, so if you think I have missed some really promising ones then feel free to add your thoughts. It is possible that a company like LS9 or KiOR will ultimately be successful, but they are going to require some technical breakthroughs. Those don't always happen (I am waiting for a laptop battery that runs my laptop for a week on a single charge). Given the great number of renewable energy start-ups, it won't be surprising if one or more of them eventually makes a contribution, but the odds are against most of them. I selected pyrolysis and gasification as strong contenders because they don't require technical breakthroughs in order to produce large amounts of fuel. The technical aspects of gasification at large scale are well-known. This is not the case with most companies seeking to compete in the next generation arena.

Personal Note on Technology Development

On a personal note, since I have long believed in the promise of gasification as a future solution to our liquid fuel problem, it may come as no surprise that my new role in Hawaii has connections into this area. While several have figured out what I am doing, I still don't have the green light to explicitly discuss it (but I should before year-end). I am not being coy, it is just that we still have some pieces to put in place, and then I will explain why I believe we are building a platform that is unique in the world. I can say that my new role is as Chief Technology Officer of a bioenergy holding company, and the platform we are putting together does not exist elsewhere to my knowledge.

One of the things I am very interested in is developing conversion technologies for woody biomass and crop wastes. I have a number of technologies on my plate right now, but I am searching for other pieces that improve the economics (scalability is important).

For example, in the earlier example of the beetle-infested forests, the logistical challenge of getting the biomass to a processing facility - without consuming a large fraction of the BTU value of the tree - is significant. Biomass has a low energy density relative to fossil fuels, and cost-effective technologies are needed for improving that equation. I am speaking to a number of people with promising technologies around this area, but am always open to speaking to others who have ideas, prototypes, or pilot plants demonstrating their technology. You can find my spam-protected e-mail in my profile.

Footnotes

* Following the publication of this essay on my blog, I had a meeting with someone inside the Department of Defense who is involved in testing fuel for the military. The person said they were able to get some algal fuel to test from one of the well-known names – for around $100/gal.

** I have heard from a couple of people that 70% seems too high, and is likely a result of an improper energy balance. I have personally seen this number several times, but I have not seen a full energy accounting to validate that. One person who is very well-versed in gasification said that total energy balance will probably put the liquid fuel recovery at about 50% of the starting BTUs. (You can't calculate an EROEI from this unless you also have the fossil fuel inputs – primarily from the logistical operations).