The Oil Drum
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

Key Questions on Energy Options

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A question was once posed here: What is the most important question concerning ethanol production? That got me to thinking about important questions regarding not only ethanol, but all of our energy sources. There are a number of issues that we must carefully consider for any of our potential energy sources.

In my opinion, they are:

1. Is the energy source sustainable?
2. What are the potential negative externalities of producing/using this energy source?
3. What is the EROEI?
4. Is it affordable?
5. Are there better alternatives?
6. Are there other special considerations?
7. In summary, are the advantages of the source large enough to justify any negative consequences?

For the purposes of this essay, I want to focus on energy sources for transportation. Let's look at some options, and get a better handle on why we have opted for the energy sources we presently use. I will not cover all of the options. In fact, nuclear, which is likely to play a bigger part in the future, is not discussed simply because I don't know enough about it.

A few comments here, as some of the questions warrant additional comment. With respect to sustainability, just because a fuel is not sustainable does not immediately disqualify it from consideration. It just means that there must eventually be something else to take its place. This could even be another unsustainable option, but these unsustainable options are unsustainable for a reason. It would be preferable to move to something sustainable.

Likewise on the negative externalities. There are negative externalities that we can tolerate, and some we can't, but most fall in between. Is increased pollution a tolerable negative externality? It obviously depends on the level and type of pollution. If the pollution level for a relatively benign substance goes from undetectable to barely detectable, that is probably an externality that we can live with. Others aren't so clear cut, but all need to be weighed against the perceived benefits.

The question of affordability is a really loaded question, as this will mean different things to different people. Does affordability mean that I can commute in a Hummer 40 miles one way to work with minimal economic impact? Or does it mean that I can continue to drive my subcompact a few miles per week while still being able to afford food? These are issues that we can discuss.

Liquid Fossil Fuels

1. Clearly not sustainable.

2. The potential negative externalities are many. Among them are Global Warming, increased pollution, using our military to keep supply options open, and potentially enabling the earth to be populated beyond its carrying capacity.

3. The energy return on fossil fuels is quite high. Despite publications that have suggested that the energy return on fossil fuels is less than 1.0, the actual energy return (from oil in the ground to fuel in the tank) is in the range of 6.0 – 7.0. That is, for 1 BTU of energy expended, at least 6 BTUs of fossil fuel can be extracted from the ground and processed into liquid fuels for a net of 5 BTUs.

4. Yes, this is our most “affordable” energy option with respect to the price we pay at the pump.

5. It depends on the definition of “better.” If better means a cheap option that supplies the U.S. with the current level of energy consumption, then “No.” But I would define better such that the source is sustainable and negative externalities are minimized. In that case, there are better alternatives, which will be covered.

6. One special consideration here is the relying on fossil fuels puts our energy security squarely in the hands of the Middle East, an intolerable situation in my opinion.

7. No.

I did not break out GTL and CTL via Fischer-Tropsch separately, although perhaps I should have. I have voiced my concerns about those in a previous essay - XTL: Promise and Peril.

Grain Ethanol

1. Not sustainable.

2. Again, many potential negative externalities. Among them are loss of topsoil, increased pollution from pesticide and herbicide runoff, aquifer depletion, and an increase in food prices due to increased grain demand (a positive externality to those who farm).

3. The energy return on grain ethanol is very low. Published studies put this number at around 1.3, but the return for fossil fuels in and ethanol out averages less than 1.1. Animal feed byproduct that is given a BTU value pushes the EROEI up to 1.3. Therefore, for 1 BTU of energy expended, less than 1.1 BTUs of ethanol can be produced, along with an additional 0.2 BTUs of animal feed. The net is then 0.3 BTUs with the byproduct credit, or about 1/17th of the fossil fuel net.

4. It is affordable, due to direct subsidies. But based on the current spot price of ethanol, it is slightly over twice the cost of regular unleaded gasoline on a BTU equivalent basis.

5. Yes. Even staying within the ethanol category, there are better choices.

6. The business of grain ethanol has revitalized many rural communities, and has made farming much more profitable. However, it also encourages farmers to preferentially plant corn instead of less environmentally harmful crops. The fossil fuel inputs into ethanol production are also largely non-liquid (natural gas and coal). In the case of natural gas, this makes a fine transportation fuel. But some ethanol supporters correctly point out that we have lots of coal, and we could use that as our primary energy source for ethanol production. Just don't tell me it's renewable in that case!

7. No.

Grain ethanol is not sustainable for primarily 2 reasons. First, it involves a loss of topsoil, and in many areas a depletion of fossil aquifers. The amount of topsoil loss has been subject to much debate, but it will vary based on many factors. Some areas are certainly more sustainable than others. The other concern is the high degree of embedded (and unsustainable) fossil fuels required for grain ethanol production. This means that in addition to the direct negative externalities, you can add secondary negative externalities caused by the usage of the fossil fuels.

The pollution issue, in my opinion, is quite serious but is typically ignored by ethanol boosters. This issue was discussed last year in an article in CorpWatch. After discussing the "carbon monoxide, methanol, toluene, and volatile organic compounds" emitted by ethanol plants, the article addressed the issue of pollution caused by corn farming:

> Modern corn hybrids require more nitrogen fertilizer, herbicides, and insecticides than any other crop, while causing the most extensive erosion of top soil. Pesticide and fertilizer runoff from the vast expanses of corn in the U.S. prairies bleed into groundwater and rivers as far as the Gulf of Mexico.
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> The nitrogen runoff flowing into the Mississippi River has fostered a vast bloom of dead algae in the Gulf that starves fish and other aquatic life of oxygen.
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> To understand the hidden costs of corn-based ethanol requires factoring in "the huge, monstrous costs of cleaning up polluted water in the Mississippi River drainage basin and also trying to remedy the negative effects of poisoning the Gulf of Mexico," says Tad Patzek of the University of California's Civil and Environmental Engineering department.
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> "These are not abstract environmental effects," Patzek asserts, "these are effects that impact the drinking water all over the Corn Belt, that impact also the poison that people ingest when they eat their food, from the various pesticides and herbicides." Corn farming substantially tops all crops in total application of pesticides, according to the US Department of Agriculture, and is the crop most likely to leach pesticides into drinking water.
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> While banned by the European Union, atrazine is the most heavily used herbicide in the United States - primarily applied to cornfields - and the EPA rates it as the second most common pesticide in drinking wells. The EPA has set maximum safe levels of atrazine in drinking water at 3 parts per billion, but scientists with the U.S. Geological Survey have found up to 224 parts per billion in Midwestern streams and 2,300 parts per billion in Corn Belt irrigation reservoirs.

In my opinion, these are negative externalities just as serious as those posed by fossil fuel usage.

Yet this is the alternative that we are scaling up just as fast as we possibly can. The real problem is that the negative externalities don't directly and immediately impact most people's lives, so they pay no heed to them. Sure, increased ethanol production might cause atrazine levels in drinking wells to increase, but it's in someone else's water. "It's not my problem if it's not in my water" is the attitude of most people. But I doubt anyone personally affected by this is going to consider it an acceptable externality.

Sugarcane Ethanol

1. Sustainable, for reasons I outlined in this article.

2. Few potential negative externalities to my knowledge. I have heard mention that expanded sugarcane production will be at the expense of rain forest, but the sugarcane plantations in Brazil are not near the rain forests. I do not know if rainforests in other tropical countries may be put in danger by expanded sugarcane production.

3. The energy return on sugarcane ethanol appears to be in the 8/1 range, which would make it better than gasoline. More on that below.

4. It is affordable, but in the U.S. we punish Brazilian ethanol with a $0.54/gallon tariff to protect our unsustainable corn ethanol production.

5. For a liquid fuel that will fit in the current transportation infrastructure, I don't think sugarcane ethanol can be beaten with existing technology. But it can't provide our current level of energy usage.

6. The industry can provide an economic boost to tropical countries, where it is sorely needed.

7. In my opinion, the advantages of sugarcane ethanol justify the costs, provided habitat is not being destroyed to grow more sugarcane.

I find it shameful that the U.S. subsidizes an unsustainable and polluting industry like grain ethanol, and punishes a sustainable industry like sugarcane ethanol. Yet even with those tariffs in place, Brazil can still ship their ethanol to the U.S. and compete with homegrown corn ethanol prices.

The energy return on sugarcane ethanol as it has been calculated does appear to be in the 8/1 range, which would make it better than gasoline. On the face of it, this seems absurd. Nature has already done the major processing for fossil fuels, and turned ancient plant material into long-chain, energy dense compounds. In the case of sugarcane ethanol, a lot of energy inputs are required, especially for purifying the ethanol, but those inputs are being satisfied by burning the sugarcane ethanol residues to produce process heat. Therefore, they are not being counted against the energy output.

However, gasoline accounting is not done in this manner. When oil is refined to liquid fuels, a lot of fuel gas is produced. That fuel gas tends to be burned in the refinery to produce process heat, but I have still charged that against the energy balance I calculated above. If I had done the energy accounting as is done with sugarcane ethanol, one could state that the energy return of gasoline is actually only the initial energy required to get the oil out of the ground, which averages about 17/1 worldwide. The refining step would get a free pass, since the energy in the oil is ultimately used to refine the oil. So no, the energy balance of sugarcane ethanol is not in fact better than that for gasoline.

Despite that, I believe sugarcane ethanol is a good option for mitigating a portion of our fossil fuel usage because it is renewable, and it lacks the negative externalities of fossil fuels. However, our present usage is much too great to be offset with sugarcane ethanol alone.

Cellulosic Ethanol

1. Sustainable.

2. Few potential negative externalities depending on the biomass source.

3. Unknown.

4. Presently, despite frequently optimistic claims, it costs significantly more to produce cellulosic ethanol than to produce corn ethanol.

5. Yes.

6. There are numerous sources of biomass that could be used to produce cellulosic ethanol.

7. Time will tell, but cellulosic ethanol did not just come onto the scene. Researchers have been trying to commercialize it for many years without much success. It will require several breakthroughs, none of which are certain to occur, before cellulosic ethanol contributes to our energy requirements.

Due to the lack of commercial cellulosic ethanol plants, the energy return is largely unknown. On the one hand, fossil fuel inputs for growing the biomass will likely be much lower than for corn. However, the ethanol concentration yielded from a cellulosic ethanol process tends to be significantly lower than the concentration obtained in a conventional ethanol production. A presentation at last year's St. Louis Renewable Energy Conference from Keith Collins, Chief Economist at the USDA, showed that corn ethanol yields 14-20% ethanol, while cellulosic is a paltry 4%. That means a lot more energy for purification.

In addition, more processing steps are required. I have seen EROEI estimates for cellulosic ethanol that range from less than 1 to greater than 8. Based on the factors mentioned here, the true estimate is likely to be closer to 1. But the truth is we just won't know until some commercial facilities are up and running.

I don't discount that technical improvements will occur with cellulosic ethanol. But many people who don't understand the nature of the challenges (or who have a vested interest not to) have presumed technical breakthroughs of a practically magical nature. If I announced that we would be making regular trips to Mars within 10 years, most people would reject this because they have some understanding of both the technical difficulty involved, and they understand that the costs would be enormous. Yet those same people may have no problem believing that we are going to transition our fossil fuel infrastructure to a cellulosic ethanol infrastructure. Yet the technical challenges involved are of the magnitude of ferrying us all back and forth to Mars.

Biodiesel

1. It depends on the source.

2. Biodiesel in general suffers from far fewer negative externalities than most biofuels, but palm

oil gets mixed reviews. On the one hand, it is a tropical crop like sugarcane ethanol, and the EROEI appears to be very good. On the other, rainforest is being destroyed to grow new palm oil plantations.

3. By most accounts, the EROEI is greater than 3, which is respectable for a biofuel.

4. It is more expensive than conventional diesel. Current subsidies make it affordable.

5. Biodiesel can be a sustainable contributor toward energy security.

6. Diesel engines are much more efficient than gasoline engines, which reduces the overall fuel requirement.

7. Again, it depends on the source. If we are going to chop down rainforest to plant palm oil plantations, then no. If we are going to use waste oils and existing high oil-yielding crops (grown sustainably), then yes.

I think the U.S. made a mistake by not favoring the diesel engine over the gasoline engine as has been done in many other countries. Diesels are much more efficient than gasoline engines, so a diesel fleet would stretch the fuel supply.

Biodiesel can be produced sustainably, but caution is warranted. We first need to make sure that absolutely all of the waste vegetable oil in the country gets collected and turned into biodiesel. But even growing crops for biodiesel may be done sustainably. Biodiesel derived from soybeans, while expensive to produce, comes at a much lower environmental price and a much better EROEI than corn ethanol. Then there is the added benefit of 1). A higher BTU value per gallon; and 2). The higher efficiency of the diesel engine. These factors combined mean that we would need less than half the biodiesel to drive the same amount of miles we could if using ethanol.

At this stage, I would put algal biodiesel in the same category as cellulosic ethanol: Technically feasible, sustainable, but it may not be commercially feasible. Also as in the case of cellulosic ethanol, there is much hype but much of it is without merit at this time. Magical technical breakthroughs are again being presumed as a given by many people. I have even been guilty of this to some extent.

Biomass Gasification

1. Sustainable.

2. Care has to be taken with respect to the source used for gasification. There are also potential air quality issues from a large-scale gasification program.

3. I have not seen an EROEI calculation, but I expect it to be much higher than for cellulosic ethanol. I would estimate an EROEI in the 6-10 range (based on the method I use for calculating a fossil fuel EROEI).

4. Currently capital costs are too high to enable biomass gasification to compete.

5. Biomass gasification has a chance to be a highly sustainable contributor toward our energy demands.

6. Biomass gasification could be used either to produce electricity (e.g., use biomass instead of coal in a power plant application) or as the first step in a liquid-fuels program. More below.

7. Yes.

I have described what I believe are the advantages of biomass gasification over cellulosic ethanol previously in Cellulosic Ethanol vs. Biomass Gasification. Briefly, cellulosic ethanol converts a small portion of the available biomass. Gasification converts all of it into syngas, which can then be used to make a wide variety of chemicals, including methanol, ethanol, or diesel.

The main problem with implementing a large scale biomass gasification is that it is presently just too expensive. The capital costs associated with processing the biomass are very high. Current estimates, which I documented in the afore-mentioned article, put the cost of a biomass gasification plant at about 7 times the per barrel cost of a conventional oil refinery or grain ethanol plant, and double the costs of a coal-to-liquids plant. At some point we may be willing to pay these costs for our fuel, but it won't be until other options are largely exhausted.

Wind and Solar

1. Sustainable.

2. Few potential negative externalities to my knowledge. Wind turbines have been implicated in the deaths of some bats and birds, and there may be some increased pollution as a result of solar panel manufacture.

3. The energy returns have been calculated in a number of different ways, but most sources show an energy balance more favorable than that of most liquid fuels.

4. Wind-generated electricity is affordable, but solar is still out of reach for the average person.

5. For electricity generation, I think these are the best, most sustainable options.

6. There are a number of special considerations for this option. First, wide-spread electric transport – an absolute must in my opinion - is not yet a reality. Battery technology still doesn't quite have the cost/benefit ratio that many consumers desire. Also, if the U.S. moves toward more electric transportation a lot of infrastructure will need to be upgraded. There are also currently issues with a shortage of silicon for making solar cells, which is keeping prices elevated. Finally, there is the issue of intermittency for both of these sources. Improvements in storage technology (such as compressed air energy storage) are needed.

7. I believe that we need to move toward transportation electrification, which in my opinion would make wind and solar power more attractive options than any of the liquid fuel options (with the possible exceptions of sugarcane ethanol and waste-derived biodiesel).

The potential advantages of a solar and wind-powered transport system are so great that our current infatuation with grain ethanol is a tremendous misallocation of resources. My vision for the future would involve some solar panels on the vast majority of houses around the world providing the electricity to run our small PHEVs. I truly believe this is the model that we will eventually implement.

Conservation

This essay wouldn't be complete without a discussion on conservation. Consider that we could save more fuel, while stretching our budgets, by choosing to embrace conservation. If we chose more fuel-efficient cars, slowed down, took fewer trips, and walked or rode a bike instead of driving, just think about the fuel we could save. We would immediately reduce our dependence on the Middle East, because we just wouldn't need as much oil. We would increase the chance that some combination of alternatives could supply a level of energy that would allow us to maintain a decent standard of living.

Yet in this rush to alternatives, conservation is typically given just a bit of lip service. Our politicians will say "Ethanol, ethanol, ethanol, and yeah, we should conserve." But money is not being thrown at conservation. Imagine if instead of spending over $2 billion a year in direct ethanol subsidies, we directed that money into conservation measures. We could offer everyone in the country direct tax breaks for purchasing fuel efficient vehicles. To me, such a policy would make a much greater contribution toward our energy independence than the policies we currently have in place. I believe we have to demand that our political leaders put more emphasis on conservation as a piece of our energy puzzle.

And don't give me Jevon's Paradox. If as a result of increased conservation in the U.S., China happens to consume the energy we saved, that's ultimately too bad for China. We will have still reduced our energy dependence and taken a step toward sustainability. When the full force of Peak Oil hits, those who have thrown out Jevon's Paradox as a reason not to conserve will finally understand the foolishness of such reasoning. What is going to matter is that we have a small energy footprint and are as sustainable as we can possibly be. Throwing out Jevon's Paradox as an argument that conservation is ultimately futile will never allow us to prepare for the effects of oil depletion on society.

When we are serious about attacking our energy dependence, we will go after the demand side. I believe that a revenue neutral gas tax would seriously cut into our demand over time. This is, of course, the main reason for Europe's success in maintaining a much lower level of energy usage. Such an approach works, and Europeans enjoy a nice standard of living. Perhaps we will decide to take this proven approach for reducing consumption before declining oil production forces higher prices on us before we have time to prepare.