The Oil Drum
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

Science 1101 Part 2: Oil as a Liquid Fuel and Expected Peak Oil Impacts

Posted by Gail the Actuary on February 8, 2008 - 11:00am
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This is Part 2 of my post relating to curriculum for a science peak oil course. It incorporates changes based on many of the comments made below. Part 1 can be found here. A PDF version which contains both Part 1 and Part 2 can be found at this link.

One theme of Part 2 is **energy**, and why energy is important to our standard of living. I try to compare the energy in oil to the energy in food. To make the comparison more understandable, I convert energy to kilocalories, since most people are familiar with calories in food. I also point out the errors of economists, both in the text and in the discussion questions at the end.

Another theme is the special characteristics of oil, and why oil is valued as a **liquid fuel**. I think we are sometimes kind of fuzzy in our thinking about substitutes for liquid fuel. We don't think about our built infrastructure, and just assume electricity can be substituted for oil when it really is at best a very long-term alternative. I discuss various alternatives including **battery-operated cars**, hydrogen, and conservation. The two sections relating to **corn ethanol** could probably be a post of their own.

I also talk about **the impact of oil on prices**. I make the point that big increases in petroleum prices are likely, with only a small shortage of oil. I also point our that **food prices** are likely to increase, partly because of the use of petroleum for food production, and partly because corn for ethanol competes with food for land use.

Part 2 – Oil as a Liquid Fuel and Expected Peak Oil Impacts

1. Why is petroleum so highly valued?

The main reason that petroleum is highly valued is *for its energy content*. If petroleum is burned, it can do *work* that makes our lives easier. For example it can be used to power an automobile or an airplane. We eat food to give us energy that allows us to do work of various kinds. In many ways, petroleum is the equivalent of food for many types of mechanical objects. For example, petroleum allows us to drive a car, and to do the work of transporting our luggage and ourselves. If we didn't have petroleum, we would have to do the work ourselves – walk and carry our own luggage.

Another reason petroleum is valued is for all the things that can be created from the petroleum itself, without burning it. Final products include fabrics, plastics, drugs, herbicides, insecticides,

and much more. At some point, we may decide oil is too valuable to burn. These products are very valuable, and it would be difficult to find replacements.

2. What is the relationship between energy use and standard of living?

There is a close tie between energy use and standard of living. Energy use gives us mechanical slaves that can do much work that we could do ourselves, but would take much longer. For example, mechanical equipment is used to plant and harvest crops, and to wash and package the food. Trucks are used to transport food to market. We could do many of these steps ourselves, by digging in the ground, picking the crops ourselves, and walking to market with the produce, but it would take much more of our own physical work.

Many economists dismiss the close tie between energy and standard of living. They say that energy costs are only a small portion of total costs, so energy is not very important. This reasoning is not correct. If there is a shortage of petroleum, it is in some ways analogous to a shortage of food. The real problem is not that we have to pay more; it is that we have to get along with less. If our diet were reduced from 2,000 calories a day to 1,900, it would make a difference to our lives. If the economy suddenly experiences a shortfall in petroleum products, fewer goods can be transported to market, and someone will have to do without a product or service that they would otherwise have had.

Robert Ayers and Benjamin Warr showed the close relationship between energy use and standard of living, disproving the standard belief of economists. In particular, they showed that there is a very strong tie between energy use, including the more efficient use of energy, and economic growth. http://www.iea.org/Textbase/work/2004/eewp/Ayres-paper1.pdf

3. Why is petroleum more highly valued than other forms of energy?

There are many reasons:

a. Its abundance. Petroleum is the largest energy source for the United States, comprising 40% of our energy use. Coal and natural gas are each a little over half as big (23%). The new alternatives are tiny in comparison.

b. The fact that it is a liquid. Liquids are easy to transport and store. Imagine filling your fuel tank with coal!

c. Its high level of concentration. Those of us who have done cooking or counted calories know that oils have a lot more calories for the same volume than other foods. It is the same way with fuel. Gasoline has 115,000 Btu per gallon, or in terms we are more familiar with, 29,000 calories (of the type you eat in food –- actually *kilocalories*) per gallon. Ethanol, which is equivalent to alcohol in alcoholic beverages, has only two-thirds as many calories (that is, energy) per gallon.

d. Its low price. The reason oil has historically been inexpensive is that it takes a relatively small amount of resources to extract oil. In the early days of production, it took roughly the energy of one barrel of oil, plus a few other inputs (human labor and iron ore) to extract 100 barrels of oil. Even recently, it has taken as little as the equivalent as 15 barrels of oil (plus human labor and a few other inputs) to produce 100 barrels of oil.

e. Very favorable energy balance. This is just the flip side of Item d, oil's low price. If it only takes one barrel of oil to produce 100 barrels of oil, a small investment can create a huge amount of energy. Even if it takes 15 barrels of oil to produce 100 barrels of oil, there is still a very favorable

return. This extra energy benefits society in many ways. It gives us the extra energy we need to build roads and malls and better our lifestyle.

f. Built Infrastructure. Nearly all of the cars, trucks, airplanes, and farm equipment currently in use were designed to burn oil products. While theoretically they could be replaced, this is a huge sunk cost. It would require technical innovation, a large investment of fuel and other resources, plus a timeframe of thirty or more years to convert to a new base.

g. Non-intermittent supply. At least historically, the supply of oil has been there, so that we could depend on it. We didn't have to worry whether the wind was blowing, or a cloud was covering the sun.

4. What are petroleum's disadvantages?

a. Not renewable. The supply is depleting. Decline may begin within a few years.

b. Not environmentally friendly. There are problems in three different areas:

Global warming gases. Oil is only 80% as bad as coal in terms of the amount of carbon dioxide formed per unit of energy, but 40% worse than natural gas. Because we use so much oil, total carbon dioxide is more from oil than from coal or natural gas.

Air pollution. Smog, airborne particulate matter, and some carcinogens are the indirect result of the burning of petroleum.

Local environmental damage. Spills. Pollution problems particularly for Canadian oil sands, where much water is required for extraction. http://www.commondreams.org/archive/2008/01/10/6304/

5. How are oil and gasoline priced?

Oil is priced based on supply and demand. If there is not sufficient oil for everyone who wants it, the price increases until some would-be buyers are priced out of the market or an alternative appears. Additionally, the price must be high enough to cover the cost of extraction of even recently discovered oil. If the price drops too low, or it the likelihood of profit is too low because of punitive taxation, oil companies will discontinue their attempts to produce more oil.

Prices tend to "shoot up" if there is a shortage oil or gasoline, because people are unwilling to go without, and substitutes are very limited. A rough estimate is that 1% shortfall in supply will result in a 17% increase in gasoline prices, and a 2% shortfall will result in a 33% increase in prices. (This is based on a shot-term price elasticity of demand of .06. See http://www.cbo.gov/ftpdocs/88xx/doc8893/01-14-GasolinePrices.pdf)

The price of gasoline is fairly closely related to the price of oil, plus the additional costs involved. One US Energy Information Administration government website shows this relationship:

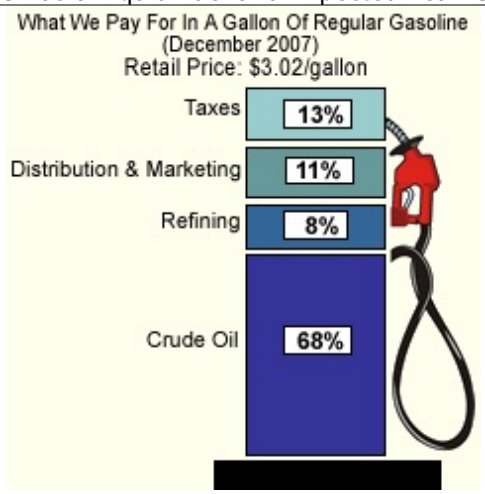

Figure 9

6. How does corn-based ethanol compare to petroleum as a solution to our energy needs?

Corn-based ethanol is a **very poor substitute** for petroleum. Actually, it is only, at best, a substitute for gasoline. Other petroleum products, such as diesel, lubricating oil, and asphalt require different types of substitutes.

The major problems with ethanol from corn are

a. Not scalable. A very large amount of land is required to produce a small amount of fuel. In 2007, over 20% of America's corn was devoted to ethanol, but this provided only the energy equivalent of 3% of our gasoline use (or 1.1% of our petroleum use). More than doubling this will be very difficult.

b. Causes food prices increases. Competition of corn for land raises food prices. We end up paying a second time for corn ethanol through higher food prices.

c. Causes fertilizer shortages. Corn uses a lot of fertilizer. Fertilizer is made from natural gas and mostly imported. Fertilizer prices are now double what they were a year ago. The situation may get worse in future years and lead to shortages of fertilizer for food crops.

d. Environmental impacts as bad as gasoline (or worse). There are problems in several areas. Ethanol produces more global warming gasses than gasoline, according to recent studies. Older studies say that ethanol might produce slightly less global warming gasses than gasoline, but even this is not much help.
http://www.rsc.org/chemistryworld/News/2007/September/21090701.asp
http://www.independent.co.uk/environment/climate-change/biofuels-make-cl...

A Stanford study says that air pollution is also worse than with gasoline. Ozone, which causes smog, is likely to be worse with ethanol than gasoline. Ethanol decreases some carcinogens, but increases others. http://news-service.stanford.edu/news/2007/april18/ethanol-041807.html

The planting of corn also has negative environmental impacts, including aquifer depletion, topsoil erosion, and fertilizer runoff. These are especially problems if expansion of corn acreage means that corn is planted in hilly or arid locations where it would not usually be planted.

e. Energy intensive. Nearly as much energy must be used to make ethanol as is gotten back in return, so we are mostly recycling scarce fuels. Ethanol is not like petroleum, which has a positive energy balance to benefit our standard of living. If corn ethanol replaces petroleum, the impact on standard of living is likely to be negative. (See Item 3e)

f. Poor fit with petroleum system. At most 10% ethanol can be used in gasoline, without causing corrosion, unless autos are especially modified. Ethanol cannot be transported by pipeline, so costly and complex special arrangements must be made.

g. Less energy per gallon than oil. Ethanol has only about two-thirds the energy (calories) of gasoline.

h. Summer gasoline price run-up. Adding ethanol to gasoline makes gasoline evaporate at lower temperatures. To counter this, the fraction of gasoline that evaporates most easily (molecules with 4 or 5 carbon atoms, rather than 6 to 10 carbon molecules) must be removed from the gasoline mixture. Removing this portion of the gasoline reduces supply in the summer, and increases prices.

i. Drought sensitive. Supply depends on good weather in growing regions. http://collinpeterson.house.gov/PDF/ethanol.pdf

j. Expensive. Requires subsidies to be cost-competitive. Subsidies raise tax levels. Even with subsidies, ethanol's cost is often higher than that of gasoline.

7. Why is ethanol so popular?

The primary reason ethanol is popular is because it makes legislators look like they are doing something about reducing imports of gasoline. People do not realize that the benefit is tiny at best, and offset by many other problems.

The use of corn ethanol was expanded before people had a chance to learn its real-world problems. Many continue to support it because they believe it will be a “bridge” to better second generation fuels, such as cellulosic ethanol.

Corn ethanol also provides income to investors in biofuel refineries and jobs in rural areas. The offsetting costs of subsidies and higher food prices are far enough removed that people are not aware of them.

Car manufacturers like ethanol also because of a loophole that allows them to get credit for cars with higher mileage than they really have. Because of this, car manufacturers can build more gas-guzzlers than they would otherwise and still meet mileage requirements.

Ethanol’s use was expanded in 2005 and 2006 because clean air laws required the use of an additive called an “oxygenate”. The previous oxygenate, MTBE, had been found to be unsatisfactory. A number of people have raised the question as to whether oxygenates are really needed any more. Engines manufactured since 1994 have substantially reduced tailpipe emissions, so that an oxygenate may not to be needed.
http://www.foxnews.com/story/0,2933,104259,00.html

8. What other possibilities are there as a replacement for oil as a liquid fuel?

Some other biofuel possibilities include the following:

a. Biodiesel from rapeseed. This is equivalent to what we in the US would call "canola oil". Use of farmland for nonfood items is likely to drive up food costs. Heavy user of fertilizer. Has somewhat better energy balance than corn-ethanol. Mostly produced in Europe.

b. Cellulosic ethanol. Can be made experimentally, but isn't yet commercially viable. Would be made from non-food bio-products such as wood, switchgrass, and corn stalks. Likely to be more energy efficient than corn ethanol, and cause less pressure on land use. Most methods are not economic at this time, but one approach claims better success.

Larger potential volume than corn ethanol, but still would not replace more than 20% of petroleum use. Cellulosic ethanol will compete with electricity generation for the use of the same biomass. Some analyses indicate that cellulosic ethanol is not the best use for biomass.
http://www.coskataenergy.com/process.html
http://www.technologyreview.com/Energy/19842/ (Requires free registration)

c. Biodiesel from left-over oil. Can be made from leftover vegetable oil or from animal fat. Energy efficient, but total volume likely to be small.

d. Ethanol from sugar cane. Not cost efficient in US; Brazil makes low-cost product with much hand labor. Brazilian product is very energy efficient, but has human rights issues for laborers. Relatively small amount available for export. Would be another source of imported fuel.

e. Biodiesel from palm oil. Also made from other tree fruits. Often grown on forest land that has been cleared for this purpose, so has very adverse environmental impacts. Often competes with food use for oil. Would be another source of imported fuel.

f. Biodiesel from algae. Under investigation, but no one has found a way to do this in a commercially viable way yet. Requires little land use.

Besides biofuel approaches, there are also fossil fuel approaches:

a. Coal to liquid. Process to convert coal to a petroleum substitute was developed many years ago. Method is quite energy intensive. Has much worse carbon dioxide impact than petroleum. Probably less expensive than most biofuels. Several plants now being planned.

b. Natural gas to liquid. It is theoretically possible to convert natural gas to a liquid fuel, but it is very expensive and not much used. Cars can also be adapted to run on compressed natural gas. Natural gas solutions may work in some parts of the world, but supply is not adequate in North America, and imports are very limited.

9. How about solutions such as wind turbines, solar voltaic panels, battery operated cars, and hydrogen powered cars?

None of these are liquid fuels. They don't directly solve our need for something to keep are current fleet of vehicles and other devices using petroleum products operating. It is possible that over the very long term they can be part of the solution, but they cannot keep our current fleet on the road and our airplanes in the air.

Wind turbines and solar voltaic panels really relate to our need for better sources of electricity. Electrical supply is likely also to be a problem in the future, but we have not attempted to address the electrical supply issue in this document.

Battery-powered cars are a worthwhile idea, but there are some obstacles that need to be

overcome. http://www.evworld.com/

a. Common materials. Batteries that require rare minerals will not scale up to the volume needed for millions of cars. If we do not require too long a range, more options may be available. It is possible that ultra-capacitors may be part of the solution. http://www.nrel.gov/vehiclesandfuels/energystorage/ultracapacitors.html

b. Long time frame. Even if technology were fully perfected today, it would still take 15 to 20 years to get factories built, and the current fleet of cars replaced. Peak oil may delay this further.

c. Electricity issues. We assume that adequate excess electricity will be available to charge the cars 20 or 30 years from now, but that may not be the case. It would be ideal if a way could be found to use solar power to charge the cars. http://www.theoildrum.com/node/3316 http://jalopnik.com/335956/austrailian-solar-bus-is-mighty-green-mighty-...

Hydrogen powered cars seem to be much farther in the future than battery powered cars. Hydrogen is not a fuel source; it is more like a battery. Somehow, we would have to produce the huge amount of energy that would be necessary to separate the hydrogen from the compounds in which it is found. Besides having to build new cars, we would have to build a new pipeline network, a new set of filling stations, and the infrastructure to make this work. The whole process would be extremely expensive and likely require over 30 years.

10. Will biofuels and the other alternatives be sufficient to compensate for the petroleum shortage?

No, not based on what we know today. If nothing else, there will be a time-gap before the transition to alternatives can be made. There are a lot of alternatives under consideration, but none, by itself, seems likely to solve our need for a liquid fuel substitute in the timeframe in which it is needed.

Conservation will need to be an important part of the solution to our liquid fuel shortage. Better use of what we have, like carpooling, is one possibility. Another is electrified rail transportation. Streetcars were used years ago in many places, and could be built again, without developing new technology. Existing rail systems could be enhanced to permit more freight to be transported by rail. In some cases, sails can be added to boats to reduce fuel needs. If need be, personal vehicles can be made much smaller than we drive today, perhaps akin to golf carts or electric bicycles. http://en.wikipedia.org/wiki/Tram

11. Besides higher oil prices, what types of impacts can we expect from peak oil?

Increasing food prices. One reason is that oil is used in planting, harvesting, packaging, and transporting food. Another reason is that growing corn for ethanol will compete with other uses of land, and drive food prices up. Also, if there are fertilizer shortages, yields may be lower.

More defaults on loans can be expected, as food and petroleum prices increase. Families will have less money left over to pay mortgages and credit card debt.

Pre-peak impacts. Increases in oil and food prices are likely to begin even before peak hits, and seem to be happening already. All that is needed is a gap between oil supply and demand (see Part 1, Figure 5), not an actual decline. Ethanol-induced land shortages also contribute to the food price increases. Higher oil and food prices may be contributing to current US financial problems.

Reduced discretionary spending. People will spend less on things like restaurant food and out-of-

town vacations.

Reduced economic growth or actual decline appears likely.

12. What are the implications of the likely shortfall in oil production on career opportunities?

Careers in fields that are very petroleum-dependent may not be good choices. For example, there will likely be fewer airline pilots in 2040 than there are today.

If there is less petroleum, people are likely to be interested in having stores nearby that they can walk to. Thus, there may be an opportunity for starting a small store in your own neighborhood, or developing a neighborhood clinic.

Recycled products, especially those using petroleum inputs, are also likely to become more important. There may be careers in buying and selling these products.

There is clearly a need for more scientist and engineers in many energy-related fields. We need to find better ways to extract the oil that is available, and we need to develop more fuel-efficient vehicles. We need to find more and better petroleum alternatives, and to find ways to scale up these alternatives to the quantities needed as replacements for petroleum products.

13. Are there any actions we should take?

These are several ideas:

a. When buying a car, purchase the smallest, most fuel-efficient model you can find.

b. Consider sharing rides with someone else who is commuting in the same general direction, or take public transportation.

c. Make greater use of work-at-home programs and distance learning programs. Or live in a dorm.

d. Move closer to work or school.

e. When distances are short, walk or ride a bicycle, rather than drive.

f. Use recycling, especially for petroleum-based products like plastic. Other recycling is also helpful from a general energy-saving perspective, but not necessarily from a petroleum-saving perspective.

g. Avoid fruits and vegetables that have been flown to the United States from around the world. These tend to be quite expensive.

h. Reduce trips taken to distant locations, whether by air or automobile.

One idea which looks at the shortfall in a different way is to reduce meat consumption by eating smaller portions of meat or by substituting beans for meat in some meals. We are currently using biofuels as a substitute for petroleum, and this puts huge pressure on the food supply. By eating less meat, a person can help reduce the pressure on the food supply.

Animals eat several times as many calories in grain products as they produce in meat calories. By eating less meat, fewer acres of grains need to be planted to meet our food needs. We also reduce

the production of global warming gasses, because animals, particularly cows, are big contributors to these gasses.

Another idea is to get involved with campus groups or political groups to try to solve some of the problems in the years ahead. It is likely to be a difficult adjustment, but working together we are likely to be able to accomplish more than we can as individuals.

Part 2 – Discussion Questions

1. US oil consumption is about 25 barrels per year for each person in the United States. There are 42 gallons in a barrel, and each gallon contains on averages 34,800 (kilo) calories (gasoline has less, asphalt has more). How many (kilo) calories does this equate to? (Answer: 36,540,000)

If we had food equivalent to this many calories, how many people could be fed with this many calories, assuming people, on average, eat 2,000 (kilo) calories a day? (Answer: 50)

What does this relationship say about the likelihood that we will be able to grow enough crops to turn into biofuels to meet our current petroleum usage?

2. If oil rationing were imposed, and the amount of gasoline you could purchase were limited to half of what you are currently using today, how would that change your driving / commuting?

3. If you were the president of the United States, and needed to impose rationing, in what order would you rank the following in priority.

a. Military
b. Farmers
c. Chemical feedstock use
d. Transportation of food
e. Mining of coal and uranium
f. Transportation of non-food items
g. Railroad and bus fuel
h. Air travel
i. Emergency services (ambulance, police)
j. People with jobs
k. People without jobs (retired, students)

4. There have been numerous governmental studies about peak oil. It is clear from public comments that Alan Greenspan is a believer in peak oil, as is former President Clinton. President Bush and Dick Cheney worked in the oil industry before their election.

Do you think that President George W. Bush is aware of peak oil? If so, how do you think it has affected Bush's presidency? How long do you think that they have been aware of peak oil? Do you think it has had any impact on their policies? Why haven't they said anything about peak oil?
http://search.doe.gov/search?output=xml_no_dtd&sort=date%3AD%3AL%3Ad1&ie...
http://www.peakoil.net/Articles2005/Westervelt_EnergyTrends__TN.pdf
http://www.straight.com/article/clinton-raises-alarm-about-oil-depletion...
http://online.wsj.com/article/SB119763743685729349.html (Greenspan)
http://www.netl.doe.gov/publications/others/pdf/Oil_Peaking_NETL.pdf

5. One of the reasons that there has been little said about peak oil is that economists keep saying that peak should not be no problem; in a free market economy, substitutes will be found.

Name three substitutes for food.

How does your answer to the substitutes for food question suggest that economic theory may be incorrect in with respect to replacements for liquid fuels?

6. If biofuels, at least at this point, seem to have as many environmental problems as oil, would it make sense to concentrate our efforts on enhanced oil recovery? How about coal to liquid?

For further reading – Relates to both Part 1 and Part 2:

A number of links are given in the reading material. In addition, some websites that may be of interest are

www.TheOilDrum.com - Discussion about energy and our future, including peak oil. Many articles written for the site, plus news items related to energy, and discussion about the various items. I write as "Gail the Actuary" for this site. A list of my articles can be found at http://www.theoildrum.com/user/Gail+the+Actuary/stories

www.EnergyBulletin.net - Peak oil related news items. No discussion.

Association for the Study of Peak Oil and Gas - USA http://www.aspo-usa.com/ Has a good weekly newsletter, and an annual conference.

Educational website about oil and gas, how it is formed, and production ins and outs http://www.ukooa.co.uk/education/storyofoil/index.cfm

"Peaking of World Oil Production: Impacts, Mitigation, and Risk Management" by Robert Hirsch, Roger Bezdek, and Robert Wendling. Analysis of peak oil and mitigation options, prepared for the US Department of Energy in early 2005. http://www.netl.doe.gov/publications/others/pdf/Oil_Peaking_NETL.pdf

Rear Admiral Hyman Rickover's 1957 speech talking about the expected future decline in fossil fuel resources and the need to tell the younger generation. http://www.theoildrum.com/node/2724

Myths of Biofuels - Talk by David Fridley - Free video for download - http://www.sfbayoil.org/sfoa/myths/index.html

Peak Oil and the Fate of Humanity – Series of downloadable presentations – Canadian http://www.peakoilandhumanity.com/chapter_choice.htm

Global Oil Supply: Barriers to Investment - Presentation by David Fyfe of International Energy Agency http://www.clingendael.nl/ciep/events/20080214/20080214_ciep_fyfe.pdf