Why Ethanol Can't "Solve" the Fuels Problem

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I was recently informed by a fuel ethanol enthusiast that the EROEI (Energy Returned On Energy Invested) of ethanol from agricultural products had been greatly increased from 1.38 to 2 He was incredulous, to say the least, when I told him that was not nearly high enough for ethanol to serve as a primary energy source that could keep business-as-usual going after the oil peak. Actually, he accused me of being a supporter of the oil industry, anti-farmer, and a despoiler of the environment, and would not listen (shouted me down in fact) when I tried to explain the realities to him. So, to restore my equilibrium, I am now imposing on you what he refused to listen to.

I show below that ethanol cannot replace the fuel shortages that peak oil will bring, at least not without a very large increase in the total amount of energy we produce. This will be a problem, to say the least, when the energy available from oil and natural gas is declining.

The deficiency of ethanol is its low energy profit ratio. To make the notion of energy profit ratio a little more precise, consider the following definition of EROEI, or Energy Returned On Energy Invested. (I like to pronounce it ee-ro-ee.)

The EROIE of a primary energy technology is the ratio of Energy Returned to Energy invested.

Energy Returned is the amount of energy that an energy producing technology produces for all uses, including further energy production. Energy Invested is the amount of energy already available for use by society that must be used by the energy producing technology to produce the Energy Returned.

Note that the Energy Invested is not the same as the sum of the energy inputs to the process of operating the energy producing technology. Energy Invested is only that part of the input energy that is already in a form in which it is ready for consumption in society--gasoline, ethanol, diesel fuel, coal ready to burn, etc, but not crude oil, sunlight, wind energy, etc.

Also note that an EOREI = 1 is the break-even EROEI. Unless a primary energy technology has an EROEI greater than 1, it is obviously useless. A fuels technology might be useful in special circumstances at an EROEI less than one, but it would take more energy from some other source to produce the fuel than the fuel delivered in use.

Let's take the EROEI of the energy derived from the oil industry in the US as a comparison. Robert Kaufman, http://www.bu.edu/cees/people/faculty/kaufmann/index.html calculates it as about 10 for extraction in the US in 2000. Because the US is a very mature oil province, this is probably low for the world as a whole. The value 10 is read from image 33 in his talk at Lawrence Livermore Labs, "Oil and the American Way of Life: Don't Ask Don't Tell", http://vmsstreamer1.fnal.gov/VMS_Site_03/Lectures/Colloquium/050601Kaufmann/index.htm (An outstanding talk, by the way.)

So, lets compare two transportation fuel producing technologies, ethanol with an EROEI=2, and diesel, gasoline, JP4, etc. with an EREOI=10. The relevant question is how much energy does society have to produce in total to get the same amount of energy for transportation use from each technology?

Petroleum's EROEI = 10 means that for each ten energy-units of oil-derived fuels you produce you get to keep 9 energy units for uses other than fuel production, since you have to put aside 1 energy-unit to produce the next ten units.

Ethanol's EROEI = 2 means that for every 2 energy units of ethanol you produce, you get to keep only 1 energy-unit for uses other than fuel production since you have to put 1 energy-unit aside to produce the next 2 energy-units. Therefore, to produce 9 energy-units of ethanol fuel for uses other than fuel production you have to produce 9 additional energy units for use in fuel production, for a total of 18 energy units of total energy production for fuels.

To restate in a general form that does not imply the invested energy is necessarily from the energy technology it's invested in: For 9 fuel energy units for uses other than fuel production you have to produce a total of 10 energy units if the 9 fuel energy units are from oil, and 18 energy units if the 9 fuel energy units are from ethanol. In other words ethanol fuels require a 1.8 times the total energy production for a given fuel-energy for uses other than fuel production compared to petroleum fuels.

Therefore, to replace a given amount, FE, of oil derived fuel energy by ethanol fuel energy, thus keeping the available fuel energy constant would require *increasing* total energy production devoted to fuels by ((18/9) - (10/9)) x FE = 0.89 x FE.

Consider a policy of keeping the energy available from oil + ethanol fuels for uses other than fuel production constant by replacing the fuels derived from oil as oil production declines at 2% per year after the peak of oil production. This constant fuel energy replacement policy would require the total energy for fuels produced by society to rise by 0.89 x 2%= 1.78% per year--a doubling time of 39 years.

This additional energy would have to come from renewables, coal, nuclear, perhaps even still more ethanol. It is a gigantic amount. World oil production will decline at a fairly constant rate of 0.5 billion barrels per year for 40 years (ASPO). This is approximately 100 gigawatts per year per year. If we assume that 2/3 of this is used as fuel, we would require an increase of total energy production of 0.89 * 2/3 * 100 = 59 gigawatts per year per year just to keep the worlds fuel energy from oil + ethanol flat. This is the energy production of, for example, 59 big nukes or big coal generating plants. That's equal to the additional energy produced by 59 *new* big nukes or new coal plants each year--just to keep the fuel energy from oil + ethanol constant.

To *increase* the transportation fuel energy from oil + ethanol by E% per year by ethanol production would require an *additional* 2 x E% increase in the total-energy production devoted to fuels. So the total increase per year in total energy production for fuels would be 1.78% per year to offset the 2% decline of oil production plus another 2 x E % per year for the E% increase.

In other words, after the oil peak, a 1% per year increase in oil + ethanol transportation energy would require 3.78% increase per year in total energy production for fuels--a doubling time of 18 years--a 2% per year increase in oil + ethanol transportation fuel energy would require a 5.78 % increase per year in total energy production for fuels--a doubling time of 12 years.

Good-bye business-as-usual. Or good-bye biosphere. Or both.