

## **A Brief Comparison between the New Pimentel/Patzek Study and Other Studies**

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July 19, 2005

The recent article by Pimentel/Patzek published in *Natural Resources Research* concludes that:

1. Corn ethanol requires 29% more fossil energy to produce than it contains
2. Herbaceous cellulosic ethanol requires 50% more fossil energy
3. Woody cellulosic ethanol requires 57% more fossil energy
4. Soybean-based biodiesel requires 27% more fossil energy to produce than biodiesel contains
5. and sunflower-based biodiesel requires 118% more fossil energy

In contrast, many other studies, including Argonne's study, conclude that corn ethanol, cellulosic ethanol, and biodiesel require less fossil energy to produce than each of the fuels contains.

In particular, Argonne's study concludes:

1. Corn ethanol requires 26% less fossil energy
2. Cellulosic ethanol requires 90% less fossil energy

In addition, a 1998 NREL study sponsored by DOE and USDA concludes that soybean-based biodiesel requires 69% less fossil energy to produce than biodiesel contains.

Argonne's quick review of Pimentel/Patzek shows that they made pessimistic assumptions for key parameters without detailed elaboration and double-counted certain energy costs. Below is a summary of some of the key differences between Pimentel/Patzek and Argonne and others on the other hand.

### **A. Corn Ethanol:**

#### ***1. Corn farming energy use:***

- a) Pimentel/Patzek conclude that corn farming consumes 94,504 Btu of fossil energy per bushel of corn, 18.2% of which is from farm labor and farming machinery (77,304 Btu/bushel, if energy embedded in farm labor and farming machinery is excluded)

- b) On the other hand, a 2002 USDA analysis conclude that corn farming consumes 57,480 Btu of fossil energy per bushel (not including energy embedded in farm labor and farming machinery)
- c) Pimentel/Patzek overestimate corn farming energy use (not including energy embedded in farm labor and farming machinery) by 34%
- d) Furthermore, it appears that Pimentel/Patzek overestimate the 18.2% of corn farming energy that is embedded in farm labor and farming machinery

**2. *Ethanol production energy use:***

- a) Pimentel/Patzek conclude that ethanol production at ethanol plants consumes 56,440 Btu of fossil energy per gallon of ethanol (56,000 Btu/gal, if energy embedded in construction materials for ethanol plants is excluded)
- b) On the other hand, a 2001 survey for USDA on ethanol plant energy use shows an energy use of 48,770 Btu/gal. of ethanol for dry mill ethanol plants and 54,240 Btu/gal. for wet mill ethanol plants, with an average of 53,010 Btu/gal.
- c) Dry mill plants built recently (all new ethanol plants that have come online recently in the U.S. are dry mill plants), may have an energy use of 42,530 Btu/gal.
- d) Pimentel/Patzek overestimate ethanol plant energy use by up to 30%
- e) Pimentel/Patzek assume an ethanol yield of 2.5 gallons per bushel of corn. Ethanol plants are reported to have a yield of above 2.6 gallons/bushel now and newly built plants could approach a yield of 2.8 gallons/bushel.

**3. *Animal feed co-products from corn ethanol plants:***

- a) Pimentel/Patzek's 29% increase in fossil energy by corn ethanol does not give any credit to animal feeds
- b) Pimentel/Patzek acknowledge that animal feeds could have an energy credit of 6,680 Btu per gallon of ethanol produced, but they fail to consider this in their conclusion
- c) Argonne's conservative estimation shows that animal feeds and other coproducts from ethanol plants may have an energy credit of 12,030 Btu per gallon of ethanol produced. Pimentel/Patzek underestimate ethanol's coproduct energy credit by 45%

**B. Cellulosic Ethanol:**

The key difference between Pimentel/Patzek and other studies lies in the energy source for steam and electricity generation in cellulosic ethanol plants.

More than 25% of the mass in cellulosic biomass is lignin, which may not be fermented into ethanol. In cellulosic ethanol plant designs under consideration by DOE and others, the lignin portion of biomass feedstock is to be burned for steam and electricity generation to meet the need of cellulosic ethanol plant operation. In fact, cellulosic ethanol plants will generate an excess amount of electricity that can be exported to the electric grid.

Contrary to the cellulosic ethanol plant designs under consideration, Pimentel/Patzek assume that fossil fuels are to be burned for steam and electricity generation in cellulosic ethanol plants.

If Pimentel/Patzek had assumed use of lignin for steam and electricity generation in cellulosic ethanol plants, they would have estimated positive energy balance values for cellulosic ethanol that are similar to those estimated by Argonne and others.

### **C. Biodiesel:**

In 1998, DOE and USDA funded a study at NREL to evaluate energy and environmental effects of soybean-based biodiesel. That study concludes that production of biodiesel consumes 69% less fossil energy than it contains. Argonne has not evaluated biodiesel.

### **D. Costs Estimates by Pimentel/Patzek:**

Pimentel/Patzek present cost estimates for corn, soybeans, switchgrass, woody biomass, soybeans, sunflowers, ethanol, and biodiesel. Argonne has not conducted cost estimates. Argonne's review of Pimentel/Patzek shows that their production cost estimates are higher than market prices, implying that farmers, ethanol producers, and biodiesel producers are in money-losing business, even taking into account subsidies farmers and producers receive.

Argonne also finds that Pimentel/Patzek's cost estimates for cellulosic ethanol contain calculation errors. In their estimation, Pimentel/Patzek use a cost of \$100 per tonne for cellulosic biomass feedstock, instead of their own estimate of \$23 per tonne.

### **E. General Issues:**

1. Though a self evaluation of ethanol's energy balance is easy to understand, it does not provide results showing the energy benefit of ethanol in replacing gasoline; meaningful analyses for energy policy debates should be conducted to compare ethanol and gasoline to assess the relative merit of ethanol. That is, it is important to put a given energy product into a broad perspective with other energy products, both of which provide same functions for society.
2. In any event, decisions on pursuing certain energy products by society have not been made on the basis of their energy balance values. For example, even though electricity generation has a huge negative energy balance value (2.3 unit of fossil energy input for a unit of electric energy output in the US), society never

questions the practice of electricity generation. The quality of energy products is a critical factor in making choice of energy products.

3. In conclusion, energy balance calculations for individual energy products in isolation could be arbitrary; their results may have little meaning without putting them into context and could be misleading.