

**BAE 103**  
**Energy in Biological Systems**

**Problem Set No. 6**  
**Concepts of Energy and Thermal Efficiency in Crop Production**  
**Due Date: Monday, February 12**

- 6.1 Using the attached tables from Shapouri et al. (1995), estimate the energy requirements (Btu/gal) for producing ethanol from corn. Carefully consider energy expended in the production and processing of the crop. Ignore the efficiency of the corn plant when it comes to converting sun light to fixed carbon, and also ignore irrigation (in Kentucky we get 40 + inches of precipitation a year).
- 6.2 What is the overall conversion energy efficiency for producing ethanol from corn?
- 6.3 Can we substitute biomass for the feedstock, and if so what will happen to the conversion efficiency? You might want to check the National Renewable Energy Laboratory (NREL-DOE) web site ([www.nrel.gov](http://www.nrel.gov)).
- 6.4 What opportunities exist for improving the efficiency of ethanol production processes?

Shapouri, H., J.A. Duffield and M.S. Graboski. 2005. Estimating the Net Energy Balance of Corn Ethanol. United States Department of Agriculture Agricultural Economic Report Number 721. July. [http://www.ethanol-gec.org/corn\\_eth.htm](http://www.ethanol-gec.org/corn_eth.htm).

**Table 1--Energy input assumptions of recent corn-ethanol studies**

<b>Study/year</b>	<b>Corn yield</b>	<b>Nitrogen fertilizer application rate</b>	<b>Inputs for nitrogen fertilizer</b>	<b>Corn ethanol conversion rate</b>	<b>Ethanol conversion process</b>	<b>Total<sup>1</sup> energy use</b>	<b>Coproducts<sup>1</sup> energy credits</b>	<b>Net<sup>1</sup> energy value</b>
	<b>bu/acre</b>	<b>lb/acre</b>	<b>Btu/lb</b>	<b>gal/bu</b>	<b>Btu/gal</b>	<b>Btu/gal</b>	<b>Btu/gal</b>	<b>Btu/gal</b>
<b>Pimentel (1991)</b>	110	136.0	37,551	2.50	73,687 (LHV)	131,017	21,500	-33,517
<b>Keeney and DeLuca (1992)</b>	119	135.0	37,958	2.56	48,434 (LHV)	91,127	8,072	-8,431
<b>Marland and Turhollow (1991)</b>	119	127.0	31,135	2.50	40,105 (HHV)	73,934	8,127	18,324
<b>Morris and Ahmed (1992)</b>	120	127.0	31,000	2.55	46,297 (LHV)	75,297	24,950	25,653
<b>Ho (1989)</b>	90	NR	NR	NR	57,000 (LHV)	90,000	10,000	-4,000
<b>This study (1995)</b>	122	124.5	22,159	2.53	53,277 (HHV)	82,824	15,056	16,193
<b>Average</b>	113	129.9	31,961	NA	NA	NA	NA	2,373

Notes:

NR: Not reported

NA: Average values are not appropriate in this case because studies using high heat values cannot be directly compared to studies using low heat values. This study and the Marland and Turhollow study used high heat values and the others used low heat values.

LHV: Low heat value--76,000 Btu per gallon of ethanol.

HHV: High heat value--83,961 Btu per gallon of ethanol.

<sup>1</sup>The midpoint is used when studies report a range of values.

**Table 3--Energy requirements of farm inputs for 9 States and 9-State weighted average**

<b>Item</b>	<b>IL</b>	<b>IN</b>	<b>IA</b>	<b>MN</b>	<b>NE</b>	<b>OH</b>	<b>MI</b>	<b>SD</b>	<b>WI</b>	<b>Weighted Average</b>
	<b>Btu/bu</b>									
<b>Seed</b>	170	189	141	148	271	162	217	290	211	186
	<b>Fertilizer</b>									
<b>Nitrogen</b>	26,995	26,356	20,322	14,671	24,228	22,382	25,719	19,163	20,828	22,631
<b>Potash</b>	757	660	452	576	218	609	529	411	693	539
<b>Phosphate</b>	2,936	3,743	1,580	2,011	85	3,142	2,390	588	1,635	1,992
<b>Lime</b>	2,331	1,757	1,335	208	0	721	3,839	0	654	1,232
	<b>Energy</b>									
<b>Diesel</b>	4,793	5,843	4,686	5,427	18,881	5,131	8,620	10,650	9,184	7,713
<b>Gasoline</b>	3,439	3,710	3,281	3,019	4,301	2,723	3,530	4,846	2,802	3,493
<b>LPG</b>	1,515	1,619	3,292	3,287	2,510	2,780	2,654	5,705	1,578	2,575
<b>Electricity</b>	1,207	2,927	511	2,907	9,270	1,011	1,209	13,627	7,537	3,432
<b>Natural Gas</b>	479	85	0	0	12,632	85	464	0	90	2,058
<b>Custom Work</b>	1,480	1,213	1,289	1,131	1,106	981	927	1,271	3,619	1,371
<b>Chemicals</b>	5,635	7,176	5,730	5,380	5,448	5,433	5,936	5,723	5,784	5,766
<b>Custom Drying</b>	902	1,153	1,463	1,321	1,153	764	1,654	39	964	1,134
<b>Input Hauling</b>	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062
	<b>Total Energy</b>									
<b>Total Energy</b>	53,702	57,493	45,144	41,148	81,165	46,986	58,750	63,375	56,641	55,164