

6-2010

# 2008 Energy Balance for the Corn-Ethanol Industry

H. Shapouri

*United States Department of Agriculture*

Paul W. Gallagher

*Iowa State University, paulg@iastate.edu*

Ward Nefstead

*University of Minnesota*

Rosalie Schwartz

*University of Nebraska - Lincoln*

Stacey Noe

*Iowa State University*

*See next page for additional authors*

Follow this and additional works at: [http://lib.dr.iastate.edu/econ\\_reportspapers](http://lib.dr.iastate.edu/econ_reportspapers)



Part of the [Agricultural and Resource Economics Commons](#), [Agricultural Economics Commons](#), and the [Oil, Gas, and Energy Commons](#)

---

## Recommended Citation

Shapouri, H.; Gallagher, Paul W.; Nefstead, Ward; Schwartz, Rosalie; Noe, Stacey; and Conway, Roger, "2008 Energy Balance for the Corn-Ethanol Industry" (2010). *Economics Technical Reports and White Papers*. 20.

[http://lib.dr.iastate.edu/econ\\_reportspapers/20](http://lib.dr.iastate.edu/econ_reportspapers/20)

This Report is brought to you for free and open access by the Economics at Iowa State University Digital Repository. It has been accepted for inclusion in Economics Technical Reports and White Papers by an authorized administrator of Iowa State University Digital Repository. For more information, please contact [digirep@iastate.edu](mailto:digirep@iastate.edu).

---

**Authors**

H. Shapouri, Paul W. Gallagher, Ward Nefstead, Rosalie Schwartz, Stacey Noe, and Roger Conway





United States  
Department of Agriculture

Office of  
the Chief Economist

Office of Energy Policy  
and New Uses

Agricultural  
Economic  
Report  
Number 846

June 2010

# 2008 Energy Balance for the Corn-Ethanol Industry





## 2008 Energy Balance for the Corn-Ethanol Industry

### Abstract

The Agricultural Resource Management Survey of corn growers for the year 2005 and the 2008 survey of dry mill ethanol plants are used to estimate the net energy balance of corn ethanol. This report measures all conventional fossil fuel energy used in the production of 1 gallon of corn ethanol. The ratio is about 2.3 BTU of ethanol for 1 BTU of energy inputs, when a portion of total energy input is allocated to byproduct and fossil fuel is used for processing energy. The ratio is somewhat higher for some firms that are partially substituting biomass energy in processing energy.

### Authors

H. Shapouri, Agricultural Economist, Office of Energy Policy and New Uses, Office of the Chief Economist, USDA

Paul W. Gallagher, Associate Professor, Economics Department, Iowa State University

Ward Nefstead, Associate Professor, Applied Economics Department, University of Minnesota

Rosalie Schwartz, Program and Recruitment Director, Agricultural Economics Department, University of Nebraska (Lincoln)

Stacey Noe, Program Coordinator, Agricultural Entrepreneurship Initiative, Iowa State University

Roger Conway, Former Director, Office of Energy Policy and New Uses, Office of the Chief Economist, USDA

## Contents

|  |    |
|--|----|
| Energy Consumption by Corn Producers ..... | 3  |
| 2008 Ethanol Producer Survey .....         | 4  |
| Conclusion .....                           | 6  |
| References.....                            | 7  |
| Tables.....                                | 8  |
| Appendix.....                              | 10 |

## 2008 Energy Balance for the Corn-Ethanol Industry

The ratio of energy in a gallon of ethanol relative to the external fossil energy required to produce the corn and process and ship the ethanol is an important measure of sustainability of the corn-ethanol industry (Pimentel). Recent updates of energy balance calculations have verified enhanced industry performance and identified methods that could yield further improvement (Shapouri, et al; Gallagher and Shapouri). The 2008 updates presented in this report record the effects of current practices used by corn producers and ethanol processors. Current fertilizer practices are taken into account using recent data collected by the USDA. The current standards of electrical and processing energy use in the corn-ethanol industry are taken from a recent survey of ethanol producers.

### Energy Consumption by Corn Producers

Corn producers use most energy products (gasoline, diesel, natural gas, liquid petroleum gas, and electricity) directly in planting, harvesting, and drying their crop. There is also considerable energy embodied in the commercial fertilizers applied to enhance plant growth.

Table 1 and Table 2 provide a summary of new USDA data on energy components and totals. The trends for components and total energy are summarized with data at 5-year intervals over the last 25 years. Agricultural Resource Management Survey (ARMS) is the source of data used to estimate total direct and indirect energy inputs used in production of corn. Energy inputs used in production of corn are derived from the responses of 1,814 corn farmers in 19 States to a survey on corn production practices and costs as part of the 2005 ARMS. The target population for the corn survey was farmers who planted corn with the intention of harvesting corn for grain. The USDA National Agricultural Statistics Service (NASS) and the Economic Research Service collect production and cost data once every 5-8 years for each commodity on a rotating basis in the ARMS. The State data from the survey are also weighted to represent all U.S. corn acreage (see Appendix Tables A1 and A2).

Importantly, the largest energy components for corn production are nitrogen and direct energy for fuel and electricity. Nitrogen use measured on a per bushel basis has declined by about 20 percent since the mid-90s. Similarly, all direct energy components have declined by about 50 percent since the mid-90s. Together, the nitrogen and direct energy reductions result in a 30 percent decline in the energy required to produce a bushel of corn. Overall, 65,285 BTU/bu (British thermal unit per bushel) were required for corn production in 1996, whereas 41,029 BTU/bu were required in 2005.

Lastly, it is the energy in corn that is actually used for ethanol production, expressed per gallon of ethanol, which is important for an evaluation of ethanol production. Ethanol yields have increased by about 10 percent in the last 20 years, so proportionately less corn is required—14,866 BTU/gal in 2005 (see Table 2). Further, only the starch fraction of the corn plant (66 percent) is used for ethanol production.<sup>1</sup> So the net corn energy used for ethanol production is 9,811 BTU/gal in Table 2. The corn energy required for ethanol production is shown in the bottom two rows of Table 2. The corn energy input to ethanol production declined to 9,811 BTU/gal from 16,346 over the most recent 10-year period.

---

<sup>1</sup> To see this, notice that a bushel of corn weighs 56 lbs, and yields 17.5 lbs of distilled grains (the protein, fiber and oil components of the corn plant). The starch component is 38.5 lbs = 56-17.5, so the starch fraction of the corn plant is  $38.5/56 = .688$ , that is, the starch (ethanol-making) component is about 2/3 of the corn. In many cases the 2/3 allocation rule is very conservative – in some plants, the corn oil is removed from the distilled grain and used for biodiesel processing (a contribution to energy output).

## 2008 Ethanol Producer Survey

A short survey of ethanol producers in Iowa, Minnesota, Nebraska, and eastern South Dakota was conducted in the fall of 2008 and the winter of 2009. This survey was conducted by the students from the National Agricultural Marketing Association Chapters of Iowa, Minnesota, and Nebraska. The survey was designed by staff at USDA and Iowa State University. The survey included questions about the extent of thermal and electric energy use, the type of energy used, the type of ethanol production process used, and processing yield (the Survey Questionnaire is given in the Appendix). Sixteen plants responded to the survey, which is marginally enough to discuss the results.<sup>2</sup>

We report only survey summary measures, to accommodate the confidentiality of individual firms. Some of the data are summarized with means, group means, and standard deviations. Other results are more conveniently expressed using regressions.

First, the ethanol processing yield of survey respondents has a mean of 2.76 gal/bu of corn. Further, the standard deviation is 0.07 gal/bu. Hence, processing yields continue a slow but steady improvement—the 2009 average yield is 3.7 percent higher than the average for the 2002 USDA survey, and 4.7 percent higher than the 1998 survey.

Second, the survey responses on external thermal energy showed that several firms were using between 10 percent and 50 percent biomass power. Hence, we summarize the thermal energy results using the following regression:

$$btu_i = 22953 ddm_i + 29421 ddd_i + 28313 dw_i - 26920 fb_i$$

(23.8)            (29.4)            (28.3)            (6.1)

Adj. R<sup>2</sup> = .98      Dep. Var. Mean = 24840      rmse = 2973      CV = 12.0%

Numbers in parentheses are t-values

Where:

$btu_i$  = thermal energy used, in BTU/gal

$ddm_i$  = 1 for dry mills selling modified distiller's grains (dg), and 0 otherwise

$ddd_i$  = 1 for dry mills selling dry dg, and 0 otherwise

$dw_i$  = 1 for wet mills, and 0 otherwise

$fb_i$  = the fraction of thermal energy from biomass, 0/1

$i$  indicates data for firm  $i$

Twenty-two observations were used for the process energy regression, because some firms that produce dry and modified dg reported energy use for both configurations.

The regression coefficient for each dummy variable indicates the average energy use of a specific processing configuration when the biomass fraction is zero. Also, a 50-percent biomass fraction would reduce the energy use of a dry mill with dry instead of wet dg by about half—a very sensible result.

---

<sup>2</sup> The standard deviation (SD) of the sample mean ( $\sigma_{\bar{x}}$ ) is related to the population S.D. ( $\sigma$ ) and sample size ( $n$ ) as follows:  $\sigma_{\bar{x}} = \sigma / \sqrt{n}$ . With the conventional sample,  $n=30$ ,  $\sigma_{\bar{x}} = 0.18\sigma$ . A sample with  $n = 16$  is almost as accurate:  $\sigma_{\bar{x}} = 0.25\sigma$ . For the farm sample,  $n = 1,814$ , sampling error of the mean is virtually eliminated, i.e.,  $\sigma_{\bar{x}} = 0.023\sigma$ .

The thermal energy regression estimate also can be used to infer the heat increment associated with producing dry dg versus wet dg, even though results are only estimated for modified and dry dg. First, the additional thermal energy required to process dry dg instead of modified dg is the difference between the coefficients for ddd and ddm: 6,468 BTU/gal. Second, modified dg consists of a 50:50 mix of wet and dry dg. So the heat required to dry dg is 6,485/0.5 = 12,936 BTU/gal, which amounts to 44 percent of the energy required for ethanol production with dry dg with typical moisture standards.

For comparison, the USDA process model of a dry mill, the USDA-Agricultural Research Service Eastern Regional Research Center “corn dry mill process and cost model” (Kwiatkowski, et al.), suggests a similar but slightly higher estimate. They calculate that 51 percent of the thermal energy used in an ethanol plant is attributable to producing dry dg with 10 percent moisture content. In subsequent calculations of the byproduct credit in corn-energy balance, we examine the survey estimate and the process model estimate.

Third, the survey responses also suggest that electricity use is related to the fraction of dg that is dried:

$$\text{elec}_i = 0.60214 + 0.15476 \text{fd}_i$$

(9.1)      (1.5)

Adj. R<sup>2</sup> = .095      Dep. Var. Mean = 0.6858      rmse = 0.1311      CV = 19.2%

Where

elec<sub>i</sub> = electricity use, in kWhr/gal

fd<sub>i</sub> = fraction of dg that is dried, 0/1

## Energy Balance Estimate

Table 3 contains an update for the energy balance results given in Gallagher and Shapouri.<sup>3</sup> The revision includes latest data for corn energy use from the USDA survey, for ethanol conversion from the National Agribusiness Marketing Association (NAMA) survey, and transportation from the GREET model (version 1.8). A dry mill with dry distiller’s grains is the reference case of Table 3. The columns report energy use with conventional fossil fuel power (Columns 1 and 2) and with biomass power (Columns 3 and 4). Finally, the byproduct credit is the heat used to prepare dry dg—we compare the regression estimate using the NAMA data (Column 2) and the engineering model estimate (Column 1).

For the conventionally powered dry mill, shown in Columns 1 and 2, the ethanol conversion estimate of heat content, 40,019 BTU/gal, is the sum of electricity and thermal energy from the NAMA regression estimates, appropriately configured. Additionally, survey reported numbers are all adjusted to an energy input basis. The corn production estimate is also the same, at 9,811 BTU/gal from the 2005 USDA data given in Table 2. The byproduct credit in Column 1 of 20,409 BTU/gal is based on the ASPEN model. But the Column 2 estimate of byproduct credit is inferred from the regression estimate. The various components of energy use are compared to the heat content of ethanol (76,300 BTU/gal). Together, the recent energy use estimates show that the ratio of energy in ethanol to the external energy used to produce ethanol is about 1.4, even without allowing for the processing component of the byproduct credit. After fully allowing for heat used to produce byproducts, the energy ratio is between 1.9 and 2.3.

---

<sup>3</sup> Our analysis updates the energy balance picture for a representative firm, using methods developed previously. At the market level, we assume that the representative firm is not part of an industry expansion that is large enough to displace land from previous uses.



Biomass power reduces the external fossil energy needed to produce ethanol. In the case of corn stover, some of the fossil energy used to produce corn-biomass is recovered. Energy required for stover harvest and fertilizer replacement is taken into account in Column 3. In a typical dry mill, biomass power would replace natural gas, but market purchases of electricity would likely continue. At the upper range of survey responses shown in Column 3, external thermal energy reduces by about one-half, to 15,961 (BTU = 29421-26920 \* 0.5) BTU/gal on an output basis, and external energy for electricity would remain at 8,720 BTU/gal. Under these circumstances, the energy balance ratio increases to 2.8, even using the lower byproduct credit from the regression results. Similar calculations that used a short rotation woody crop (willow) instead of stover yielded similar energy balance estimates.

In Column 4, complete replacement of external processing energy for thermal energy and electricity extends beyond the range of survey responses. But the possibilities are interesting. Corn residues, which contain about the same energy (BTUs) as the corn, are presently discarded. But residues represent enough energy to replace all of the process heat and electricity needed for ethanol, and combined heat and power plants are capable of producing the required process heat and electricity. Hence, the energy balance could increase to about 25.7 when half of the renewable energy produced in corn production (the residue) is no longer discarded.

## Conclusion

A dry grind ethanol plant that produces and sells dry distiller's grains and uses conventional fossil fuel power for thermal energy and electricity produces nearly two times more energy in the form of ethanol delivered to customers than it uses for corn, processing, and transportation. The ratio is about 2.3 BTU of ethanol for 1 BTU of energy in inputs, when a more generous means of removing byproduct energy is employed.

Some dry mills are already using up to 50 percent biomass power. The energy output for these plants is near 2.8 times energy inputs, even using the conservative byproduct allowance. As processors master the logistics of handling bulky biomass, the energy balance ratio could reach 26 BTUs of ethanol per BTU of inputs used.

Overall then, ethanol has made the transition from an energy sink, to a moderate net energy gain in the 1990s, to a substantial net energy gain in the present. And there are still prospects for improvement.

## References

Economic Research Service Staff, "Briefing Room: Agricultural Resource Management Survey (ARMS)," <http://www.ers.usda.gov/Briefing/ARMS/>, U.S. Department of Agriculture, accessed 10/7/2009.

Gallagher, P., M. Dikeman, J. Fritz, E. Wailes, W. Gauthier, and H. Shapouri, Biomass from Crop Residues: Some Cost and Supply Estimates, Agricultural Economic Report Number 819, U.S. Dept of Agriculture, January 2003.

Gallagher, P. and H. Shapouri, "Improving Sustainability of the Corn-Ethanol Industry," in Biofuels, W. Soetaert and E. Vandamme, eds, John Wiley, West Sussex (UK), December 2008.

Kwiatkowski, Jason, McAloon, Andrew, Taylor, Frank, Johnston, David; "Modeling the Process and Costs of Fuel Ethanol by the Dry-Grind Process, Industrial Crops and Products 23(2006)," pp. 288-296.

Pimentel, David, "Ethanol Fuels: Energy Security, Economics, and the Environment," Journal of Agricultural and Environmental Ethics 4(1991):1-13

Shapouri, Hosein, James A. Duffield, and Michael Wang, "The Energy Balance of Corn Ethanol: An Update," U.S. Department of Agriculture, Office of the Chief Economist, Office of Energy Policy and New Uses, Report No. 813(July 2002).

Shapouri, H., and P. Gallagher, USDA's 2002 Ethanol Cost-of-Production Survey, U.S. Department of Agriculture, Office of Energy Policy and New Uses, Agricultural Economic Report No. 841(July 2005).

## Tables

**Table 1. Energy-related inputs used to grow corn, nine-State weighted average**

|   |               | <b>1991</b> | <b>1996</b> | <b>2001</b> | <b>2005</b> |
|---|---------------|-------------|-------------|-------------|-------------|
| Seed <sup>c</sup>   | Pounds/acre   | 19.62       | 19.61       | 22.11       | 18.29       |
| Fertilizer:   |               |             |             |             |             |
| Nitrogen  | Pounds/acre   | 124.5       | 129.38      | 133.52      | 133.39      |
| Potash  | Pounds/acre   | 52.77       | 59.25       | 88.52       | 61.26       |
| Phosphate   | Pounds/acre   | 58.17       | 48.16       | 56.81       | 54.36       |
| Lime <sup>b</sup>   | Pounds/acre   | 242.18      | 382.18      | 350         | 554.36      |
| Energy Input:   |               |             |             |             |             |
| Diesel  | Gallons/acre  | 6.85        | 8.6         | 6.85        | 5.81        |
| Gasoline  | Gallons/acre  | 3.4         | 3.09        | 1.7         | 1.92        |
| LPG   | Gallons/acre  | 3.42        | 6.36        | 3.42        | 3.2         |
| Natural gas   | Cubic ft/acre | 246         | 200         | 245.97      | 208.9       |
| Electricity   | kWh/acre      | 33.59       | 77.13       | 33.59       | 20.41       |
| Custom work   | Dollars/acre  | 6.68        | 15.07       | 10.12       | 8.45        |
| Chemicals   | Pounds/acre   | 3.99        | 3.49        | 2.66        | 2           |
| Custom drying   | Dollars/acre  | 1.79        |             | 0           | 2.09        |
| Purchased water   | Dollars/acre  |             |             | 0.18        | 0.08        |
| Yield, 3-year average bu/acre                                       |               | 121.9       | 125         | 139.34      | 159.7       |
| <sup>a</sup> Includes energy loss and transmission loss (LHV)       |               |             |             |             |             |
| <sup>b</sup> Lime use in 1996 is an average of 1991, 2001, and 2005 |               |             |             |             |             |
| <sup>c</sup> Seed conversions calculation shown below:              |               |             |             |             |             |
| seeds per acre  |               | 25,501      | 25,495      | 28,739      | 23,771      |
| pounds of seed/acre   |               | 19.62       | 19.61       | 22.11       | 18.29       |
| bu seed/bu corn   |               | 0.0029      | 0.0028      | 0.0028      | 0.002       |
| BTU/bu corn seed  |               | 166.94      | 182.91      | 141.14      | 83.89       |
| magnification factor  |               | 4.7         | 4.7         | 4.7         | 4.7         |
| BTU/bu corn, adjusted   |               | 784         | 859         | 663         | 394         |

**Table 2. Total energy requirements of farm inputs for nine-State average**

| <b>Energy Used</b>               |                     |  |             |             |             |             |
|----------------------------------|---------------------|--|-------------|-------------|-------------|-------------|
| Conversion factors: <sup>a</sup> |                     |  |             |             |             |             |
| Energy inputs to BTU             |                     |  |             |             |             |             |
|                                  |                     | <b>in BTU/bu corn:</b>                   | <b>1991</b> | <b>1996</b> | <b>2001</b> | <b>2005</b> |
| 394.26                           | BTU/pound           |  | 784         | 860         | 663         | 394         |
| 24,500                           | BTU/pound           |  | 25,023      | 25,358      | 23,477      | 20,464      |
| 3,000                            | BTU/pound           |  | 1,299       | 1,422       | 1,899       | 1,151       |
| 4,000                            | BTU/pound           |  | 1,909       | 1,541       | 1,631       | 1,362       |
| 558                              | BTU/pound           |  | 1,109       | 1,706       | 1,402       | 1,937       |
| 152,372                          | BTU/gallon          |  | 8,562       | 10,483      | 7,491       | 5,539       |
| 144,211                          | BTU/gallon          |  | 4,022       | 3,565       | 1,759       | 1,735       |
| 85,895                           | BTU/gallon          |  | 2,410       | 4,370       | 2,108       | 1,722       |
| 1,046                            | BTU/ft <sup>3</sup> |  | 2,111       | 1,674       | 1,846       | 1,368       |
| 9,365                            | BTU/kWh             |  | 2,581       | 5,779       | 2,258       | 1,197       |
| 154,150                          | BTU/pound           |  | 1,590       | 3,340       | 1,581       | 648         |
|                                  |                     |  | 1,030       | 0           | 0           | 642         |
|                                  |                     |  |             |             | 136         | 75          |
|                                  |                     | <b>Total:</b>                            | 58,095      | 65,285      | 49,819      | 41,029      |
|                                  |                     | <b>conversion to BTU/gallon ethanol:</b> |             |             |             |             |
|                                  |                     | BTU/bu                                   | 58,095      | 65,285      | 49,819      | 41,029      |
|                                  |                     | gal/bu                                   | 2.50        | 2.64        | 2.66        | 2.76        |
|                                  |                     | BTU/gal                                  | 23,238      | 24,767      | 18,715      | 14,866      |
|                                  |                     | starch fraction                          | 0.66        | 0.66        | 0.66        | 0.66        |
|                                  |                     | ethanol's share (BTU/gal)                | 15,337      | 16,346      | 12,352      | 9,811       |

**Abbreviations:** DDG: dry distillers grains; NG: natural gas; GREET: Greenhouse Gasses, Regulated Emissions, and Energy Use is Transportation Model; SRWC: short rotation woody crops, and LPG: liquefied petroleum gas.





**Table A1. Energy-related inputs used to grow corn in nine States and nine-State weighted average, 2005**

|                 |                      | IL        | IN      | IA        | MI      | MN        | NE        | OH      | SD      | WI      | Nine-State<br>Weighted<br>Avg. |
|-----------------|----------------------|-----------|---------|-----------|---------|-----------|-----------|---------|---------|---------|--------------------------------|
| Yield (2004-06) | <i>Bushels/acre</i>  | 161.8     | 159.61  | 173.34    | 141.4   | 164.61    | 157.34    | 153.09  | 116.77  | 142.55  | 159.70<br>0                    |
| Seed            | <i>Kernels/acre</i>  | 24,180    | 23,660  | 24,700    | 23,010  | 24,700    | 21,710    | 24,050  | 20,540  | 24,960  | 23,771                         |
| Fertilizer:     | <i>Pounds/acre</i>   |           |         |           |         |           |           |         |         |         |                                |
| Nitrogen        | <i>Pounds/acre</i>   | 147.51    | 146     | 128.87    | 119.43  | 129.18    | 130.42    | 161.37  | 107.5   | 101.7   | 133.39                         |
| Potash          | <i>Pounds/acre</i>   | 94.19     | 104.91  | 60.64     | 72.55   | 54.85     | 6.59      | 79.05   | 10.73   | 51.1    | 61.26                          |
| Phosphate       | <i>Pounds/acre</i>   | 64.68     | 67.84   | 46.87     | 40.19   | 52.66     | 60.06     | 59.31   | 36.48   | 34.8    | 54.36                          |
| Lime            | <i>Pounds/acre</i>   | 836       | 858     | 714       | 644     | 112       | 188       | 722     | 2       | 676     | 554.36                         |
| Energy Inputs:  |                      |           |         |           |         |           |           |         |         |         |                                |
| Diesel          | <i>Gallons/acre</i>  | 4.50      | 4.20    | 3.00      | 4.70    | 4.10      | 17.00     | 3.70    | 2.60    | 6.60    | 5.81                           |
| Gasoline        | <i>Gallons/acre</i>  | 1.80      | 2.50    | 1.70      | 2.70    | 2.10      | 1.70      | 2.20    | 1.60    | 2.00    | 1.92                           |
| LPG             | <i>Gallons/acre</i>  | 2.00      | 4.10    | 2.60      | 1.60    | 8.10      | 1.70      | 3.70    | 0.40    | 3.60    | 3.20                           |
| Natural gas     | <i>Cubic ft/acre</i> | 90.00     | 40.00   | 0.00      | 80.00   | 30.00     | 1,200.00  | 100.00  | 10.00   | 70.00   | 208.90                         |
| Electricity     | <i>kWh/acre</i>      | 25.70     | 14.40   | 6.80      | 10.90   | 16.70     | 50.60     | 7.00    | 11.40   | 32.00   | 20.41                          |
| Custom work     | <i>Dollars/acre</i>  | 7.09      | 7.05    | 6.81      | 8.69    | 8.99      | 11.87     | 8.05    | 8.78    | 13.38   | 8.45                           |
| Custom drying   | <i>Dollars/acre</i>  | 2.18      | 0.20    | 3.34      | 2.60    | 2.98      | 0.25      | 2.10    | 0.24    | 3.90    | 2.09                           |
| Purchased water | <i>Dollars/acre</i>  | 0.00      | 0.00    | 0.00      | 0.00    | 0.00      | 0.57      | 0.00    | 0.00    | 0.00    | 0.08                           |
| Chemicals       | <i>Pounds/acre</i>   | 2.47      | 1.71    | 1.75      | 2.22    | 1.71      | 2.27      | 2.85    | 1.34    | 1.60    | 2.00                           |
| 2005 production | <i>1,000 bushels</i> | 1,708,850 | 88,8580 | 2,162,500 | 288,860 | 1,191,900 | 1,270,500 | 464,750 | 470,050 | 429,200 | 8,875,190                      |

**Table A2. Total energy requirements of farm inputs for nine States and nine-State weighted average, 2005**

|                         | IL                              | IN            | IA            | MI            | MN            | NE            | OH            | SD            | WI            | Nine-State Weighted Avg. |
|-------------------------|---------------------------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|--------------------------|
|                         | BTU to produce 1 bushel of corn |               |               |               |               |               |               |               |               |                          |
| Seed                    | 412                             | 408           | 300           | 437           | 355           | 506           | 469           | 386           | 474           | 394                      |
| Fertilizer:             |                                 |               |               |               |               |               |               |               |               |                          |
| Nitrogen                | 22,336                          | 22,411        | 18,215        | 20,693        | 19,227        | 20,308        | 25,825        | 22,555        | 17,479        | 20,464                   |
| Potash                  | 1,746                           | 1,972         | 1,049         | 1,539         | 1,000         | 126           | 1,549         | 276           | 1,075         | 1,151                    |
| Phosphate               | 1,599                           | 1,700         | 1,082         | 1,137         | 1,280         | 1,527         | 1,550         | 1,250         | 976           | 1,362                    |
| Lime                    | 2,883                           | 3,000         | 2,298         | 2,541         | 380           | 667           | 2,632         | 10            | 2646          | 1,937                    |
| Energy Inputs:          |                                 |               |               |               |               |               |               |               |               |                          |
| Diesel                  | 4,238                           | 4,010         | 2,637         | 5,065         | 3,795         | 16,463        | 3,683         | 3,393         | 7,055         | 5,539                    |
| Gasoline                | 1,604                           | 2,259         | 1,414         | 2,754         | 1,840         | 1558          | 2,072         | 1,976         | 2,023         | 1,735                    |
| Liquefied Petroleum Gas | 1,062                           | 2,206         | 1,288         | 972           | 4,227         | 928           | 2,076         | 294           | 2,169         | 1,722                    |
| Natural gas             | 582                             | 262           | 0             | 592           | 191           | 7,978         | 683           | 90            | 514           | 1,368                    |
| Electricity             | 1,488                           | 845           | 367           | 722           | 950           | 3,012         | 428           | 914           | 2,102         | 1,197                    |
| Custom work             | 537                             | 541           | 481           | 753           | 669           | 924           | 644           | 921           | 1,150         | 648                      |
| Custom drying           | 661                             | 62            | 946           | 903           | 889           | 78            | 673           | 101           | 1,343         | 641                      |
| Purchased water         | 0                               | 0             | 0             | 0             | 0             | 533           | 0             | 0             | 0             | 75                       |
| Chemicals               | 2,353                           | 1,652         | 1,556         | 2,420         | 1,601         | 2,224         | 2,870         | 1,769         | 1,730         | 1,928                    |
| Input hauling           | 1,213                           | 1,279         | 966           | 1,099         | 277           | 479           | 1,129         | 70            | 1,172         | 868                      |
| <b>Total energy</b>     | <b>42,714</b>                   | <b>42,606</b> | <b>32,601</b> | <b>41,627</b> | <b>36,679</b> | <b>57,310</b> | <b>46,284</b> | <b>34,003</b> | <b>41,909</b> | <b>41,029</b>            |

Energy in custom work accounts for 16%, diesel fuel is used as source of energy

Energy in custom drying account for 80%, propane is used as source of energy

Energy in purchased water account for 90%, electricity is source of energy

Energy used for seed is 4.7 times higher than energy used for corn

Weighted average of insecticides and herbicides are used to estimate energy in pesticides

Energy used to haul input to farm is equal to weight of lime, diesel fuel, gasoline, LPG and pesticides multiplied by 218.5 BTU per pound

## **Appendix: Survey Forms**

### **2008 NAMA Ethanol Producer Energy Use Survey**

This survey asks for your use of energy during the course of producing ethanol. The information you provide will be used to calculate an industry average “benchmark” of the ethanol industry’s energy balance ratio. In this fashion, any improvement in the ethanol industry’s performance as a biofuel can be documented. The current benchmark is also useful to individual firms because they can identify areas of potential improvement.

This survey also asks a few optional questions about a few cost components that change over time with changing technology. The questions focus on a few components of operating cost and plant construction expenditures—overall production cost is not requested.

If you are currently an ethanol producer, please fill out the questionnaire and return it to the on-site interviewer. Otherwise, return the completed questionnaire in the enclosed envelope. Every individual’s response will remain confidential. But statistical summary measures will be used for analysis of the industry and made available to the public.

All of the questions ask for energy use or cost on a “per gallon of non-denatured ethanol basis.”

### **About NAMA**

The National Agribusiness Marketing Association (NAMA) provides professional development activities for university students majoring in Agribusiness. NAMA chapters at the University of Minnesota, University of Nebraska, and Iowa State University are conducting the survey.

**Questions for Dry Mill Producers:**

**Section A – Ethanol producer’s energy use**

The net energy balance of ethanol producers depends on a few critical energy use parameters. A separate list of questions is given below for dry mill producers and for wet mill producers.

- 1d. What is your yield of ethanol produced per bushel of corn processed?  
(in gallons of non-denatured ethanol/bushel of corn )
- 2d. What is your thermal energy used in the production of ethanol and dry dg?  
(in BTU/gallon of ethanol )
- 3d. What is your thermal energy used in the production of ethanol and modified (not dried) dg?  
(in BTU/gallon of ethanol )
- 4d. How much electricity is used in the production of ethanol and dry dg?  
(in kWh/gallon of ethanol )
- 5d. What percent of your distiller’s grain is sold as wet\_\_\_\_, modified\_\_\_\_, or dry\_\_\_\_?  
(in percent, 1% to 100%)
- 6d. What is the source of your thermal energy for steam production?  
natural gas\_\_\_\_ coal\_\_\_\_ biomass\_\_\_\_  
(check with X, or provide percentages if more than one applies)
- 7d. How much corn did you process last year?\_\_\_\_\_  
(in million bushels)

**Section B – Optional Cost Survey. Answers should be in \$/gallon of non-denatured ethanol.**

1. What are your operating costs, in total (in \$/gallon ethanol)?  
Note: operating costs typically include electricity, fuel, waste management, water, enzymes, yeast, chemicals, denaturant, labor, administrative costs, and labor
2. What are your electricity costs (in \$/gallon ethanol)?
3. What are your fuel costs (in \$/gallon ethanol)?
4. What are your labor costs, excluding administrative costs (in \$/gallon ethanol)?
5. What initial expenditure did you incur building your plant (in \$)?
6. What is your plant capacity (in million gallons of ethanol/year)?
7. When was your plant built (e.g., in 2003)?



**Questions for Wet Mill Producers:**

**Section A – Ethanol Producer’s Energy**

- 1w. What is your yield of ethanol produced per bushel of corn processed?  
(in gallons of non-denatured ethanol/bushel of corn )
- 2w. What is your thermal energy used in the production of ethanol and byproducts (gluten feed, gluten meal, and corn oil)?  
(in BTU/gallon of ethanol )
- 3w. How much electricity do you purchase from the grid (in kWh/gallon of ethanol)?
- 4w. What is the source of your thermal energy for steam production?  
natural gas \_\_\_\_\_ coal \_\_\_\_\_ biomass \_\_\_\_\_ other \_\_\_\_\_  
(check with X, or provide percentages if more than one applies)
- 5w. How much corn did you process last year? \_\_\_\_\_  
(in million bushels)

**Section B – Optional Cost Survey. Answers should be in \$/gallon of non-denatured ethanol.**

1. What are your operating costs, in total (in \$/gallon ethanol)?  
Note: operating costs typically include electricity, fuel, waste management, water, enzymes, yeast, chemicals, denaturant, labor, administrative costs, and labor
2. What are your electricity costs (in \$/gallon ethanol)?
3. What are your fuel costs (in \$/gallon ethanol)?
4. What are your labor costs, excluding administrative costs (in \$/gallon ethanol)?
5. What initial expenditure did you incur building your plant (in \$)?
6. What is your plant capacity (in million gallons of ethanol/year)?
7. When was your plant built (e.g., in 2003)?

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or a part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250-9410 or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.