RENEWABLE FUELS ASSOCIATION

# CORN ETHANOL'S ENERGY BALANCE CONTINUES TO IMPROVE

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Given that corn producers and ethanol processors have continued to become more efficient since the U.S. Department of Agriculture (USDA) last evaluated ethanol's energy balance six years ago, the RFA undertook a brief analysis to develop an updated estimate. **The bottom line: corn ethanol's energy balance ratio has improved to 2.8-3.0 on average, and the top-performing facilities have a ratio of 3.7-4.0.** In layman's terms, the energy balance ratio is a measure of how much energy a particular fuel source provides to the user compared to the amount of energy needed to produce and distribute the fuel. Thus, our estimate means every unit of energy invested in the production and distribution of ethanol results in roughly three units of energy, on average, available to the user.

## Background

The USDA last estimated that the energy balance ratio of corn ethanol produced at dry-mill biorefineries was between 2.1 and 2.3 (Gallagher et al., 2016). However, the USDA estimate was overly conservative at the time of its publication because of the following issues with their analysis:

- It was based on a 2008 survey of 18 dry mills and a 2010 survey of corn production practices and costs;
- The reference case assumed that all distillers grains were dried, which was not representative of industry practices and resulted in an overestimation of energy usage; and
- The extraction of corn distillers oil (CDO), which is now nearly universal, was not considered.

Accordingly, shortly after the release of the USDA report in 2016, the RFA conducted an analysis incorporating more recent data on ethanol facilities' usage of thermal energy and electricity. RFA found that the average energy balance ratio of corn ethanol was 2.6-2.8, and the energy balance of the top-performing quartile of biorefineries based on data from Christianson Benchmarking, LLC was 3.2-3.4. Furthermore, proper accounting of CDO would likely have increased the average energy balance ratio to approximately 2.9-3.0.

## Current Estimates

RFA has updated its previous analysis to reflect changes in the amounts of energy used in corn production and ethanol processing. Together, these accounted for 94% of total energy usage in the 2016 USDA report.

RFA updated estimates of on-farm energy usage and the energy associated with fertilizer and chemicals applied to corn acres, which represented 93% of the energy used in corn production in the 2016 USDA analysis. Since it does not appear that the USDA has published recent data regarding on-farm usage of energy (e.g., diesel, electricity, and propane/LPG), estimates were taken from the 2021 version of the Greenhouse gases, Regulated Emissions, and Energy use in Technologies (GREET) model developed by the Department of Energy's Argonne National Laboratory.

Updated data on the amounts of nitrogen, potash, and phosphate applied to corn acres are available from the USDA's Economic Research Service; however, the changes from 2010 are similar to those incorporated into the GREET model. For consistency, the percentage changes in the GREET model were applied to fertilizer energy usage estimated in USDA's 2016 report. A similar method was used to update the estimate of energy usage associated with chemicals applied by corn growers.

The amount of energy used in these aspects of corn production has fallen to 8,481 British thermal units (BTU) per gallon of ethanol, nearly 6% lower than the 9,007 BTU estimated by the USDA in 2016 based on 2010 data. Separately, in the absence of more current data, RFA adopted USDA's 2016 findings that an additional 1,330 BTU of energy were associated with farm machinery and 701 BTU were used for transportation of corn to ethanol facilities. As USDA explained, "The machinery estimate accounts for the energy required to produce, maintain, and transport the farm machinery."

For ethanol processing, thermal energy and electricity usage statistics for 2021 were provided by Christianson Benchmarking, LLC, which tracks and analyzes operational and financial metrics for ethanol plants and allows them to conduct performance comparisons. The firm collects quarterly data from over 60 dry-mill facilities.[1]

Average thermal energy usage among surveyed plants was 26,307 BTU/gallon (higher heating value) in 2021, down 3% from 27,043 BTU/gal in 2015. To provide an appropriate comparison to the USDA estimate, this was converted to its lower heating value (LHV) of 23,755 BTU/gal.[2] Average electricity use was reported at 0.599 kWh/gal (6,897 BTU/gal after considering energy loss), down 11% from 0.67 kWh/gal. Thus, average total energy use was 30,652 BTU/gal.

Exhibit 1 compares key dry-mill energy usage statistics from reports published over the last decade, along with energy balance estimates by USDA and RFA. Notably, the average energy use values from Christianson Benchmarking and Mueller & Kwik include data from biorefineries that do not dry all of their distillers grains, thereby reducing energy use. This is in contrast to the USDA reference case, which appears to assume all distillers grains are dried. Monthly data from USDA's National Agricultural Statistics Service

[1] Personal communication with Christianson Benchmarking, LLC. More information on the service is available at https://www.christiansoncpa.com/services/biofuels-benchmarking/

[2] Ethanol's higher heating value (HHV) is 84,530 BTU/gal, and its lower heating value (LHV) is 76,330 BTU/gal. (U.S. Department of Energy). Thus, HHV can be converted to LHV by multiplying by 0.903.

(NASS) indicate that 57% of the distillers grains produced in 2021 were dried, while 32% were sold wet and 11% were partially dried, which is similar to the percentages from 2015.[3]

**The average energy balance ratio for corn ethanol in 2021 is estimated to be 2.8-3.0, compared to the 2.1-2.3 found in the 2016 USDA report. The ratio for the top-performing quartile of biorefineries is 3.7-4.0.** These estimates are likely conservative because, due a lack of current data, we retained USDA's 2016 energy use values for corn transport, ethanol transport, and farm machinery—even though the energy efficiency has likely improved for each of those lifecycle phases. To ensure a consistent comparison, the energy balance estimates in Exhibit 1 are provided using both the survey-based and model-based co-product credit values that were included in USDA's analysis.

**Exhibit 1: Energy Balance Ratio of Corn Ethanol (BTU/gal (LHV), Except Electricity in kWh)**

| | USDA (2016) | RFA Based on Mueller & Kwik (2013) | RFA Based on Christianson Benchmarking (2016) | | RFA Based on Christianson Benchmarking (2021) | |
|---|---|---|---|---|---|---|
| | Reference Case (Dry DG) | Average | Average | Top Quartile | Average | Top Quartile |
| Corn Production | 9,007 | 9,007 | 9,007 | 9,007 | 8,481 | 8,481 |
| Corn Transport | 701 | 701 | 701 | 701 | 701 | 701 |
| Total Ethanol Conversion: | 38,141 | 32,501 | 32,127 | 26,856 | 30,652 | 24,111 |
| *Thermal (Natural Gas)* | 29,421 | 23,862 | 24,409 | 20,405 | 23,755 | 19,646 |
| *Electricity (kWh)* | 0.757 | 0.75 | 0.67 | 0.56 | 0.599 | 0.388 |
| *Electricity Adjusted for Loss* | 8,720 | 8,639 | 7,718 | 6,450 | 6,897 | 4,465 |
| Ethanol Transportation | 993 | 993 | 993 | 993 | 993 | 993 |
| Farm Machinery | 1,330 | 1,330 | 1,330 | 1,330 | 1,330 | 1,330 |
| Total Energy Used | 50,172 | 44,532 | 44,158 | 38,887 | 42,157 | 35,616 |
| Co-product Credit (CPC)-Survey | (14,717) | (14,717) | (14,717) | (14,717) | (14,717) | (14,717) |
| Energy Use Net of CPC-Survey | 35,455 | 29,815 | 29,441 | 24,170 | 27,440 | 20,899 |
| Co-product Credit (CPC)-Model | (16,591) | (16,591) | (16,591) | (16,591) | (16,591) | (16,591) |
| Energy Use Net of CPC-Model | 33,581 | 27,941 | 27,567 | 22,296 | 25,566 | 19,025 |
| Ethanol Energy Output | 76,300 | 76,300 | 76,300 | 76,300 | 76,300 | 76,300 |
| | | | | | | |
| **Energy Ratio, w/o CPC** | 1.52 | 1.71 | 1.73 | 1.96 | 1.81 | 2.14 |
| **Energy Ratio, w/ CPC--Survey** | **2.15** | **2.56** | **2.59** | **3.16** | **2.78** | **3.65** |
| **Energy Ratio, w/ CPC--Model** | **2.27** | **2.73** | **2.77** | **3.42** | **2.98** | **4.01** |

Sources: USDA, RFA analysis of data from Mueller & Kwik and Christianson Benchmarking, LLC

It is important to recognize that none of these energy balance ratios fully account for the impact of CDO removal on ethanol's energy efficiency. CDO has its own distinct energy value as a feedstock for biodiesel or renewable diesel production. Today, the vast majority of dry mills extract CDO from distillers grains. The energy input (mostly electricity)

[3] U.S. Department of Agriculture, National Agricultural Statistics Service. "Grain Crushings and Co-products Production." Current Agricultural Industrial Report. Available at: https://usda.library.cornell.edu/concern/publications/n583xt96p?locale=en

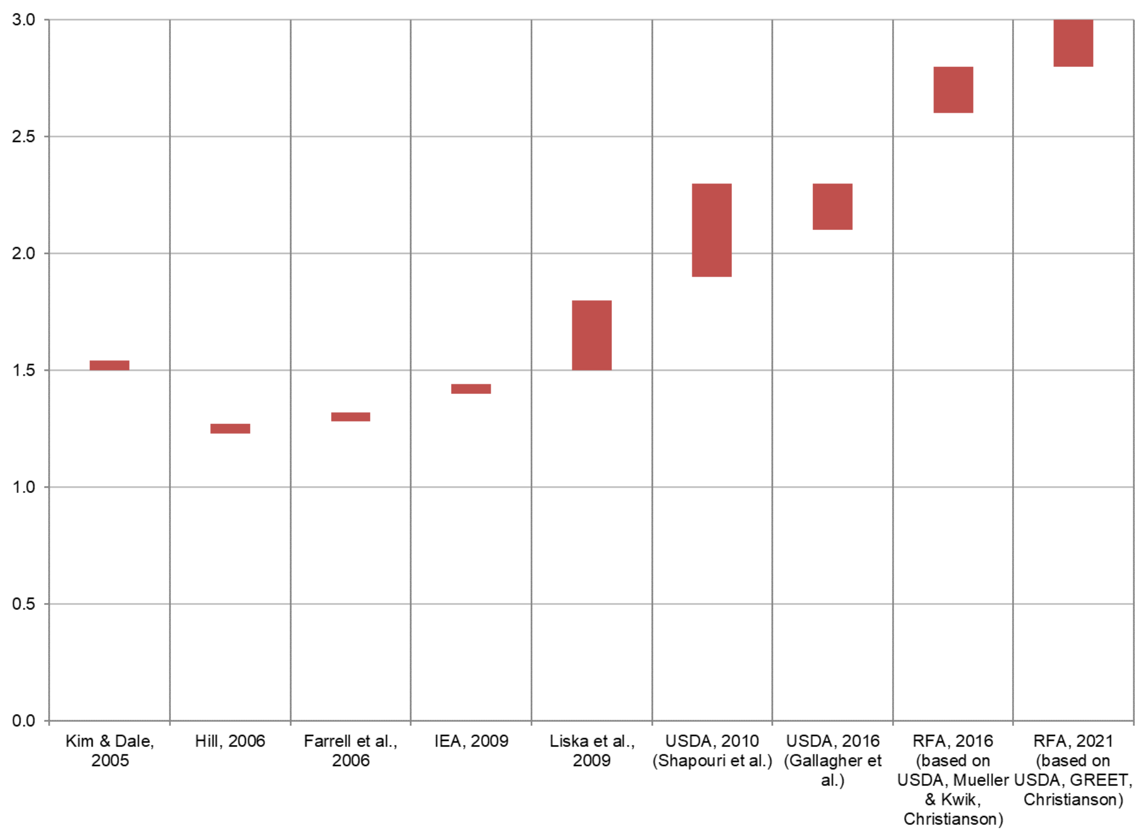
 

required to remove CDO is modest and is already included in the energy use data from Christianson Benchmarking. However, the energy output associated with CDO is not reflected in Exhibit 1. Depending on the accounting method used, CDO extraction would result in either a larger co-product credit or more BTUs of energy output. Either way, proper accounting of CDO would likely boost the average energy balance ratio to approximately 3.2.

## Historical Context

Estimates of the average energy balance ratio for corn ethanol have increased sharply over time, particularly compared to analyses conducted from 2000 to 2010 but also relative to the USDA's 2016 report (Exhibit 2). This demonstrates continued progress in the efficiency of corn production and ethanol processing.

**Exhibit 2: Dry-Mill Corn Ethanol Avg. Energy Balance Ratio Estimates, 2005-2021**

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