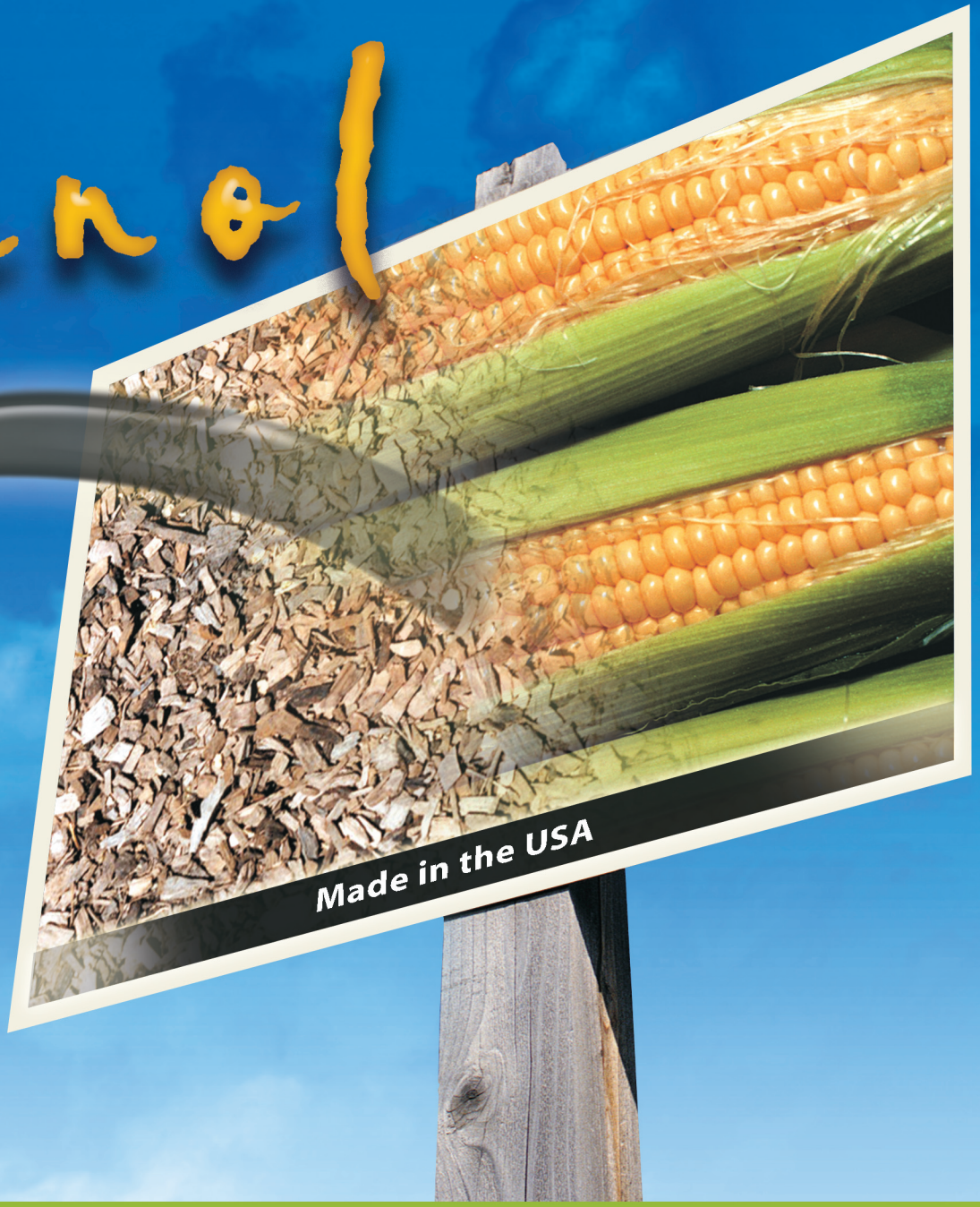
# ethanol




## the complete energy lifecycle picture

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

FreedomCAR & Fuel Partnership

Biomass

# ethanol: the complete

An industry-standard-setting total lifecycle model has been developed that allows researchers to evaluate various vehicle and fuel combinations with a consistent methodology. The Greenhouse gases, Regulated Emissions and Energy use in Transportation (GREET) model was developed by Dr. Michael Wang, Argonne National Laboratory's Center for Transportation Research, with support from the U.S. Department of Energy's (DOE's) Office of Energy Efficiency and Renewable Energy (EERE).

The peer-reviewed model has laid to rest some long-held misunderstandings about ethanol (EtOH) and its important role in reducing petroleum use and greenhouse gas emissions. In terms of key energy and environmental benefits, Argonne's GREET shows that cornstarch ethanol clearly outpaces petroleum-based fuels, and that tomorrow's cellulose-based ethanol would do even better.

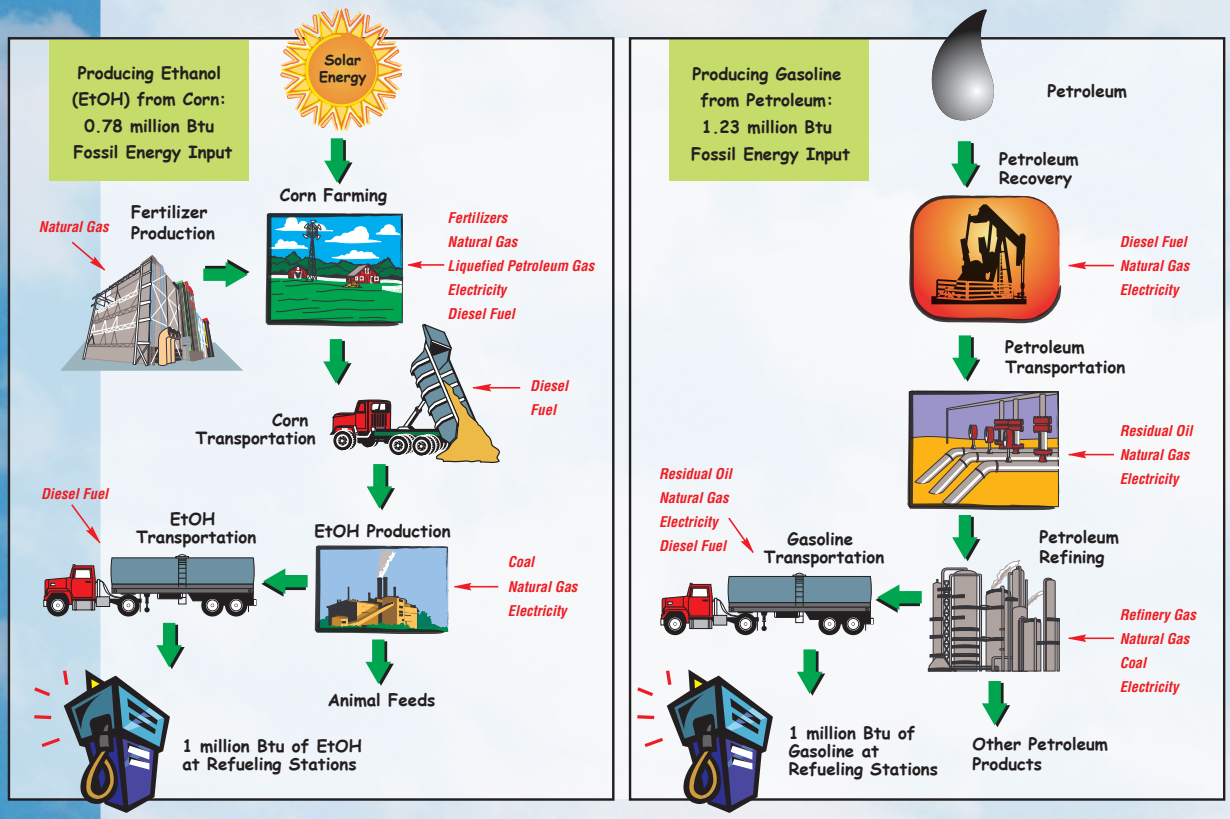



*Figure 1: Fossil energy inputs used to produce and deliver a million Btu of EtOH and gasoline to a refueling station.*

According to GREET's calculations, the *fossil* energy input per unit of ethanol is lower—0.78 million British thermal units (Btu) of fossil energy consumed for each 1 million Btu of ethanol delivered—compared to 1.23 million Btu of fossil energy consumed for each 1 million Btu of gasoline delivered (see Figure 1).

Some confusion arises because a portion of the *total* (not fossil or petroleum) energy input in the ethanol cycle is the "free" solar energy that ends up in the corn. Since the solar energy is free, renewable, and environmentally benign, it should not be taken into account in the energy balance calculations.

While the *total* (includes solar) energy needed to produce a unit of ethanol is more than the total energy needed to produce a unit of gasoline, ethanol is superior when calculating either (1) the amount of *fossil* energy needed or (2) the amount of *petroleum* energy needed (see GREET results in Figure 2).

Moreover, the use of ethanol reduces greenhouse gas (GHG) emissions. On a per-gallon basis, GREET shows that corn ethanol could reduce GHG emissions by 18% to 28%; cellulosic ethanol offers an even greater benefit, with an 87% reduction in GHG emissions (see Figure 3). However, if coal is used in EtOH plants, corn EtOH may not have GHG reduction benefits.

# energy lifecycle picture

A range of studies has looked at the fossil energy required to produce ethanol (see Figure 4). Studies above the "zero line" (including GREET) found that ethanol has a positive net fossil energy value (that is, less fossil energy is used to produce ethanol than the energy that is available in ethanol). Studies below the "zero line" found that ethanol has a negative fossil energy value. Most of the studies and, more importantly, the preponderance of the recent studies, show that ethanol has a positive net fossil energy value.

## Total Btu Spent for One Btu Available at Fuel Pumps

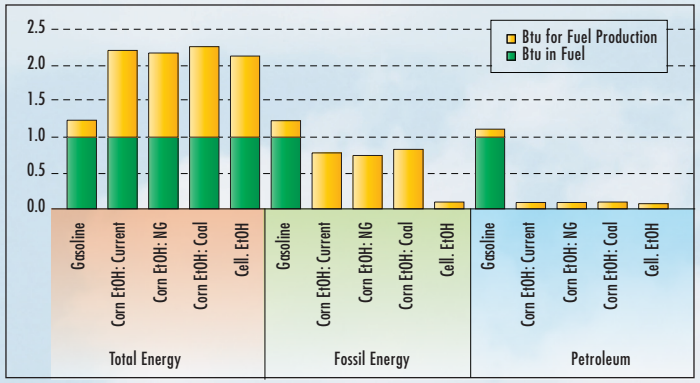



*Figure 2: The energy benefits of fuel ethanol result from (1) reduced fossil energy and petroleum use in production and (2) the absence of fossil and petroleum content in the final product.*

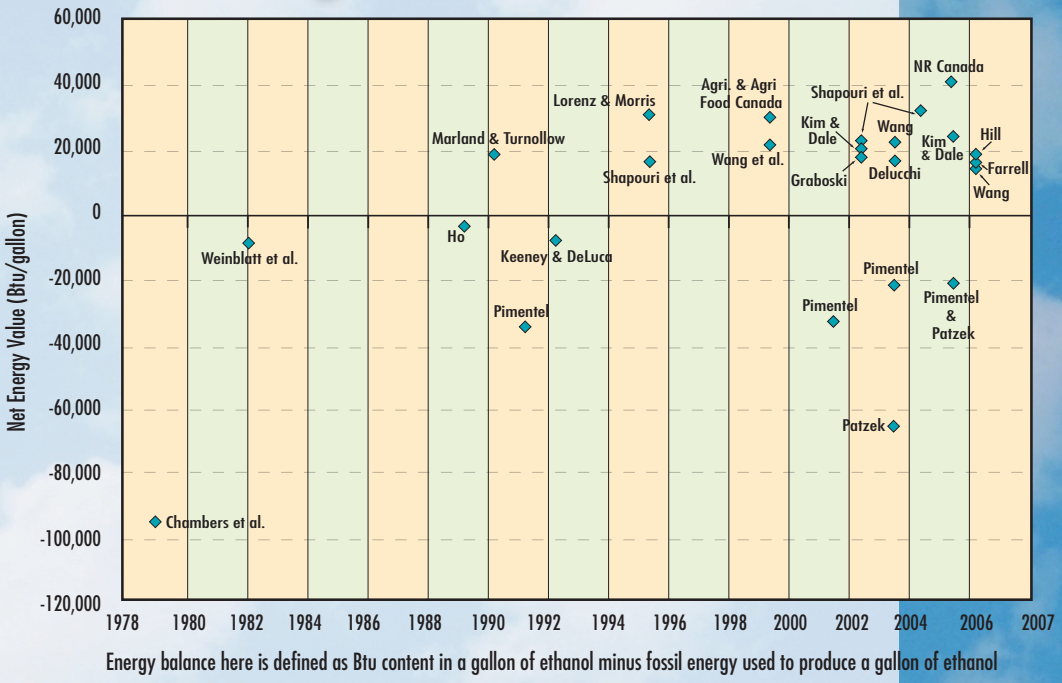



*Figure 4: The majority of corn ethanol/fossil energy studies (especially more recent studies) show that corn ethanol has a positive net fossil energy value.*

## Replacement of a gallon of a gasoline with equivalent EtOH

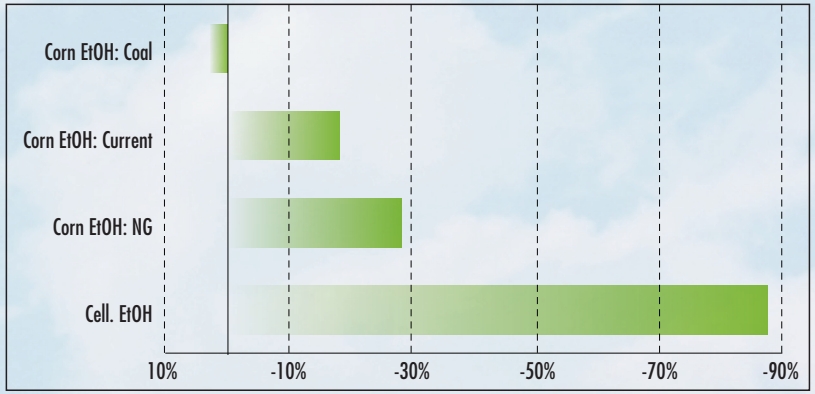



*Figure 3: Ethanol generally produces fewer greenhouse gas (GHG) emissions.*

## CONCLUSION

GREET's lifecycle analysis shows that any type of fuel ethanol can help to reduce petroleum use in the transportation sector. An investigation of the energy balance alone would be less meaningful because it does not provide comparative results between ethanol and the energy products it replaces (i.e., gasoline). Even the fossil energy balance, which is favorable, does not show the critical petroleum savings benefits of ethanol which may be the greatest energy concern. In addition, while corn-based ethanol can achieve moderate reductions in GHG emissions, cellulosic ethanol (the focus of DOE/EERE research) can produce much greater energy and GHG benefits.

**Guide to abbreviations:**

| | |
|---|---|
| Btu | British thermal units |
| Cell. | Cellulosic |
| EtOH | Ethanol |
| GHG | Greenhouse gas |
| NG | Natural gas |

**A Strong Energy Portfolio for a Strong America**

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

**For more information contact:**
EERE Information Center
1-877-EERE-INF (1-877-337-3463)
www.eere.energy.gov

**Principal Investigator:**
Michael Wang, Ph.D.
Center for Transportation Research/Argonne National Laboratory
630-252-2819
mqwang@anl.gov

Second revised edition, March 2007

Publishing and support services provided by Argonne National Laboratory's Technical Services Division.