

BIOFUELS

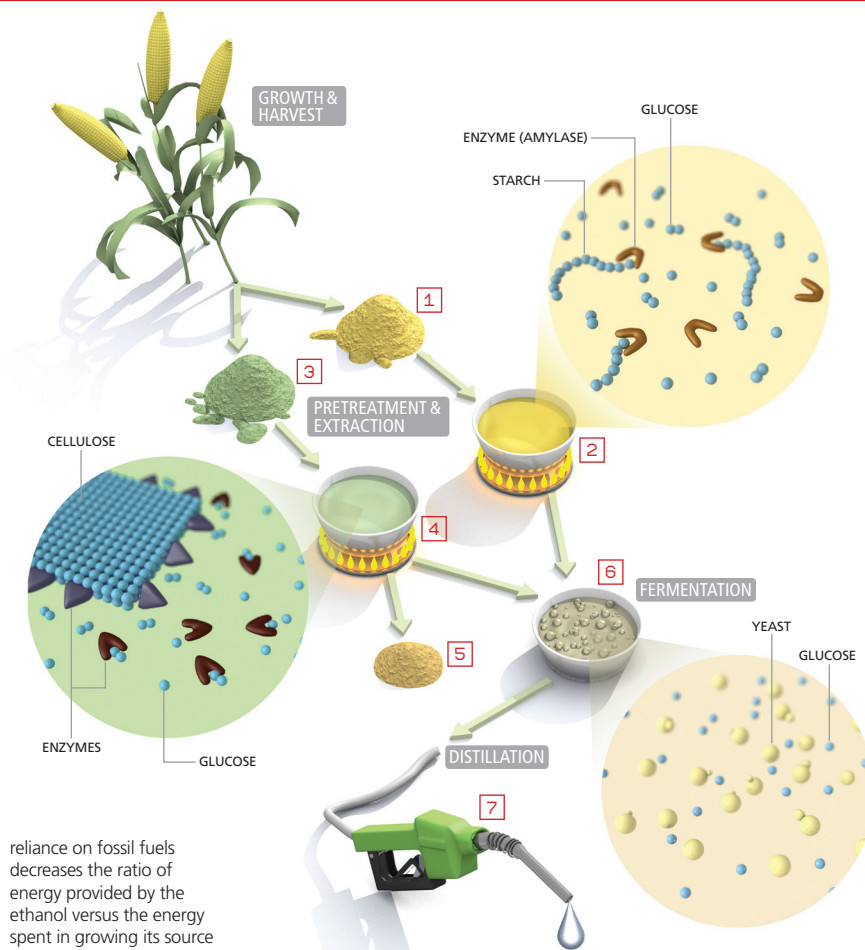
Are biofuels a viable replacement for fossil fuels? How are they made, and can their production be improved?

RISING ENERGY COSTS and concerns over climate change from emissions of CO₂ have renewed interest in moving beyond fossil fuels. This is especially true where transportation is concerned, as it accounts for 70 percent of oil burned in the United States. **Biofuels**—fuels made from living things—are one potential replacement. Biofuels come in many forms, such as wood, manure, and animal and vegetable oils. Unlike fossil fuels, biofuels are renewable and potentially **carbon-neutral**: Burning a plant releases no more carbon than it absorbed while growing. In the US today's predominant biofuel is **ethanol**. Typically produced from corn, American ethanol works as an alternative to gasoline in most cars and trucks. But corn-based ethanol may cause more problems than it solves.

OUT OF FRYING PAN, INTO FIRE

Using the same crop as a source for both food and energy increases demand for it, which can cause rapid increases in food prices. When using corn, only the kernels are used and energy stored in other parts of the plant goes to waste. Fortunately, a more complex process can create ethanol from **cellulose**, the main component of plant stems and leaves; this process is less disruptive to the food supply and uses material that would otherwise be wasted.

Though in theory ethanol can be carbon-neutral, in practice growing and harvesting corn or cellulose uses substantial amounts of fossil fuels. This



reliance on fossil fuels decreases the ratio of energy provided by the ethanol versus the energy spent in growing its source crop. While corn is easier than cellulose to convert into ethanol, it requires more resources to grow than many other cellulose sources. In general, using agricultural crops for biofuel poses problems of environmental degradation and resource depletion similar to those that occur in other forms of industrial agriculture.

MAKING ETHANOL

Producing ethanol from either corn or cellulose requires four basic steps: **growth and harvest**, **pretreatment and extraction** of sugars, **fermentation**, and **distillation**.

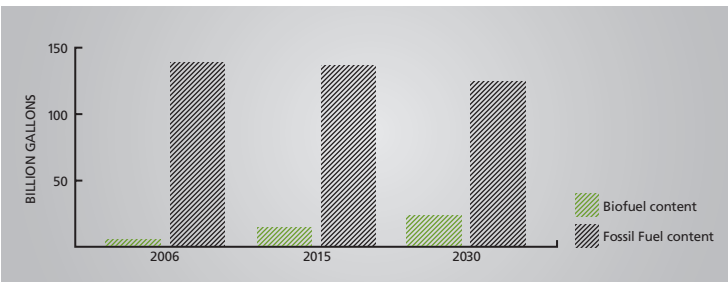
PRETREATMENT AND EXTRACTION

After harvest, neither corn nor cellulose is immediately convertible to ethanol, which is a direct product of the sugar that's extracted and fermented. Several different processes can extract sugar from corn and cellulose, but each requires pretreatment of the source material to make extraction easier. For corn, the kernels are milled to produce cornstarch **1**, a mixture of two large molecules comprising chains of the sugar glucose; an enzyme called amylase then breaks down the mixture into glucose **2**. Getting glucose from cellulose-rich plant material is more difficult. The material is pretreated with acids, steam, or ammonia to free the cellulose from plant-cell walls **3**. Like starch, cellulose is made of chains of glucose molecules, but its molecules have far more bonds between them. And so, cellulose requires multiple enzymes to break up into glucose **4**. Lignin, another component of plants, must be separated from the glucose-rich mixture before fermentation **5**. Consequently, cellulosic ethanol production currently lags far behind ethanol production from corn, sugarcane, and other food crops.

FERMENTATION AND DISTILLATION

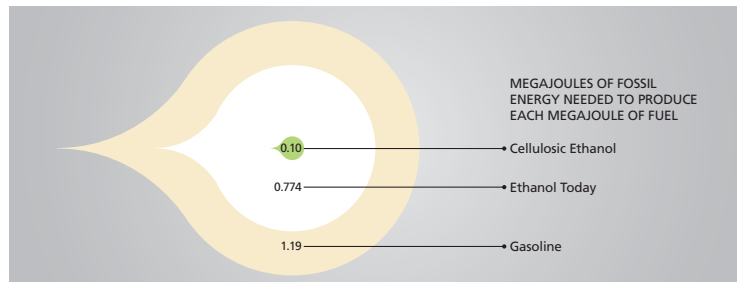
Once the sugar is extracted from the cornstarch or cellulose, it is mixed with yeast or other microbes **6**. The microbes ferment the sugar into alcohol, releasing carbon dioxide as a byproduct and leaving behind an unfermented mass called stillage, which can be recovered and used as a feed supplement for livestock. When fermentation is complete, the mixture is distilled and treated with chemicals to remove water, resulting in fuel-grade ethanol that can then be blended with gasoline and transported to pumping stations for distribution **7**.

BIOFUEL CONTENT OF U.S. GASOLINE SUPPLY



As US biofuel production ramps up, more ethanol will be mixed with the gasoline supply. Even by 2030, however, fossil fuels are projected to remain the primary constituents of gasoline.

FOSSIL FUELS FOR BIOFUELS



Today both ethanol and gasoline production rely on energy from fossil fuels. Producing ethanol from cellulose rather than crops like corn will almost certainly require much less fossil-fuel energy.

THE ISSUE: THE NEXT GENERATION OF BIOFUELS

The first generation of modern biofuels was made from food crops like corn because processing these plants is relatively easy, but their energy yields are low and their negative effects are many. "Second generation" biofuels like cellulosic ethanol are made from inedible materials like agricultural waste and wood chips, but their production has yet to be perfected, and the amount of energy they could deliver is unlikely to fulfill the entirety of our growing energy needs. Viable biofuels await us in the third generation or beyond, when highly energy-efficient production of fuel from algae or genetically modified microorganisms could become a reality.

SOUNDBITE

Though promising as alternative energy sources, biofuels can have social, environmental, and energy costs rivaling those of fossil fuels. Future generations of biofuels may solve these problems.