Ethanol in Minnesota: From Farm to Fuel

An overview of ethanol fuel and its impacts to environment, energy security and economics.
For use in grades 9 - 12

Objectives:
The *Ethanol in Minnesota: From Farm to Fuel* overview can be used (1) in conjunction with the companion PowerPoint presentation as supporting information, (2) as a stand-alone resource for teachers, or (3) as assigned reading for students.

Students will understand:

- Fuel for vehicles can come from diversified sources including non-renewable and renewable options.
- Agriculture provides feedstocks for production of renewable fuels and other products.
- Fuels of all types have both positive and negative characteristics to consider.
- Ethanol is one option for replacing and extending the supply of fossil fuels.

Introduction

The world's petroleum resources developed over hundreds of millions of years as tiny plants and animals died and were buried on the ocean floor. Over time, they were buried deeper and deeper under layers of sand, silt and rock. Immense heat and pressure turned them into oil and gas.

In 2019, the United States consumed a total of 7.5 billion barrels of petroleum products, an average of 20.5 million barrels per day, according to the U.S. Energy Information Administration (EIA). At 42 gallons per barrel, that is 861 million gallons per day.

> Crude Oil: petroleum in its raw state before it is refined.
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> Petroleum: oil that is obtained from the ground and that is the source of gasoline, kerosene, and other oils used for fuel.
>
> Merriam Webster

In the U.S. and throughout the world, petroleum has been a vital part of our daily lives, not only because it powers much of the transportation, machinery and equipment used, but also because it is used for black top, tires, plastics and cleaners. Petroleum products are found in clothing, purses, toys, furniture and many other everyday items. While petroleum is a useful resource for developing fuel and other products like these, it also comes with other costs including energy security and environmental impacts.

Energy Security: The EIA defines energy security as "the uninterrupted availability of energy sources at an affordable price". Though the U.S. is now importing much lower levels of oil than it has in recent past, supply and pricing of petroleum is dependent on oil producing countries and can be affected by political situations throughout the world and sometimes even extreme weather events. This dependence can threaten energy security.

Alternatives to petroleum-based fuels and products are available and much work is being done to research, produce and put these alternatives into use. Renewable alternatives to fossil fuels include ethanol, biodiesel, renewable diesel, electricity and renewable natural gas. These alternatives can be produced from renewable resources like plants, solar energy, wind energy and gases from decaying waste.

Ethanol Basics

What is ethanol? Ethanol is a colorless, flammable liquid that can be used as a fuel for vehicles.

Chemical formula: Ethanol is a 2-carbon alcohol. Its molecular formula is C_2H_6O or CH_3CH_2OH. Ethanol is abbreviated as EtOH, representing the ethyl group (C_2H_5-) with Et. The oxygen component allows ethanol to burn more completely than gasoline resulting in fewer emissions.

Physical properties: Ethanol is a volatile, colorless liquid with a slight odor. It burns with a smokeless blue flame.

Ethanol production: Ethanol is historically produced by fermentation of plant sugars. In the United States today, ethanol is primarily produced from the starch component of the corn kernel. It is also being produced from other grains like sorghum, cellulosic feedstocks like corn kernel fiber, and beverage and food waste. In Brazil, ethanol is made from sugar cane. Other feedstocks may also be used such as agricultural, forestry, and municipal wastes or specially grown energy crops.

Two methods are used for producing ethanol from corn, dry milling and wet milling. Dry milling is used for around 90% of U.S. ethanol production.

Dry Milling:

- The entire grain kernel is ground into meal (powder).
- The meal is then mixed with water to form a mash.
- Enzymes are added to the mash to convert the starch to sugar.
- The mash is cooked, then cooled and transferred to fermenters. Yeast is added to convert sugars to alcohol.
- After fermentation, the resulting "beer" is separated from the remaining stillage.
- The ethanol is distilled (heated and condensed) and dehydrated (water removed), then blended with about 2% denaturant (such as gasoline) to make it unfit for human consumption (ethanol must be denatured so that it is not taxed as an alcohol). It is then ready for shipment and blending with gasoline.
- The stillage is sent through a centrifuge that separates the solids from the solubles. These co-products eventually become distillers grains (animal feed) and corn distillers oil.

Solubles: the dissolved remains and fine particles left after the solid grains have been strained from the residue from alcoholic distillation.

Wet milling:

- The grain is first separated into its basic components (germ, fiber, protein, starch) through soaking.
- After steeping (soaking), the slurry is processed through grinders to separate the corn germ.
- The remaining fiber, gluten (protein) and starch components are further separated.
- The gluten component is filtered and dried to produce animal feed.
- The remaining starch can then be fermented into ethanol, using a process similar to the dry mill process.

~Source: Renewable Fuels Association

In 1982, there was just a small number of ethanol production plants in the U.S., which produced only 350 million gallons of ethanol. Over the years the number of plants has increased and in 2019, approximately 200 plants produced nearly 16 billion gallons of ethanol. A majority of these plants are located in the Midwest, close to corn farming areas. This helps increase efficiencies, reduce energy inputs and decrease the cost of production. Minnesota is home to 18 plants with a production capacity of 1.3 billion gallons, ranking fourth in ethanol production.

Why Use Ethanol?

Ethanol can be blended with gasoline in varying percentages to produce a variety of fuel blends. Adding ethanol to gasoline provides important benefits including:

- Increasing octane
- Reducing emissions: both tailpipe and lifecycle greenhouse gas emissions
- Reducing dependence on petroleum and extending the amount of petroleum available
- Utilizing a renewable fuel
- Supporting local businesses and industries, such as agriculture, ethanol production and others that support these industries

Increasing octane: When you pull up to the fuel pump at the gas station, you will likely see gasoline grades labeled by their octane rating, commonly 87, 89 and 91 or 93. Ethanol has a high-octane rating of 113. This makes ethanol fuel a popular way to meet octane ratings of various gasoline options. For example, if you start with a gasoline that has an octane rating of 84, adding 10% ethanol results in the 87-octane gasoline required for a majority of vehicles on the road today.

Octane is the measure of how much compression a fuel can withstand before igniting. Higher octane fuels are compatible with higher compression engines that can increase efficiency and performance while potentially reducing emissions by combusting the fuel more completely. Most vehicles require an 87 octane gasoline; high performance and turbo-charged engines often require a higher octane rating.

The compound tetraethyl lead (TEL), was once used to increase octane in gasoline but was then phased out after it was shown to have detrimental health effects and interfered with catalytic converters (vehicle emission control equipment). This resulted in what we now call "unleaded gasoline". A variety of options for increasing octane are available, however ethanol is the leading choice due to its lower cost, reduced emissions and renewability.

Reducing emissions: Ethanol's oxygen content allows it to burn more completely than gasoline, reducing emissions.

Ethanol also reduces lifecycle greenhouse gas emissions, a primary contributor to climate change. A study published by researchers from Environmental Health and Engineering Inc., Harvard University and Tufts University shows corn ethanol emits 46 percent fewer greenhouse gas (GHG) emissions than gasoline. Cellulosic ethanol can provide even greater reductions. A study by Argonne National lab showed average emissions reductions for cellulosic ethanol compared to conventional gasoline range from 88% to 108% depending on feedstocks used.

The term "**lifecycle**" is used to account for the inputs and/or outputs of the full process of fuel production and use. In the case of ethanol and other renewable fuels, that includes activities from planting the seed, through production of fuel, to fueling a vehicle; or in the case of gasoline, the extraction of the fuel, refining into gasoline, through fueling the vehicle.

Greenhouse Gas Emissions (GHGs): Gases that trap heat in the atmosphere, such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and fluorinated gases.
www.EPA.gov

Utilizing a renewable fuel: Ethanol is produced from plants. In the case of ethanol production from corn, the starch is used to produce ethanol and the remaining parts of the kernel are used to produce other valuable coproducts, like livestock feed, carbon dioxide for use in carbonated beverages and dry ice, and corn distillers

oil for use as a biodiesel feedstock or feed ingredient. These plants are renewable, they can be grown again each season to produce a new supply of fuel and co-products.

Fossil fuels in contrast are considered "nonrenewable", having been formed over millions of years; once the supply is used, it does not renew in time to satisfy the need. Blending ethanol with gasoline reduces the amount of gasoline needed, extending the supply.

Increasing Energy Security: Minnesota does not have any oil wells or other fossil fuel resources. All petroleum used in the state is imported from other countries or states. Producing fuels within the state from plants grown in the state supports farmers, renewable fuel producers and related industries in Minnesota, and creates a shorter, more secure supply line from production to the fuel station.

Reducing the nation's dependence on petroleum and increasing use of homegrown alternatives also reduces dependence on other nations for energy resources, which increases energy security.

Job Creation and Economic Impact: Ethanol production and use in the U.S. creates and supports jobs at the ethanol plant, at farms and at many supporting businesses and industries, often in communities where other jobs may be limited.

According to the Renewable Fuels Association, in 2019:

- Production of 15.8 billion gallons of ethanol directly employed 68,684 people in renewable fuel production and agriculture in the U.S. It also supported 280,327 jobs in businesses that support the industry or utilize the product, across all sectors of the economy.
- The U.S. ethanol industry added $43 billion to the nation's Gross Domestic Product (GDP - the total value of goods produced and services provided in a country during one year). The sector's economic activity and job creation helped raise household income by $23.3 billion. The U.S. ethanol industry spent over $27 billion on raw materials, other inputs, and goods and services.

Minnesota's Fuel Supply: Much of Minnesota's petroleum comes from the Oil Sands of Alberta, Canada. Oil sands are mined and refined to produce products similar to those produced from oil pumped from conventional oil wells, however extracting oil from oil sands is much different than conventional oil recovery. Oil from oil sands is very heavy and thick. Recovery of oil from oil sands includes processes to separate bitumen (dense, thick, petroleum-based hydrocarbon) from the clay, sand, and water that compose the oil sands. Because it is so thick and doesn't "flow" like conventional oil, bitumen must be diluted with lighter hydrocarbons to make it transportable by pipelines. Mining and processing of oil sands involves a variety of impacts, such as greenhouse gas emissions, disturbance of mined land, and impacts on the local environment.

How is Ethanol Used?

Ethanol is now available in a variety of blends, each of which can be used by different sets of vehicles and equipment.

E10 (10% ethanol, 90% gasoline) – the most common blend of ethanol is the 10% blend. This blend has been used for decades to:

- Reduce emissions. Minnesota first required using low levels of ethanol as part of a strategy to combat carbon monoxide issues during winter months in the Twin Cities. Soon after, the state expanded the requirement to be statewide and year-round. Carbon monoxide levels are now very low.

- Increase octane. Ethanol is now a preferred source of octane due to emissions benefits, availability, price and support for its homegrown, job creating benefits. Adding 10 percent ethanol to 84 octane gasoline increases the octane to 87.
- Extend gasoline supplies and reduce petroleum demand by replacing a percentage of gasoline. Approximately 96 percent of U.S. gasoline contains a 10 percent ethanol blend.

E10 can be used in any gasoline vehicle as well as boat engines, motorcycles, lawn mowers and other small engines. The state of Minnesota requires 10% biofuel content in virtually all gasoline sold in the state. No extra labeling is required, and it is most often identified at a gas station as "unleaded" or "UNL." All regular, mid-grade and premium gasoline grades in Minnesota will have this 10 percent blend, with the exception of premium that is specifically labeled as "Non-Oxy Premium," and is only available for use in collector vehicles, off-road vehicles, motorcycles, boats, snowmobiles, and small engines, not for current gasoline vehicles.

E15 (15% ethanol and 85% gasoline) has been approved by the U.S. Environmental Protection Agency for use in light duty vehicles Model Year 2001 and newer and for flex fuel vehicles of any model year. It has not been approved for vehicles older than 2001 or for motorcycles, boats or any small engines. A decal on the fuel dispenser indicates that the fuel offered is E15 and provides a notice about which vehicles are approved to fuel with it. E15 typically has an octane rating of 88 and is often priced 5 to 10 cents less than gasoline. E15 may also be labeled as Unleaded 88 or 88 Octane.

FlexFuel Blends – blends of ethanol higher than 15% are for use in "flex fuel vehicles" or FFVs.

E85/Ethanol Flex Fuel (between 51% and 83% ethanol, with the remainder being gasoline) has an octane rating of approximately 105, depending on the season and ethanol content. E85 has the most renewable content and largest greenhouse gas emissions reduction per gallon of all the ethanol blends.

Because ethanol has a lower energy content than gasoline, vehicles fueled with E85 do see lower miles per gallon (MPG) than when running on gasoline, often in the range of 15% - 20%. However, because ethanol is typically priced less than gasoline, E85 can also be offered at a lower price than gasoline and at most Minnesota stations is offered at a price that is competitive with gasoline even with those MPG reductions.

E20 – E50: Many stations have other "mid-level" ethanol blends like E20 (20% ethanol), E30 (30% ethanol), E40 (40% ethanol) or E50 (50% ethanol). These blends should also only be used in FFVs. Due to the lower ethanol content, drivers fueling their FFVs with mid-level blends see less of a mileage loss, and in some cases, do not see any difference in MPG.

FLEX FUEL VEHICLES (FFVS)

FFVs are capable of using up to 85% denatured ethanol, and are flexible – meaning they can use E85, straight gasoline, or any blend of ethanol between 0 and 85%. The same fuel tank is used for any blend and there are no adjustments for the vehicle driver to make – the vehicle adjusts for the ethanol blend. E85 can be used when it is available, and gasoline can be used if it is not. Flex fuel vehicles provide drivers with choices at the pump: gasoline, E85, or any blend of ethanol in between.

FFVs have been available since the late 1990s and the compatibility comes standard on many popular vehicle models including cars, crossovers, SUVs, minivans and trucks. Because it comes standard, many people with an FFV don't even know they are driving a vehicle that can run on anything other than traditional gasoline.

FFVs can be identified by a decal inside the fuel door, a yellow fuel cap, or a flex fuel badge on the side or rear of the vehicle.

High Octane Low Carbon (HOLC) Fuels: A vehicle with a high-compression engine that uses higher octane fuels can result in better fuel economy. Federal agencies, automakers and fuel industry groups are partnering in research and testing to determine best vehicle technologies and octanes needed to meet increasing U.S. fuel economy targets. Mid-level ethanol blends may play an important role in meeting these targets.

Mid-level blends are often sold through a fuel dispenser called a "blender pump" or "flex pump" which blends two fuels from two different underground storage tanks together at certain percentages as they enter the fuel dispenser. This results in another fuel, without needing an extra storage tank for that fuel blend. Blending E85 with E10 at different rates results in these mid-level ethanol blends or E15.

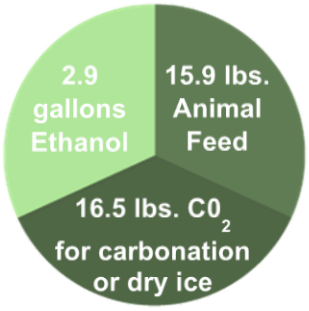
Other Considerations

Energy Balance: Turning resources, like crude oil or plants, into fuel that we can use to power vehicles takes energy inputs. Ethanol production efficiency has improved greatly over the years and is net energy positive. In fact, U.S. Department of Agriculture's 2015 Energy Balance for the Corn-Ethanol Industry shows a nationwide average of 2.1 units of energy resulting from each unit of energy used in production. At some Minnesota and Iowa locations where ethanol producers use lower corn energy, market wet distillers grains (instead of dried distillers grains) to local livestock industry, and sell ethanol locally, ethanol production efficiencies can be even better, estimated at 4.0 units of energy resulting for every one unit used in production.

Water Use: Fuel production uses water at various stages. Extracting crude oil and refining it into gasoline and other products utilizes water. Growing crops and refining them into fuel and other products also requires water. Corn crops need water to grow. Most corn grown in Minnesota is watered by rainfall, not by irrigation. Ethanol production also requires some water, about 2.7 gallons of water for each gallon of ethanol. Both processes also recycle water for reuse.

Feeding and Fueling the World: Ethanol is produced from "dent" corn (commonly known as "field" corn) that has traditionally been used for animal feed, not the sweet corn that humans enjoy. Ethanol is produced from the starch of the corn kernel. The valuable protein portion of the kernel remains as a co-product of ethanol production as a feed for livestock, poultry and swine that provide protein for human diets. Producing ethanol from corn provides both food and fuel.

1 Bushel of Corn



Plus .8 lbs corn distillers oil for use as a biodiesel feedstock or feed ingredient

Information included in this lesson has been sourced from:

Energy Information Administration: EIA.gov
Renewable Fuels Association: EthanolRFA.com
Minnesota Corn Growers Association: MNCorn.org
National Corn Growers Association: NCGA.com
American Lung Association in Minnesota: MNFuels.com
Minnesota Bio-Fuels Association: MNBiofuels.com
Minnesota Department of Agriculture: MDA.state.mn.us
U.S. Department of Agriculture: USDA.gov