Dr. Dave: My state legislature (Montana) is currently debating a bill to mandate 10 percent ethanol in all gasoline. Is that a good idea? I've read that ethanol causes problems.

A. Montana is one of six states that has in place or is currently debating, an ethanol mandate. One state, Minnesota, has a mandate for the use of vegetable oil/diesel blends. To answer your question, let's start, as we always do, with some basic background.

Ethanol is another name for pure alcohol. Anyone who has made beer or wine has taken the first step toward making ethanol. Microorganisms ferment sugars into ethanol (and carbon dioxide). Wine consists of about 10 percent alcohol (20 proof). To produce fuel or industrial ethanol (unlike beverage ethanol) the low content alcohol goes through a series of distillation phases to eliminate the water. The final product is 100 percent alcohol (200 proof). That is what is mixed into our gasoline.[1]

The sugars used to make ethanol can be extracted from many types of plants. The cheapest sources of sugar are plants like sugar cane where the sugars are immediately available. Corn is the next cheapest feedstock, along with other higher cost cereals like wheat. When using these crops, the first step is to break down the starch into sugars, a simple and relatively inexpensive process.

In the near future we will extract sugars from the planet's most abundant and potentially lowest cost living material: cellulose. Cellulosic materials include fast growing trees, grasses, corn stalks, wheat straw, waste paper, seaweed and many other kinds of plants. Extracting sugars from cellulosic materials is a relatively costly process because one must first break down lignin to get to cellulosic materials, and then break these down into various kinds of sugars, and then use different techniques to ferment different kinds of sugars. The process is near to commercialization. At least one commercial cellulose-to-ethanol plant is scheduled to become operational by 2006.

Fuel ethanol has many critics. Some are concerned that we may end up feeding our cars at the expense of our stomachs. That is a legitimate, although by no means an inevitable problem. When ethanol is made from corn, for example, as noted above, it is made from the corn starch. The plant's protein content is untouched. Indeed, the resulting product concentrates the protein. That product, called distiller's grain, is a high-grade animal feed. It often displaces corn itself. The world does not suffer from a shortage of starch or sugars.

Cellulose is available in vast quantities from waste (e.g. waste wood, agricultural residue, etc.). Cellulosic crops can grow on land not currently used for growing food, can achieve high yields, and could even produce animal feed as one of its products.

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[1] Actually it is a bit more complicated than that. As a holdover from the Prohibition era, fuel ethanol producers have to poison their product before they can sell it. About 2-4% of the final ethanol product thus contains gasoline components. This is done to prevent the fuel ethanol from being diverted to the much higher priced beverage market.

Some critics worry about the environmental impact of producing large quantities of fuel ethanol. Some focus on the impact of the crop cultivation on soils and water. Others focus on the air quality impacts of the use of ethanol itself. Again, such concerns are legitimate but the overall environmental impact must be examined in a holistic context.

One of these issues is to compare it to using other fuels. No fuel is perfect. For example, MTBE was chosen by a number of states over ethanol as a fuel additive to meet Clean Air Act requirements because it was assumed to be slightly better than ethanol in terms of improving air quality. But then we discovered that MTBE quickly pollutes groundwater. Eighteen states so far are phasing out MTBE in their gasoline. The cost of MTBE cleanup can run into the tens of billions of dollars.

In examining the environmental impact, many critics focus on the amount of energy needed to make ethanol from crops like corn. (For those interested in examining the various studies and making up their own minds, see The Energetics of Ethanol: An Introduction and Links to Studies.) Virtually all studies indicate a positive net energy ratio (energy out over energy in), and all indicate that farmers and ethanol refineries have become more efficient over the years.

In Brazil, the energy output/input ratio is over 8 to 1. One major reason is that the bagasse, that is the fiber portion of the sugar cane, comes along with the cane to the sugar mill and is used to provide all the energy needed by the mill and the ethanol refinery.

Some critics worry about the possible negative impact of the large-scale use of ethanol on soil erosion and fertilizer runoff into streams and rivers. These problems, however, stem from cultivation practices, not from the use of ethanol. For example, soil erosion from corn is reduced by some 80 percent with no and low till cultivation practices. Fertilizer use is reduced dramatically when crops are rotated and when fertilize is applied only when and where needed.

Cellulosic crops should have relatively few erosion and fertilizer runoff problems, although they will need fertilizers and probably pesticides.

With regard to ethanol and air quality, the issue becomes terribly complex. The reason is that atmospheric chemistry is still an infant science. Pollution is usually a result of a a mixture of chemicals in a specific climatic situation. In any event, there seems to be a consensus on the following:

- A 10 percent ethanol blend will reduce the overall toxicity of the gasoline significantly.
- A 10 percent ethanol blend significantly reduces the amount of carbon monoxide (CO), a pollutant in its own right and a precursor to ozone (smog).
- A 10 percent ethanol blend reduces air particulates.

The controversy becomes much more heated when we discuss ethanol's potential impact on ozone formation. The reason is that when small amounts of ethanol (e.g. 2 percent) are added to gasoline, the volatility of the gasoline increases. That means an increase in volatile organic compounds (VOCs) in the air. VOCs help form ozone.

We know that as more ethanol is added to the gasoline (e.g. going from 2 percent to 10 percent), the volatility of the mixture does not increase. When the ethanol component rises above 25 percent, the volatility declines about to where it was before a drop of ethanol was added. Ethanol itself has a volatility about half that of gasoline. Thus 100 percent ethanol cars do not create a VOC problem.

Ozone is formed by the interaction of a number of chemicals. One of them is carbon monoxide. As was noted above, ethanol use significantly reduces carbon monoxide emissions. Also, although ethanol does, in modest blends, increase VOCs, it doesn't necessarily lead to increased ozone levels because the VOCs are less reactive. When ethanol is used in gasoline it often substitutes for the most volatile components of gasoline.[2]

Overall, the range of difference among studies of the impact of ethanol blends on ozone formation is surprisingly small. They vary from a finding of a small increase in ozone formation to a small decrease in ozone formation.

There is one final element in a discussion of air quality: greenhouse gas emissions. On this ethanol is a clear winner, even when derived from corn, and becomes a very significant component of an greenhouse gas reduction strategy when derived from cellulose (when the waste from that process are used to provide the energy for the process).

Finally, people ask how much ethanol we can produce? Do we have enough land area to allow biofuels (ethanol and vegetable oils) to significantly displace our transportation fuels. The answer is, yes and no. In the United States, grains can provide about 10-15 billion gallons of ethanol. This is triple the amount used in 2004, but is still, in energy equivalents, only about 5 percent of the nation's use of gasoline. The nation's oil seeds could produce about 3-4 billion gallons of vegetable oils, about 7 percent of the nation's diesel fuel.

In Brazil sugar cane derived ethanol already has displaced 40 percent of its gasoline, and could displace 100 percent by 2008.

And as ethanol is derived from cellulose, the amount of feedstock available soars. The Institute for Local Self-Reliance has calculated that there is sufficient land (that is not

[2] Gasoline is a chemical stew of over 100 individual chemicals. The gasoline you buy in the summer has a different chemical composition than the gasoline you buy in the winter. The same grade of gasoline you purchase on one side of the street may vary from the gasoline you purchase on the other side, even in the same season. Ethanol, on the other hand, is a single chemical. Except for the additives required by the Bureau of Alcohol, Tobacco and Firearms, fuel ethanol is the same wherever you buy it.

currently growing food) and waste materials available to produce over 100 billion gallons of ethanol a year, on a sustainable basis.

That's the good news. The bad news is that biofuels, or for that matter, any other energy source, will never displace gasoline and diesel if we continue to increase our consumption of oil and continue to drive inefficient vehicles. A biofuels strategy, like any other renewable energy strategy, must emphasize reducing demand as much as increasing supply. For those interested in examining a comprehensive transportation strategy that relies on currently available technologies and materials to completely displace our need for oil, see A Better Way.

There are a couple of other important points to consider about ethanol. One is cost. Until recently, ethanol has been much more costly than gasoline and vegetable oil has been much more costly than diesel. But at prices above $55 per barrel of crude oil, biofuels are competitive without any incentives. Brazil eliminated its ethanol subsidies in the mid 1990s. Today the price of ethanol at Brazilian gas stations is about half that of the price of gasoline.

The issue of cost should also be viewed in a couple of other ways. First, we should take into account the real costs of using gasoline. At a minimum this would include the military costs of protecting our access to oil. The costs of the Iraq war, for example, are $250 billion and rising. Before the Iraqi War, the Pentagon estimated the portion of the military budget that could be allocated to oil protection. This amount, if imposed as a tax at the gas pump, would eliminate the need for biofuels subsidies.

Also, we should recognize that biofuels are a unique form of renewable energy because they come with built-in storage. The energy from most renewables, like wind power and solar power, must be stored. Thus an electric car requires batteries. Ethanol is its own "battery" as well as its own fuel source. Thus in comparing costs of various energy sources we should include the cost of storage as well.

Finally, biofuels contain molecules that can be made into physical products. We cannot make physical products out of wind or sunlight. Thus we cannot ever think of wind or sunlight displacing petrochemicals (e.g plastics). Some believe that in the future ethanol refineries will become biorefineries, producing a variety of chemical products in the same way that oil refineries produce multiple products.

And finally, we come to the question of the economic impacts of biofuels. Because of the bulky nature of plant matter the processing of plants into biofuels will occur in agricultural areas. Biorefineries can be economical at much smaller scale than petroleum refineries. Thus they lend themselves to farmer ownership. Farmer-owned operations dramatically improve the biorefineries' positive economic impact on the farmer, the community and the region. Regrettably, the federal biofuels incentives do not try to maximize the economic benefits of the incentives, nor are they designed to tackle our immense agricultural problems while they address our energy problems. Some states, like Minnesota, have designed policies that have succeeded in establishing a significant farmer-owned, fuel-producing sector (see Ethanol Production – The Minnesota Model).

And now, to answer your question (for those of you who have hung around to this point): Personally, I prefer performance rather than prescriptive standards. That means standards that establish a performance guideline rather than mandate the use of a specific fuel. Thus I favor a renewable fuels standard rather than an ethanol or even biofuels mandate.

More than a dozen states have enacted a renewable portfolio standard for electricity use. This is a good model. In practice, the renewable portfolio standards have been wind energy mandates, but they do not mandate wind. Similarly, a renewable fuels standard for cars would be, for the next 10-20 years, functionally a biofuels mandate. But in establishing a performance standard, it allows for flexibility. In the future electric vehicles fueled by wind generators, or hydrogen vehicles that use biomass as their hydrogen source, would qualify.