tested, but results to date are tentative and the chemicals are too costly for recommendations to be made. Beyond these, no specific practices can be recommended.

The use of resistant cultivars is the only acceptable tool for the farmer. We know that resistant germplasm is present in all major crops that have been tested. Likewise, there are a number of resistant cultivars on the market and in use. Most of these are being inadvertently used by farmers because other qualities of the cultivars are desirable. Currently however, there are no specific programs with a focus on breeding for ozone resistance. Such programs may or may not become viable depending on the success of current ozone control strategies. Farmers could request information on the likely susceptibility to ozone of crop cultivars that they plan to use.

Our primary recommendation to farmers is to become knowledgeable about the effects of ozone on crop production systems and to give some consideration to cultivar selection and management practices where they may be helpful. A knowledge of the symptoms associated with ozone on the crops of interest and how these translate to effects on yield can be used to help the farmers make management decisions. Those who keep up with EPA attempts to control ozone concentrations will have a better idea of the future importance of ozone in production management. ■

Alternative Fuel Sources

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by John W. McClelland, Agricultural Economist, Office of Energy, USDA, Washington, DC

President Bush declared that "Every American expects and deserves to breathe clean air . . . . " Toward that end, agriculture has a crucial role to play. Farm products not only can substitute for fossil fuels, but are also renewable, and we do not have to depend on other countries for them. Agriculture also must adjust, along with other sectors of the U.S. economy, as the Nation moves closer to the goal of clean air.

Passage of the 1990 Clean Air Act Amendments marked the first major overhaul of the Nation's clean air legislation in more than a decade. This legislation will have a significant impact on U.S. agriculture. Mandates for clean fuels and oxygenated fuels are likely to boost the demand for

ethanol and nearly double the size of the industry by the year 2000. Further, the Budget Reconciliation Act of 1990 extends to the year 2000 tax credits that help make ethanol cost-competitive with other clean fuel additives. These tax credits, combined with the successful development of ETBE (ethyl tertiary butyl ether), an ethanol oxygenate compound, could increase the yearly demand for ethanol by 535 million gallons before the turn of the century.

Corn is the main feedstock used in ethanol production, but research and development money provided in the 1990 farm bill will help develop improved conversion technologies and diversify alternative fuels production in the agricultural sector. Research on using vegetable oils to produce a marketable replacement for diesel fuel could also increase the demand for these oils. This total package of legislation, research, and development could increase net farm income and provide American farmers with an opportunity to have a positive impact on an important resource: the air we breathe.

In this chapter, we will discuss those provisions of the Clean Air Act and other recent legislation that affects U.S. agriculture.

Carbon Monoxide Nonattainment Areas

Carbon monoxide is formed when fuels are burned incompletely. Automobile fuels, in particular, do not burn well at high altitudes because the oxygen content in the atmosphere is reduced and there is no oxygen in conventional gasoline. Cold weather can also increase the amount of carbon monoxide produced by automobile emissions. Carbon monoxide gets priority attention in the Clean Air Act because high levels of carbon monoxide are known to be hazardous to human health.

Under the Clean Air Act Amendments, carbon monoxide nonattainment areas are designated as moderate or severe. Table 1 shows the atmospheric levels and mandated dates for attainment. States with areas designated as moderate must make an inventory of all carbon monoxide sources and take steps to enhance vehicle inspection and monitor vehicle miles traveled. Areas of serious carbon monoxide nonattainment must meet these same standards as well as the standards for a severe ozone

Table 1—Carbon monoxide classification areas

Area classification	Design value	Attainment date
Moderate	9.1 to 16.4	Dec. 31, 1995
Serious	16.5 and above	Dec. 31, 2000

nonattainment area (see table 2 and discussion below). There are also provisions for controlling particulate matter from stationary and nonstationary sources, along with standards for sulfur dioxide, nitrogen dioxide, and lead.

Ozone Nonattainment Areas

Ozone is of major concern because ozone pollution is caused by the presence in the atmosphere of nitrogen oxide and other volatile organic compounds (VOC) that interact with sunlight to create smog. VOC's result from the evaporation of gasoline and other solvents, and from car and truck exhaust. Nitrogen oxides result from burning fossil fuels, including gasoline and coal. Ozone is a greenhouse gas that contributes to global warming. Aside from its contribution to global warming, ozone pollution is also associated with human health problems, and significant reductions in crop yields have been reported. Even brief exposure to high levels of ozone can cause temporary loss of some lung function, but there is only limited understanding of the risks of long-term exposure. Scientists in California estimate yield reductions as high as 45 percent for some crops in areas with high levels of ozone pollution.

According to the new Clean Air Act Amendments, areas can be classified as ozone nonattainment areas if they fall into any of the five categories listed in table 2. States that contain all or part of a nonattainment area are required to submit both State-level implementation plans for compliance with the law and a State emissions inventory. Areas classified as moderate or above are required to reduce emissions of VOC's and nitrogen oxides. Areas classified as serious or above will further be required to provide economic incentives for moving toward clean fuel vehicles. Severe areas must, in addition, enact an emissions reduction program that offsets any increase in emissions that would

Table 2—Ozone classification areas

Area classification	Ozone design value (parts per million)	Deadline for compliance
Marginal	.121 up to .138	3 yrs. after enactment
Moderate	.138 up to .160	6 yrs. after enactment
Serious	.160 up to .180	9 yrs. after enactment
Severe	.180 up to .280	15 yrs. after enactment
Extreme	.280 and above	20 yrs. after enactment

be caused by an increase in vehicle miles traveled. Finally, extreme areas must meet all previously mentioned requirements and make further use of clean fuel technologies at large commercial sites.

Methane

By 1992, the Environmental Protection Agency (EPA) Administrator is required to submit reports to Congress that identify the activities and processes for reducing methane emissions. The EPA Administrator must also prepare, with the Secretary of Energy and the Secretary of Agriculture, a report that will include an evaluation of methane emissions from agricultural activities. In particular, the report must include an inventory of activities in rice farming and livestock production, and the intentional burning of agricultural waste, grassland, wood, and forests.

Within 2 years after the studies are completed, the Administrator must submit a report to Congress outlining measures that could stop or reduce methane pollution from these sources. It is difficult to determine what steps might be taken to meet methane reduction goals in the agricultural sector, and the effects they will have. They could include regulations on waste disposal and changes in production practices. One possibility would be to improve existing technology that allows farmers to capture the methane from farm waste and convert it to usable forms of energy.

Ethanol's Role in Clean Air

Ethanol began to attract attention as a motor fuel additive in the late 1970's when the Federal Government got serious about eliminating lead emissions. Ethanol is an octane booster and can be used as a substitute for lead, and for VOC's, such as benzene, that have also been used as lead substitutes. Ethanol contains oxygen and thus can be used as an ingredient in oxygenated fuels. There is also a process that uses ethanol to remove sulfur and other impurities from coal, thus reducing sulfur dioxide emissions that contribute to acid rain.

The Clean Air Act Amendments call for the EPA to issue regulations establishing requirements for reformulating gasoline. The regulations are to be in place by October 1, 1992, for carbon monoxide nonattainment areas, and January 1, 1995, for ozone nonattainment areas. These regulations will also include the following requirements:

- Nitrogen oxide emissions from reformulated gasoline cannot exceed those from standard gasoline.
- The oxygen content of reformulated gasoline must exceed 2 percent by weight in ozone nonattainment areas and 2.7

percent by weight in carbon monoxide nonattainment areas.
- Benzene content cannot exceed 1 percent by volume.
- There can be no lead in reformulated gasoline, and aromatic hydrocarbons (these include benzene, toluene, and xylene) must not exceed 25 percent by volume.
- Fuel volatility (evaporation rate) must be reduced during the summer in high-ozone areas.

A system of market credits will also be established that allows producers to earn credit for reformulated gasoline that exceeds these standards. The credit system will allow distributors to average the oxygen content of all gasoline sold in a nonattainment area. Thus, a distributor may average the oxygen content of gasoline exceeding the standard with that of gasoline below the standard, and have the average of the two meet the standard.

Ethanol can be used as a blending agent to achieve the requirements of new regulations for reformulated gasoline. Gasohol contains 3.7 percent oxygen, well above the required standards—thus providing blenders with possible market credits. Since ethanol is an octane booster it can replace lead and aromatics in gasoline blends. Ethanol does increase fuel volatility (the rate at which VOC's evaporate into the atmosphere), but the legislation provides an ethanol exemption by setting higher volatility standards for ethanol blends.

Ethanol Demand From the Clean Air Act

Ethanol is not the only fuel additive that can be used by gasoline producers to meet the new standards. Methanol is an alcohol produced from natural gas or coal. Methanol alone cannot be easily blended with gasoline to produce a usable fuel. However, it can be converted to an ether called methyl tertiary butyl ether (MTBE) that can be blended easily with gasoline.

A major advantage of MTBE blends over ethanol blends is cost. MTBE blends can be produced at the refinery and transported in standard pipelines, while ethanol must be splash-blended and cannot be shipped in a pipeline. Ethanol blends also require increased diligence on the part of blenders and service station operators to maintain clean tanks that are not contaminated with residues from other fuels, water, or dirt. Ethanol is a solvent that will readily take these impurities from contaminated facilities and hold them until they are filtered or burned. This causes plugging of filters in gas pumps and cars, adding to the cost of providing ethanol blends.

In 1990 the United States produced about 875 million gallons of ethanol. Ethanol's advantage is

its high oxygen content. The EPA allows ethanol to be blended at a 10-percent rate to produce gasohol. Gasohol has an oxygen content of 3.7 percent. MTBE can be blended at a 15-percent rate, but contains only 2.7 percent oxygen; 11-percent MTBE blends contain 2.0 percent oxygen.

Under the regulations, blenders could get by using only MTBE blends, but in carbon monoxide nonattainment areas, all gasoline sold during times of the year when oxygenated fuels are required would have to be reformulated, and distributors would not be able to earn any credits. Using gasohol would allow sellers of gasoline to take advantage of credits because the high oxygen content of gasohol could be averaged with straight gasoline or MTBE blends to meet the minimum requirements.

While cost will be a consideration, the passage of the Clean Air Act will cause the demand for ethanol to increase. USDA and EPA have estimated that 20 percent of the market for oxygenated fuel will go to ethanol in 1993. This would require an additional 246 million gallons of ethanol, the equivalent of 98 million bushels of corn. Current annual U.S. ethanol production stands at 825 million gallons. Table 3 shows preliminary estimates of additional ethanol demand up to the year 2000 and the corn feedstock equivalent. Actual demand will depend on future technologies for producing ethanol and on future policies.

Enhancing Ethanol

An important innovation that may soon have an effect on ethanol's position in the market is ethyl tertiary butyl ether (ETBE). ETBE is made from ethanol and isobutylene, an oil refinery gas. ETBE incorporates the positive properties of neat (100 percent) ethanol, but ETBE blends, similar to MTBE, can be transported in pipelines and handled as regular gasoline.

Corn is the main feedstock used in ethanol production. However, research and development provided for in the 1990 Farm Bill will help develop new technologies that can permit use of diversified alternative fuels that will be produced in the agricultural sector.
Gene Alexander/USDA SD-885-23A

This will reduce some of the additional costs associated with neat ethanol. ETBE also reduces fuel volatility to levels that meet the new standards. A recent study by Phillips Petroleum Corporation found ETBE to be superior to both ethanol and MTBE as a blending agent.

Because ETBE is still experimental, it is difficult to predict its effect on the oxygenated fuel market. Positive test results suggest that ETBE could strengthen ethanol demand over the next 10 years.

Vegetable Oil as a Diesel Fuel Substitute

Unprocessed vegetable oils such as soybean, sunflower, rapeseed, and crambe oil tend to be 20 times or more thicker than diesel fuel. They will not flow in cold weather and when burned produce sticky deposits on engine parts, quickly leading to engine failure.

Table 3—Estimated demand for gasoline, oxygenated fuel, ethanol, and corn feedstock to meet Clean Air Act, 1993-2000

Year	Gasoline (billion gallons)	Oxygenate (ethanol equivalents) (million gallons)	Ethanol[1] (million gallons)	Corn feedstock (million gallons)
1993[2]	115.4	1,230	246	98
1994	116.5	1,242	248	99
1995[3]	117.7	2,544	509	204
1996	118.9	2,570	514	206
1997	120.1	2,596	519	208
1998	121.3	2,622	524	210
1999	122.5	2,648	530	212
2000[4]	123.7	2,674	535	214

[1] Assumes 20 percent market penetration.
[2] Clean Air Act (CAA) requires 2.7 percent oxygen in 41 cities not meeting the CO standard, effective Oct. 1, 1992. (Assumes a 4-month winter CO period with an additional month spillover to assure delivery. It also assumes a 15-percent spillover into adjacent areas that are in compliance due to distribution patterns).
[3] CAA requires 2.0 percent oxygen yearround in nine cities not meeting the ozone standard, effective Jan. 1, 1995. Assumes a 15-percent spillover into adjacent areas that are in compliance due to distribution patterns).
[4] CAA requires 3.1 percent oxygen in any area not meeting the CO standard by Jan. 1, 2000. The estimates shown do not consider the impact of any area not meeting the standard.

But through a process called esterification, whereby ethanol or methanol is added in the presence of a catalyst, a restructured vegetable oil is formed that is nearly equivalent to diesel fuel. It even has some properties that make it superior to diesel, including its extremely low level of sulfur and sharply reduced particulate levels. Even a 15-percent blend of esterified vegetable oil will sharply reduce the smoke from a diesel bus, truck, or tractor. Esterified vegetable oil can replace or be blended with diesel fuel, without affecting engine service life.

Research is continuing to determine the exact components of vegetable oil emissions and to improve the conversion process and reduce production costs so that it can compete with diesel fuel.

Twenty percent of the market for oxygenated fuel will go to ethanol in 1993. This would require an additional 246 million gallons of ethanol, the equivalent of 98 million bushels of corn.
USDA BN-14327

How Other Legislation Affects Alcohol Fuels

Two other pieces of legislation passed in 1990 will also facilitate development and production of ethanol from agricultural products.

The 1990 farm bill authorizes $20 million for each fiscal year, 1991 through 1995, for research on alcohol fuels, industrial oilseed crops for diesel and petrochemical substitution, and other biomass as a feedstock for alcohol production. The bill provides that at least 50 percent of these funds be made available for research on technologies to increase the energy efficiency and commercial feasibility of alcohol production.

Research priorities include improvement in cellulose conversion and membrane technology, improvement of byproducts as animal feed, and development of new markets for byproducts. Appropriations for fiscal year 1991 are $514,000. The provisions of this bill could significantly improve the technology used to produce alcohol fuels and diversify the number of agricultural products that can be converted to alcohol.

The Budget Reconciliation Act of 1990 extends tax credits for ethanol as an alternative fuel under the Clean Air Act, because it affects the cost of producing ethanol and the market price of ethanol. This Act changes the alcohol

fuels tax credits and provides an additional tax credit for "small" producers of ethanol. The tax credit for producers or blenders has been reduced from $.60 per gallon of ethanol to $.54 per gallon. In lieu of the income tax credit, a $.054 per gallon exemption from the Federal fuel excise tax may be claimed for sales of fuel that is 10 percent ethanol. These exemptions are extended through the year 2000. The law also provides small producers with an additional $.10 per gallon income tax credit for the first 15 million gallons of ethanol production from facilities that have a total annual production capacity of less than 30 million gallons. These provisions help to make ethanol cost-competitive in the marketplace. They also provide additional incentives for small producers who lack economies of size, and for those who may use other feed stocks, such as cheese whey, which are available in areas outside the Corn Belt. ■

Interagency Alternative Fuels Research

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by Roger Conway, Director, and Earl Gavett, Consultant, Office of Energy, USDA, Washington, DC

USDA fosters clean air goals by coordinating with other Federal agencies in order to achieve environmental objectives as efficiently as possible. Some of these efforts have just begun; others are recently completed or still in process. All of these efforts seek to achieve and maintain cleaner air while at the same time supporting strong and sustainable economic growth with a sound energy policy. Whenever possible, market-based approaches are pursued.

USDA and DOE Work Together on Alternative Fuels Research

USDA and the U.S. Department of Energy (DOE) are collaborating on research to develop alcohol and substitute diesel fuel from biomass energy crops, which would enhance air quality and improve U.S. energy security. To facilitate this cooperation, a Memorandum of Understanding was recently approved by the two Departments. The Memorandum provides a strategy that outlines goals, oppor-