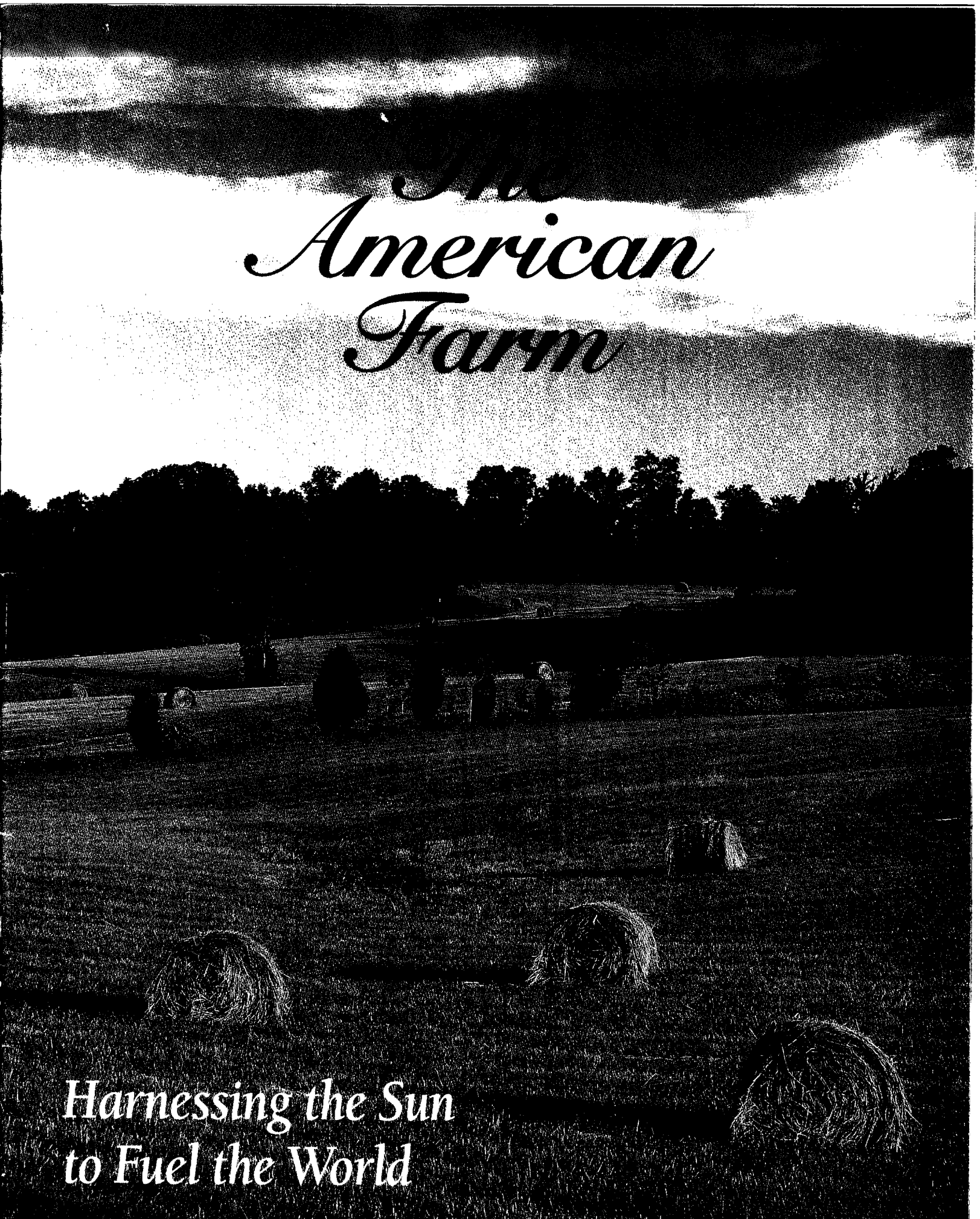


The American Farm

Harnessing the Sun to Fuel the World

The Great American Energy Harvest

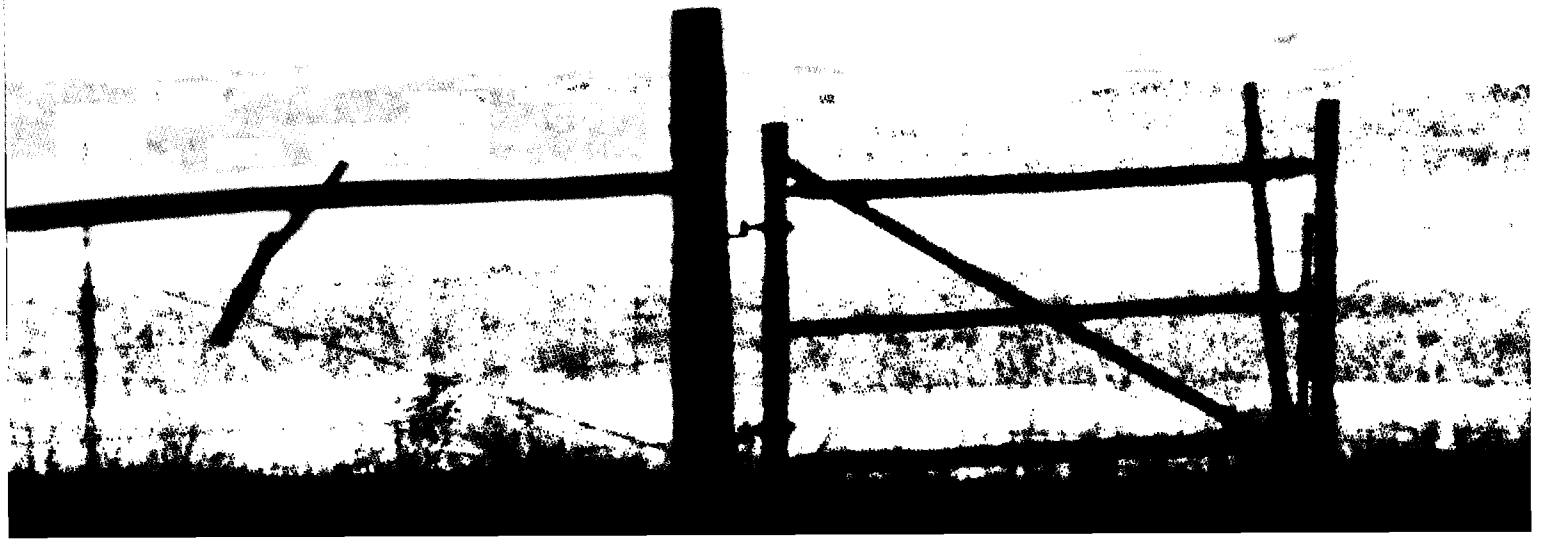
Green plants harvest the energy of the sun.
When people eat vegetables or animals that eat plants,
we call this solar energy FOOD. When cows eat corn,
we call this solar energy FEED. When paper companies take energy-rich
plant materials and turn them into cardboard, we call this FIBER.
American farmers excel at using the sun to make food, feed, and fiber.

Farmers have already begun to harness the sun to make the
same kinds of energy we get today from fossil fuels. They grow energy crops to
make biodiesel and alcohol FUELS. Soon energy crops will also produce
ELECTRICITY and CHEMICALS such as plastics.
Energy crops include corn, oilseeds, and fast-growing trees and grasses.

Farmers work hard to feed the nation.
With good conservation practices, there's plenty of land left over to grow
energy crops—enough to replace some of the coal and oil the nation uses.
Home-grown solar energy is going to be more than plentiful
food, feed, and fiber. The new solar energy harvest will provide
an abundant source of fuels, electricity, and chemicals.

Government officials, utilities, biofuel companies, farmers, and foresters
are already thinking about how to create large regional energy networks
based on energy crops. They want tomorrow's energy harvest to be bigger and
more profitable than it is today, while fully sustaining our resources.

Growing crops for energy will bring energy industries into rural areas.
Transporting energy crops is expensive. Power plants and fuel companies
will be within 50 miles of the farms that grow energy crops.
New energy industries will create jobs and bring money
back into rural America.



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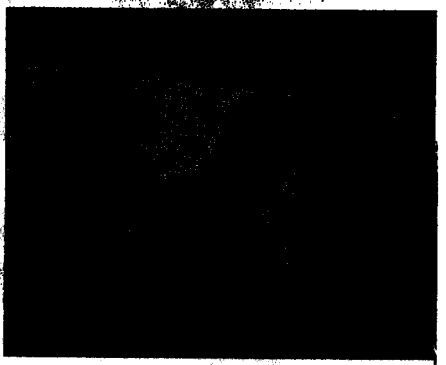
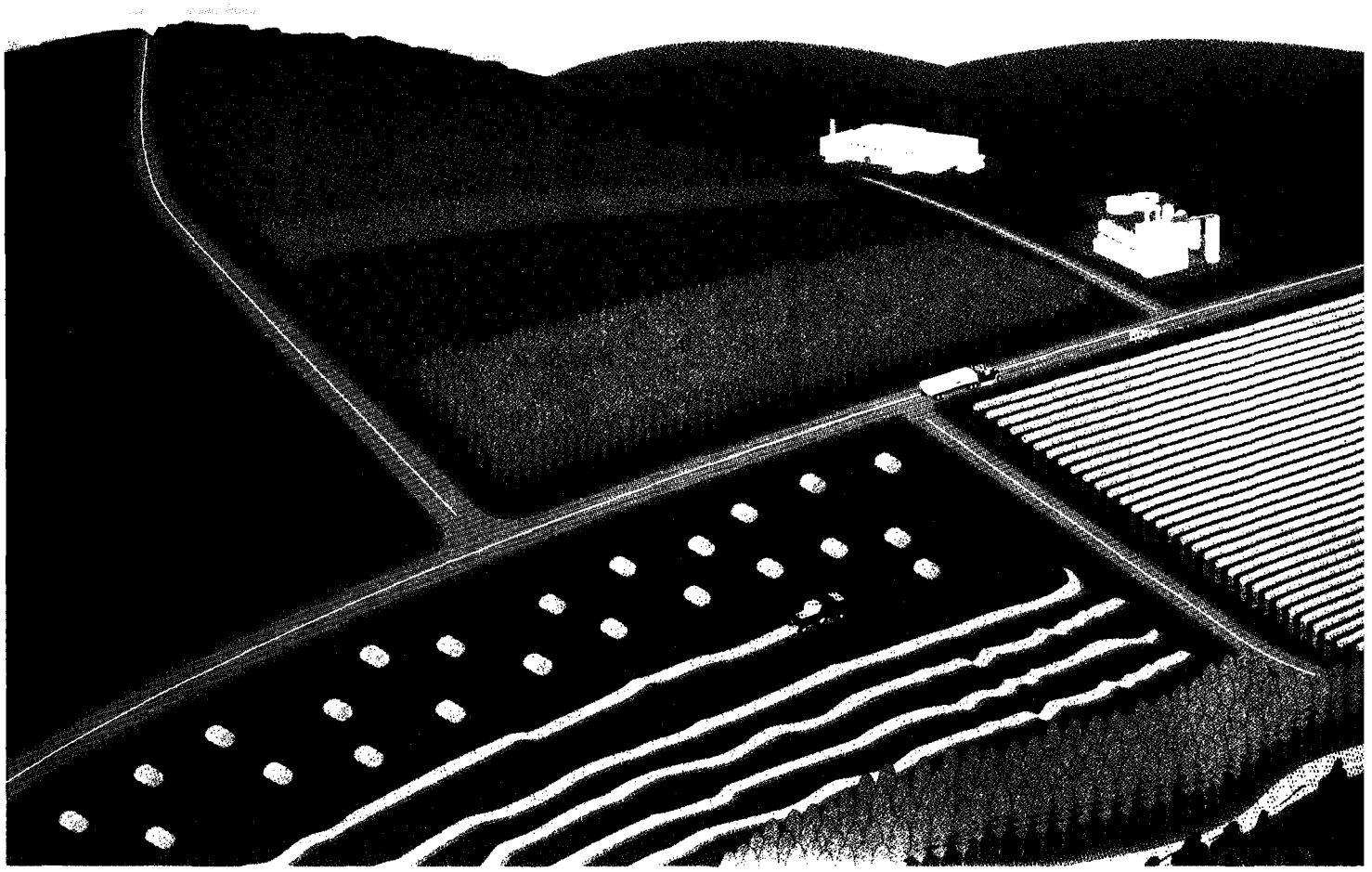


AMERICA'S FARM OF THE FUTURE WILL PRODUCE NOT ONLY FOOD, FEED, AND FIBER, BUT ALSO ELECTRICITY, FUELS, AND CHEMICALS.



Expanding the Horizons of Agriculture

Tomorrow's farm will produce crops like corn, soybeans, rapeseed, and sunflowers for food and fuel. Farmers will harvest switchgrass and then sell it for feed or to make ethanol. They'll cultivate tree crops for as long as a decade and then harvest them for fiber or energy.

Farmers will plant food crops as usual. Perennial energy crops will surround food crops, creating islands of soybeans, corn, and other intensely cultivated crops. The trees and grasses will renew the soils and help sustain our resources. They'll soak up chemical run-offs, protecting the groundwater and nearby streams and lakes.

Large farms can supply an energy plant year-round. A power plant, an ethanol facility, and a plastics company are possibilities. Smaller farms will contract with an energy cooperative for energy processing. These regional energy industries will employ friends and neighbors.

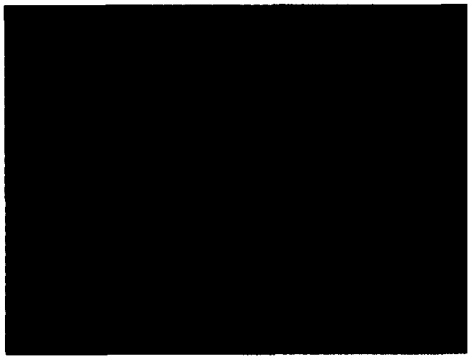
Power plants will contract with farmers to return nutrient-rich residues to the land. The ash left over from burning trees contains minerals to replenish the soil. Recycling this ash is safe. It reduces the need for fertilizer and makes soils less acidic.

Coproducts from ethanol plants could be a nutritious, inexpensive feed for farm animals. To take advantage of this, farmers might want to integrate fuel crop production with dairy, beef, pork, or poultry farming. Livestock manure could be returned to the soil as fertilizer, or farmers could convert it to biogas to make electricity.

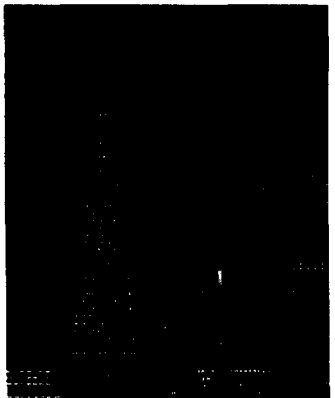
Growing food and energy. Raising livestock. Conserving the land and its resources. Recycling. Neighbors working together. American farmers have done these things for more than 300 years. Energy crops and new markets won't change this, they'll just make it more profitable.

Trees and grasses are an excellent resource for making clean-burning transportation fuels such as ethanol.

Tomorrow's Farm



Farmers grow crops that provide many valuable chemicals. This brochure was printed using biodegradable soybean inks, shown here.



By 2010, energy crops could generate enough electricity to meet the residential needs of 20 cities the size of San Francisco.

PLANTING TREES BETWEEN ROW CROPS AND STREAMS PROTECTS THE WATER FROM BEING POLLUTED BY FERTILIZERS AND PESTICIDES.

A scientist tests water quality in a creek protected by poplar trees that filter run-off water from nearby crop fields.

Farming that Protects the Environment

Many farmers think they're misunderstood by environmentalists. Ranchers and farmers deal with nature every day to make a living. They worry as much as anyone else about soil erosion, water pollution, and the weather. Probably more so.

Farmers like the idea that energy crops replenish the land. Trees and grasses aren't replanted every year. This helps control erosion. Tree and grass crops help create new soils. The crops' deep roots help retain organic matter.

Organic matter keeps moisture and nutrients in the soil. Crops need less fertilizer. Worms and beetles thrive. These organisms aerate the soil and carry nutrients deep into the ground.

Trees and grasses filter chemicals. Farmers can protect lakes, rivers, and streams from agricultural run-offs with buffer zones of energy crops.

Farmers can plant energy crops along river banks, around lake shores, or between farms and natural forests or wetlands. This creates habitat for wildlife and encourages biodiversity.

Farmers will grow crops for energy and fiber on agricultural lands. No one is suggesting that people cut down natural forests to make tree farms.

Producing electricity with energy crops is good for the air. Energy crops produce fewer acid gas emissions than does coal. Fuels and electricity made from energy crops don't add carbon dioxide to the air, either. In fact, trees and grasses remove as much carbon dioxide from the air when they grow as they release when burned for energy. Replacing fossil fuels with biofuels will help reduce the threat of global climate change.

Farmers can use biofuels. For instance, farm machinery can run on diesel fuels made from soybeans. And ethanol made from corn, grass, or trees works just as well for automobiles in the country as it does for those in the city.

Home-grown fuels can help farmers take care of their land.

Fields of trees or grasses grown for energy can provide habitat for wildlife and birds such as this warbler family.

The nation's forests and woodlands will be preserved by growing tree crops for fiber and energy.

One way to make farming more profitable is to grow energy crops on lands that aren't needed for food, feed, and fiber.

Making the Land Productive & Profitable

Farmers and ranchers work with the land—planting trees, rotating crops or pastures, and practicing the stewardship it takes to keep the soil in place and make it fertile. They work hard to keep their land productive. America's abundant food supplies are a testament to the farmers' and ranchers' success. It's ironic that there are times when it's hard to make a decent living farming.

One way to make farming more profitable is to develop new markets for crops. Grass and tree crops can be grown on land that isn't needed to grow food, feed, and fiber. At first, government incentives may be necessary for the new crops to be as profitable as today's crops.

A few local markets for energy crops already exist. Some pulp and paper companies purchase wood for fiber and energy. There are about 1000 small power plants in this country equipped to run on wood or agricultural wastes. And there are large power plants that may start burning wood with coal to reduce air emissions.

The U.S. Department of Energy (DOE) may spearhead regional demonstrations of new energy technologies based on energy crops. Where there isn't already a market for energy crops, farmers could get involved with one of these demonstrations. Many farmers must be involved in these demonstrations to successfully establish new markets.

Once there is a market, energy industries and farmers can negotiate long-term agreements with each other. After that, growing energy crops will be stable and profitable. Farmers won't need incentives to keep land out of production.

New energy industries will create local jobs and raise the standard of living in rural communities. These firms, as they grow, will bring new business and stimulate the whole region. In fact, energy crops could make agriculture one of the nation's fastest growing businesses.

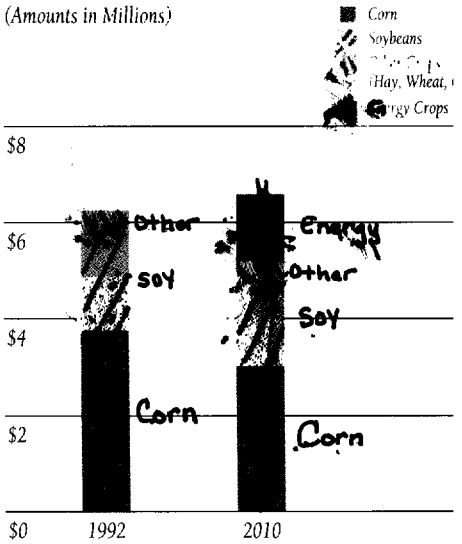
With energy crops, some of the money spent on oil imports could flow into rural America. There would be more money for schools, police and fire protection, libraries, senior centers, and other community services.

That's not all. The whole country would benefit from using clean and renewable fuels grown right here at home.

New rural energy industries will create local jobs. There will be more money for schools, libraries, and community services.

Potential Value of Crop Productio with Energy Crops

(Amounts in Millions)



1992 figures and 2010 projections are for a hypothetical midwestern state with a large farm industry.

RAPESEED IS A SOURCE OF BOTH CANOLA OIL AND BIODIESEL FUEL. THIS FARMER CAN SELL HIS HARVEST FOR FOOD OR ENERGY.

American farmers grow plentiful supplies of food; soon they'll produce plentiful supplies of energy.

Food & Feed: Triumph of American Ingenuity

The American farm has been transformed during the last 100 years. It's no longer a self-sufficient family enterprise producing only modest amounts of food for sale. The American farm has become big business. Every year, farmers grow enough food for more than 250 million people. They also produce enough feed to support thriving beef, pork, poultry, and dairy industries.

Remarkably, American farmers still export one-quarter of all the food they raise. The export market—worth $30 to $40 billion—is nearly equal to the cost of oil imports.

Farmers have a lot to be proud of. The U.S. farm output doubled from 1950 to 1980. Chemical fertilizers, improved seeds, better machinery, larger fields, and better pest control all made a difference. Today, farmers feed more than four times as many people as they did just 40 years ago.

This trend is likely to continue into the next century. American farmers will continue to produce plentiful supplies of food and feed. They will do this with even less land in the future than they need today.

The Department of Agriculture estimates that there will be about 100 million acres available for growing energy crops in the 21st century.

American farmers produce enough feed to support prosperous beef, pork, poultry, and dairy industries.

Fiber: Growing Trees for Pulp, Paper, & Energy

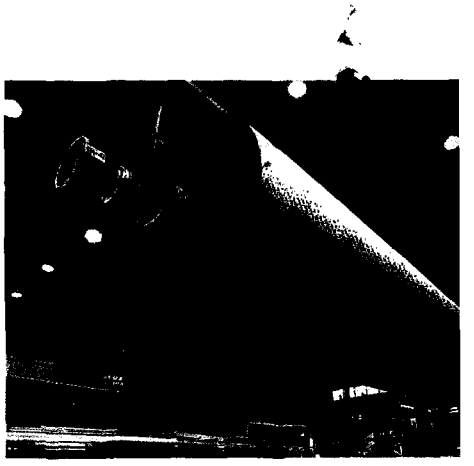
Until the 1930s, Americans just cut down trees whenever they needed more wood. Today, we manage forests more wisely. We also recycle sawmill residues and wastepaper to make new products.

Paper companies grow much of their wood on carefully tended plantations. When they harvest trees after 40 to 60 years, they plant more. These companies must be good stewards of the land, because that's how they keep wood chips flowing to their paper mills year after year.

Not surprisingly, America maintains the world's largest paper and paperboard industry. The industry has sales of more than $130 billion a year.

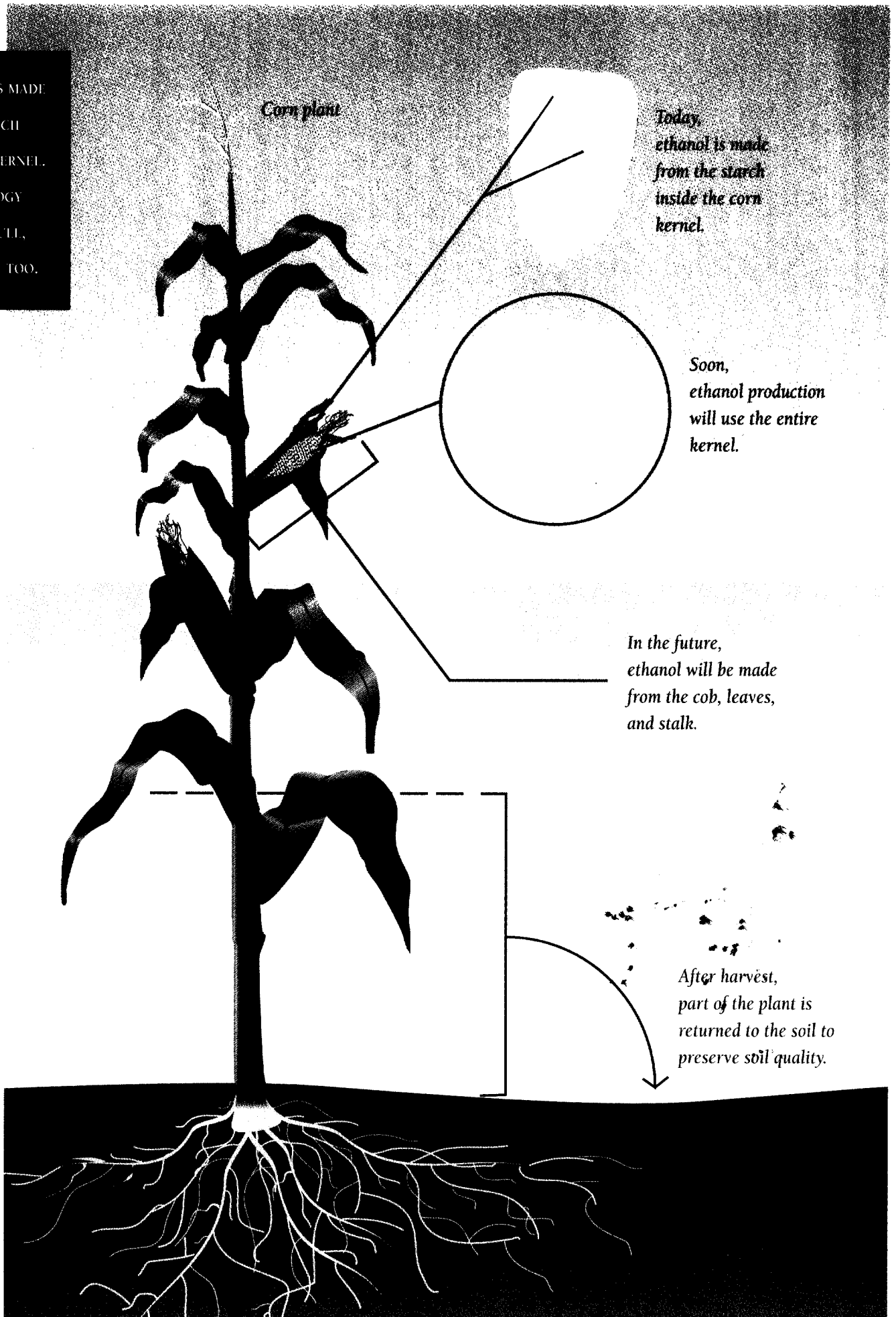
Most paper companies use their trees for fiber and energy. The demand for fiber and energy influences the economics of tree farming. The synergism is working well.

Healthy competition will keep tree farming profitable. More markets will lower the risk of planting new tree crops. And growing tree crops protects our natural forests.



The pulp and paper industry pioneered techniques for growing tree crops to meet the nation's demand for fiber.

TODAY, ETHANOL IS MADE FROM THE STARCH INSIDE THE CORN KERNEL. NEW TECHNOLOGY WILL USE THE HULL, COB, AND STOVER, TOO.



Home-Grown Electricity, Fuels, & Chemicals

Home-grown energy isn't new. Our ancestors began burning wood for warmth, light, and cooking more than 400,000 years ago. More than 2 million Americans heat their homes with wood. The forest products industry burns its own wood wastes to produce about half of the energy it consumes.

Many small power plants across the United States burn wood, wood wastes, or agricultural residues. Together, they generate about 1% of the electricity the nation uses each year. Local utility companies purchase about one-third of this power. The wood and paper industries, which own many of the power plants, use the rest.

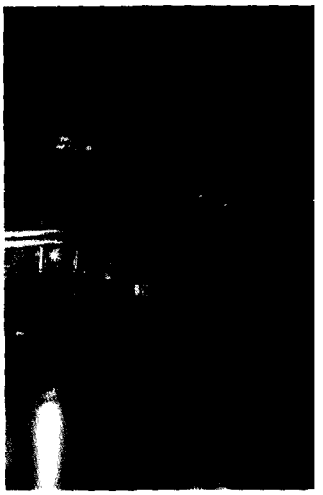
Automobile pioneer Henry Ford first championed the use of fuel alcohol in the 1920s. He thought it would benefit the farm industry. During the 1930s, more than 2000 Midwestern service stations offered gasoline containing anywhere from 6% to 12% ethanol made from corn. Because of its high cost, "gasohol" disappeared in the 1940s.

Today's corn ethanol industry traces its beginning to this "power-alcohol" movement. Ethanol-gasoline blends were reintroduced in 1979 in response to oil supply disruptions. In 1992, farmers sold more than 5% of their corn crop to make about 1 billion gallons of ethanol.

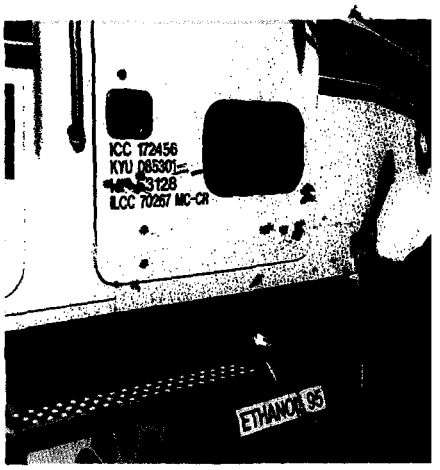
Sorghum, soybeans, and other "food" crops can also be made into fuels or chemicals. Forage sorghum is a raw material for producing ethanol. Oils made from soybeans, sunflower and safflower seeds, and rapeseed are good raw materials for producing biodiesel fuels.

Vegetables, trees, and other crops provide raw materials for many important chemical products. For instance, about three-fourths of the nation's newspapers now use soy ink. Other valuable chemicals derived from plants include cosmetics, soaps, medicines, resins, lubricants, adhesives, paints, varnishes, wax, plastics, solvents, and fabrics such as rayon.

Multi-use annual crops give farmers flexibility. They make it easier to rotate crops and supply diverse markets. Trees and perennial grasses offer these same advantages plus better control over soil erosion.



Agrilectric Power in Lake Charles, Louisiana, is a commercial power plant fueled by rice husks.



This truck's engine has been modified to run on 95% ethanol, a biofuel made from corn.

THE WHEELABRATOR SHASTA ENERGY COMPANY USES BOILERS AND STEAM TURBINES TO CONVERT WOOD AND AGRICULTURAL WASTES INTO ELECTRICITY.

Wheelabrator Shasta Energy Company, Anderson, California.

The National Renewable Energy Laboratory developed this fast-pyrolysis technology to convert energy crops into biocrude oil. Biocrude oil is a source of fuel additives and fuel for making electricity.

New Energy Markets for Farmers

Government researchers are working to make fuels from wood, corn, and other plant materials more competitive with fossil fuels.

For more than 15 years, DOE, through its National Renewable Energy Laboratory (NREL), in Golden, Colorado, has explored new technologies to make biofuels as affordable as natural gas, petroleum, or coal. These technologies will help create new markets for energy crops.

Energy crops are the only resource capable of offsetting a major fraction of the petroleum the nation uses for transportation fuels. There aren't enough wastes to do this. The nation's corn crop must be used primarily for food and feed.

New technology will make it possible to get more ethanol from corn. NREL has developed a process for making ethanol from cellulose-rich trees, grasses, and crop residues such as corn stover. Making ethanol from residues will pave the way for making fuel from trees and grasses.

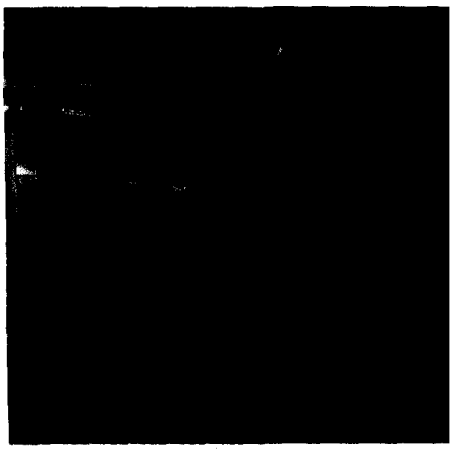
During production, trees and grasses require fewer fossil fuel inputs than corn. The conversion process produces a coproduct suitable for use as a boiler fuel. This fuel provides electricity and process heat for the fuel plant.

The result is a product containing five times more net energy than that required to produce it. By 2000, this process will make ethanol from the cellulose in paper or agricultural wastes competitive with gasoline at today's prices.

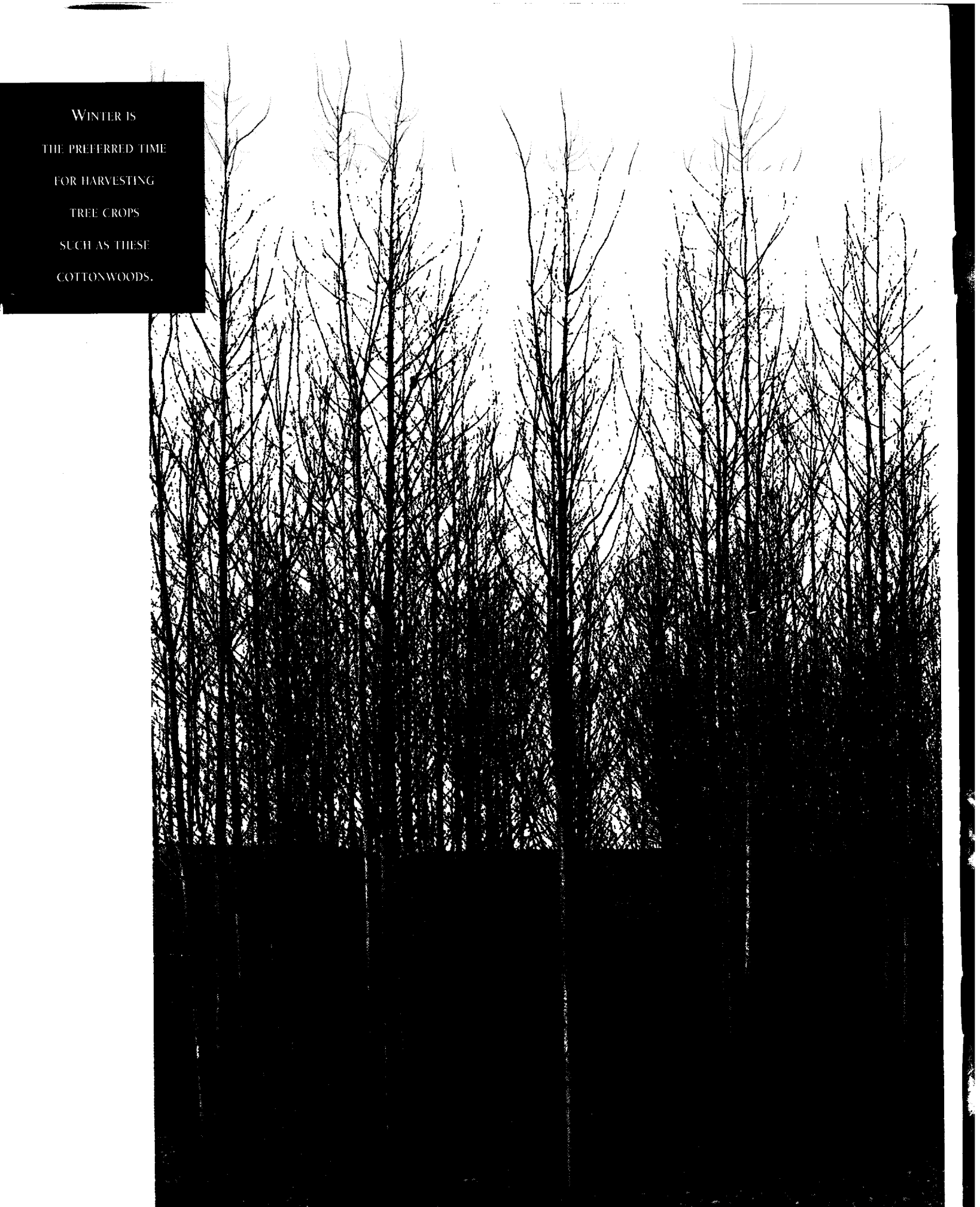
DOE has also figured out how to convert energy crops into biocrude oil. Biocrude oil contains chemicals needed to make biodegradable plastics, adhesives, and gasoline additives such as MTBE and ETBE that reduce carbon monoxide emissions.

DOE is working with industry to develop a gasifier to convert wastes or energy crops into gas. The gas can be used to generate electricity or make methanol, an alcohol fuel similar to ethanol.

New technologies will allow energy crops to generate electricity by means of high-efficiency gas turbines such as this one made by Westinghouse Electric Corporation.



These mills at New Energy Company of Indiana, in South Bend, are used to grind corn for fermentation into ethanol fuel.



WINTER IS THE PREFERRED TIME FOR HARVESTING TREE CROPS SUCH AS THESE COTTONWOODS.

Energy Crops: Diversity & Stability

The typical modern farm concentrates on the production of one or two major commercial products such as corn, soybeans, milk, or beef. The net income of the entire operation is often vulnerable to fluctuations in market demand, unanticipated production costs, the weather, and other factors. With capital investments in land and equipment that can easily top $1 million, there is much to be gained from reducing these risks and stabilizing farm income.

Energy crops provide crop diversity. They may be more resistant to disease and pests than food crops are. They are relatively inexpensive to grow. Costs are still falling.

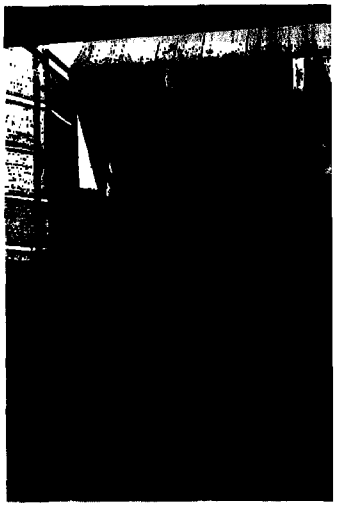
Both trees and grasses are easy to grow as a secondary crop in conjunction with large farming operations. Once trees and grasses are established, they require less fertilizer, fewer pesticides, and less maintenance than annual crops. They improve soil and water resources.

With their deep root systems, perennial energy crops tolerate drought or flooding better than annual crops. They can withstand harsh winter weather. Any way you look at it, perennial energy crops are less vulnerable to the weather than annuals.

Local markets for energy crops should be fairly stable once they are established. Power and fuel plants need reliable resource supplies. These companies might be willing to negotiate long-term agreements that could include annual payments for tree crops.

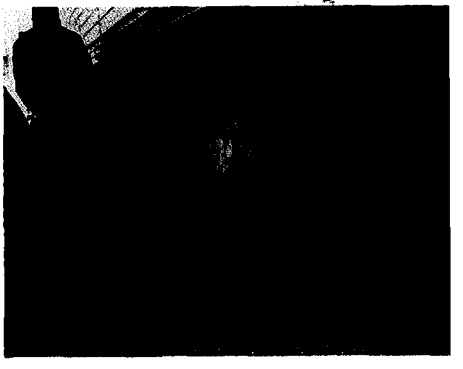
Trees and grasses can be sold for fiber or feed in addition to energy. Multiple markets should allow farmers to turn their tree and grass crops into a dependable source of income.

Crop diversity is money in the bank. It's protection against bad weather, food crop failures, or low commodity prices. It's something to fall back on if price supports disappear. It's good business.



Clean, dry wood chips arrive at a wood-fired power plant.

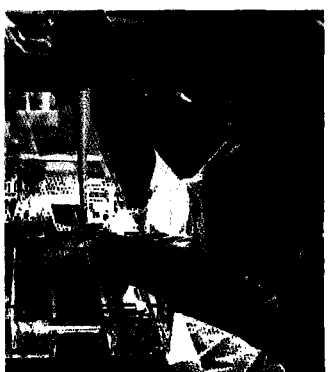
Energy Crops



Corn kernels are delivered to a fuel plant. This facility can convert the entire kernel, including the hull, into ethanol.

"I LIKE TO ENCOURAGE PEOPLE TO CONSIDER TREES AS A CROP ALTERNATIVE. WE CAN ALWAYS USE MORE WOOD FLOWING TO OUR MILLS."

Don Rice, supervisor, Lower C[illegible] Fiber Farm, James River Corporation.



Scientists at Oak Ridge National Laboratory are using techniques such as gel electrophoresis to map poplar genes. Genetic studies will lead to improved tree crops in the future.

Tree Crops

Farmers can now plant profitable tree crops, thanks to more than 15 years of research at Oak Ridge National Laboratory in Oak Ridge, Tennessee. DOE sponsored this research. During this time, researchers tested more than 100 different trees to find the best energy crops.

Hardwood tree crops include hybrid poplars (aspen, poplar, and cottonwood trees), silver maple, sycamore, black locust, sweetgum, eucalyptus, and willow. These trees are undergoing field trials in the Midwest, the Southeast, and the Pacific Northwest. Plant scientists are finding out which species grow best in specific soils and climates.

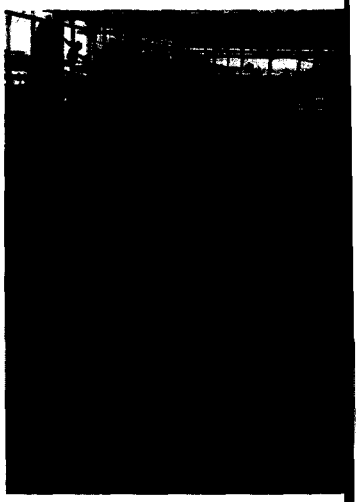
Research now focuses on hybrid poplars as a model tree crop. In the Midwest, researchers are breeding poplars to develop resistance to canker and cottonwood leaf beetle. In the Pacific Northwest, researchers at the University of Washington and Washington State University are mapping poplar genes. They've already identified the gene that controls growth.

Research is paving the way for farmers to produce large volumes of wood. Tree farming belongs to agriculture, not forestry. Standard agricultural practices produce good yields of tree crops. The industries needed to support those practices are already in place.

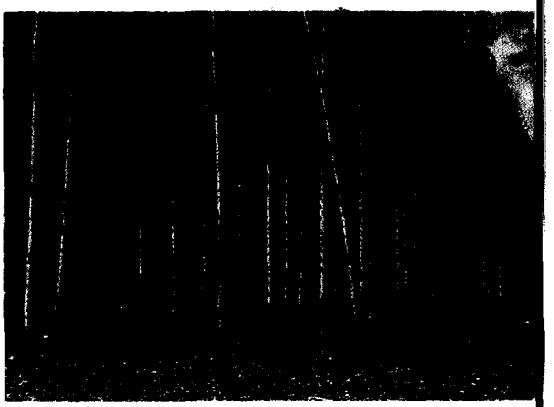
After planting, weed control is necessary for 2 years. The moderate use of herbicides produces good results. At some sites, farmers may need to fertilize the trees in alternate years. Once the canopy closes, tree crops require less care for 3 to 6 years until harvest. Time to harvest is a function of the kind of tree, the spacing between the trees, and climate.

Ideally, farmers should plan to harvest trees in the winter after the leaves fall. They can harvest and chip the trees on site or deliver them whole to a power plant. Tree harvest requires specialized equipment that several farmers may want to own cooperatively.

With today's technology, tree crops yield two to five times as much wood per acre as do natural forests. By 2010, breeding and genetic engineering should make it possible to increase yields by 50%.

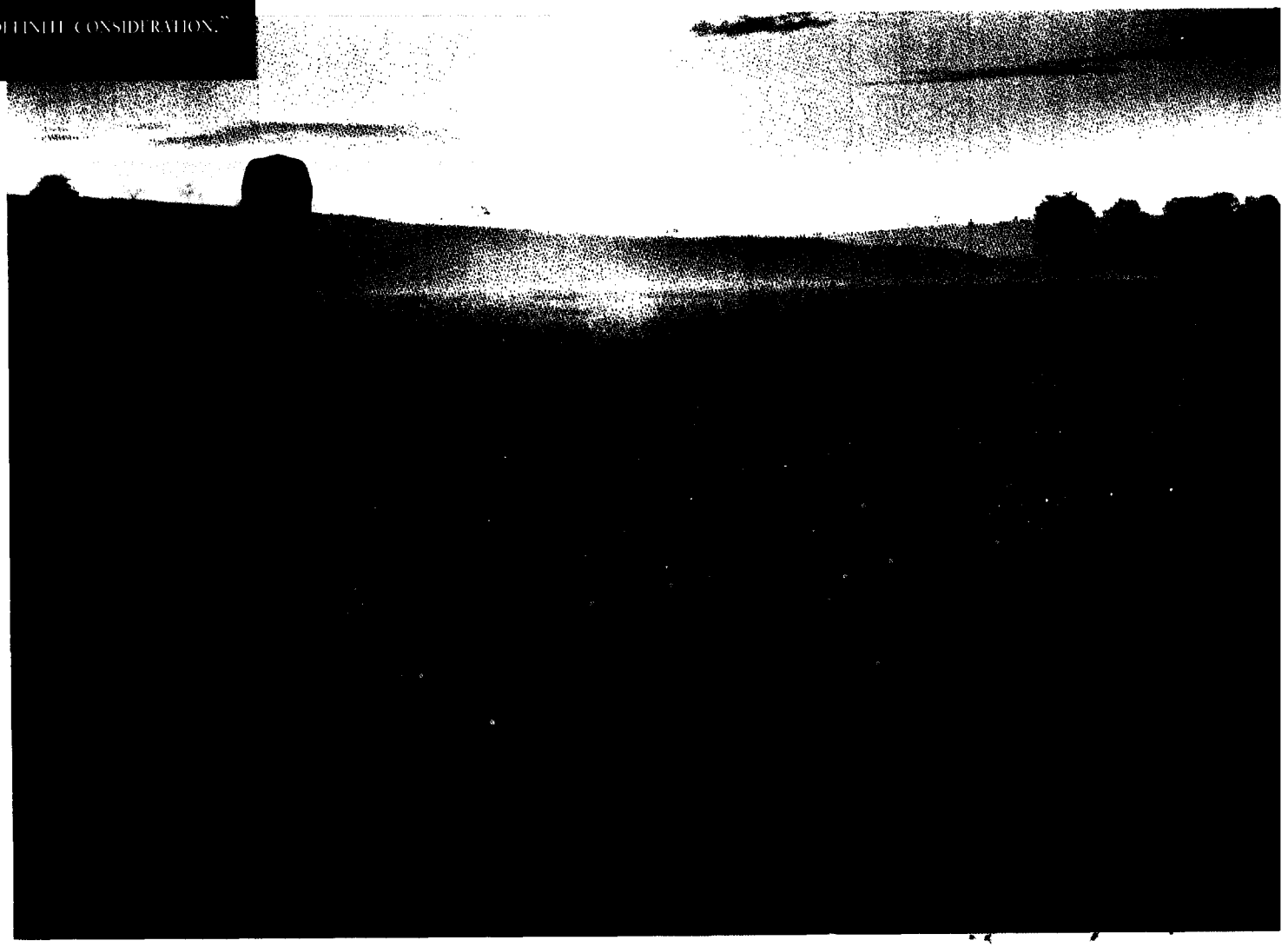


This tree nursery houses a breeding program for hybrid cottonwood trees. These trees grow rapidly and are also resistant to disease and pests.



A harvester known as a "feller buncher" cuts trees and lays them down in bunches. Another machine moves the bunches to the edge of the field for chipping.

"The beauty part is that switchgrass produces tremendous tonnage with no fertilizer. With costs going up, this is a definite consideration."



Texas rancher, Alan Koemel.

A tall native prairie grass, switchgrass is also an energy crop. Its roots extend more than 2½ feet into the ground, helping control erosion and build new soils.

Prairie Grasses

Switchgrass was once like water in a boundless sea of prairie grasses stretching from Canada to South America. It nourished the buffalo. Its roots helped form the sod from which settlers built their houses. Sending up new shoots each spring, it grew tall in the warmest, driest months of the year.

Today, switchgrass is an ideal energy crop. A hearty perennial, this thick-stemmed grass can grow higher than 6 feet. Its deep roots allow it to thrive in depleted soils. It typically produces high yields even in drought years, and it's farmed just like hay or alfalfa.

It takes 1 year to establish a new switchgrass crop from seed. After that, with proper management, switchgrass just keeps coming up year after year. Because its roots are busy building new topsoil, an established switchgrass crop requires a minimum of fertilizer and care. Energy harvests can take place once or twice during a growing season.

Switchgrass should always be harvested after the first killing frost. If two cuts are desired, the first cut should take place in mid-summer—well after the nesting season for birds and other wildlife that inhabit energy croplands. The two-cut system gives higher yields, but this may not always justify the additional cost. Farmers can also harvest this good-quality feed crop as hay for cattle.

However switchgrass is harvested, farmers should leave enough material to maintain the planting and to protect the soil and wildlife. To replenish the nutrients taken in the harvest, farmers should add back some nitrogen and any residues from the energy conversion process. Growing switchgrass is pretty simple.

Other perennial grasses also make good energy crops. These include prairie grasses, such as bluestem and wheatgrass, and tall tropical grasses. Some legumes, such as the high-yield sericea lespedeza, make especially good choices because they add nitrogen back to the soil.

Annual crops such as sorghum can also be high-yield energy crops. Because they are annual crops, they require more fertilizer. They should be planted on flat lands, which are less sensitive to erosion.

It takes 1 year to establish a new switchgrass crop from seed. After that, this hearty perennial practically takes care of itself.

Farmers harvest switchgrass just like hay—once or twice during a growing season for energy, more often for feed.

America's Energy Future: Realizing the Vision

Before the 1920s, farmers grew a form of energy along with food crops. It was called feed—for horses that pulled their plows, cultivators, mowers, and reapers. Then fossil fuels came along. Ninety million acres were freed from growing hay to fuel horses. Today, only a few million acres are devoted to energy (fuels) made from corn or oilseeds.

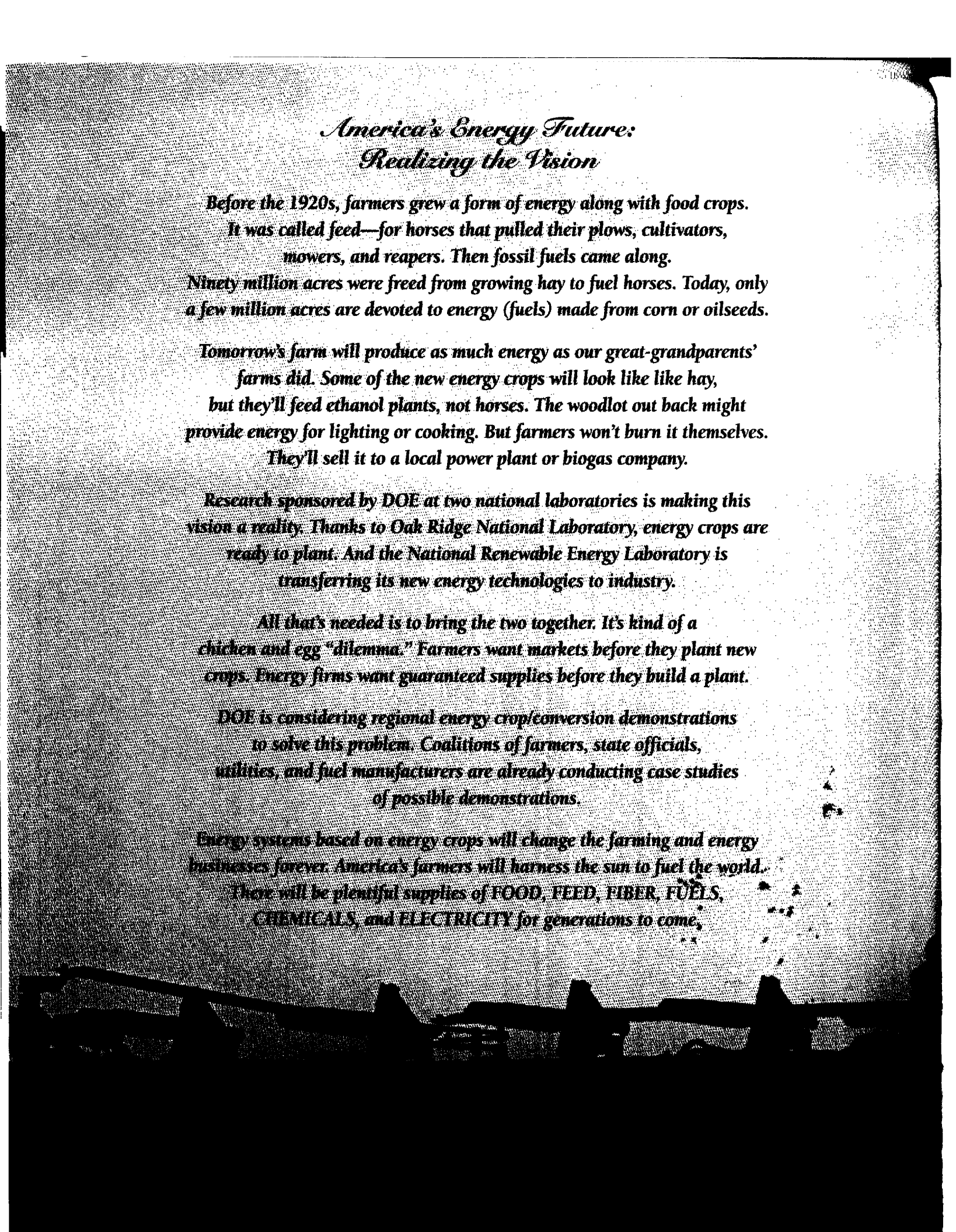
Tomorrow's farm will produce as much energy as our great-grandparents' farms did. Some of the new energy crops will look like like hay, but they'll feed ethanol plants, not horses. The woodlot out back might provide energy for lighting or cooking. But farmers won't burn it themselves. They'll sell it to a local power plant or biogas company.

Research sponsored by DOE at two national laboratories is making this vision a reality. Thanks to Oak Ridge National Laboratory, energy crops are ready to plant. And the National Renewable Energy Laboratory is transferring its new energy technologies to industry.

All that's needed is to bring the two together. It's kind of a chicken and egg "dilemma." Farmers want markets before they plant new crops. Energy firms want guaranteed supplies before they build a plant.

DOE is considering regional energy crop/conversion demonstrations to solve this problem. Coalitions of farmers, state officials, utilities, and fuel manufacturers are already conducting case studies of possible demonstrations.

Energy systems based on energy crops will change the farming and energy businesses forever. America's farmers will harness the sun to fuel the world. There will be plentiful supplies of FOOD, FEED, FIBER, FUELS, CHEMICALS, and ELECTRICITY for generations to come.



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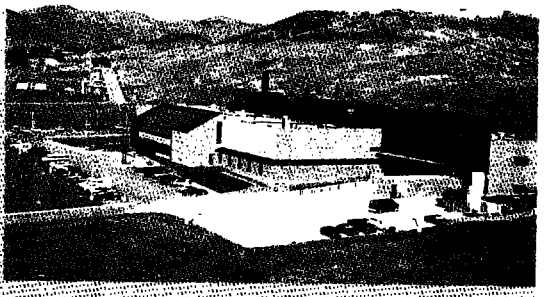

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Your local soil conservation district office or representative

Your state agricultural experiment station

Your county cooperative extension agent

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