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**STATE OF NEW HAMPSHIRE**

OFFICE OF THE GOVERNOR

JEANNE SHAHEEN
GOVERNOR

November 8, 1999

The Honorable William J. Clinton
President of the United States
The White House
1600 Pennsylvania Avenue
Washington, DC

Dear Mr. President,

I am writing to urge your support for Section 107 of S. 1792, which would extend a credit for energy produced from certain renewable resources and expand the credit to include biomass energy facilities.

During my three years as Governor, one of the greatest challenges facing the forest products industry in New Hampshire has been developing and retaining economically viable markets for low-grade wood. These markets are essential to the practice of responsible forestry, as they allow landowners to remove poor quality trees, letting the remaining forest grow to economic maturity.

In New Hampshire, this tax credit has the potential to benefit important segments of the forest industry.

New Hampshire has eight wood-energy electricity plants, two of which are idle. These plants provide an important market for low-grade wood, as well as residue from the state's many sawmills. These plants operate under rate-orders with Public Service of New Hampshire, the state's largest utility. As these rate-orders expire or get bought out, this tax credit would help the plants remain viable as they enter a restructured electricity market.

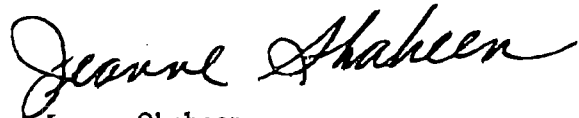
In Berlin, the largest city in northern New Hampshire, American Tissue Company operates a pulp and paper plant. This plant, the largest single employer in the state's forest products sector, operates a wood-fired boiler that would be eligible for the tax credit under certain circumstances. This plant, which serves as the anchor of the Coos County economy, was recently purchased from the Crown Vantage Corporation. This tax credit would help American Tissue Company, and thus benefit many northern New Hampshire citizens.

The Honorable William J. Clinton
The President of the United States
November 8, 1999
Pg. 2 of 2

The state's forest products industry is important to the environmental and economic stability of New Hampshire. The forest industry directly employs over 16,000 individuals, and contributes \$3.9 billion through direct and indirect expenditures annually. New Hampshire is the second most forested state in the nation, with 83% of our land base forested. Four out of five acres of New Hampshire forest are in private hands, and markets that allow for continued forestry are key to the economic and environmental health of the Granite State.

Thank you for the opportunity to share my thoughts on this important matter, and I look forward to continuing to work with you on issues that matter to New Hampshire.

Sincerely,



Jeanne Shaheen
Governor

cc: The Honorable Albert Gore
Vice President of the United States

OGDEN**POWER PACIFIC, INC.****PACIFIC OROVILLE POWER INC.**

3050 S. Fifth Ave.

Oroville, CA 95965

Telephone: 530 532-0597

Fax: 530 532-1245

October 20, 1999

President William J. Clinton
The White House
1600 Pennsylvania Ave., NW
Washington, DC 20500

Dear President Clinton:

We wish to thank you for your support in creating a robust biomass ethanol industry in the U.S. and look forward to working with your Administration in the future. We would also like to commend you on your recent Executive Order regarding the "tripling U.S. use of bio-based products and bioenergy by 2010."

This lofty goal contained in your Executive Order will require much support from both the Administration and Congress to reach fruition. Biomass has much potential throughout the U.S. using what would otherwise be waste in the form of agriculture residues such as sugarcane bagasse and rice/wheat straw, the cellulosic component of municipal solid waste, orchard and vineyard prunings, and lumber mill waste.

The biomass ethanol industry is now poised to begin building three plants in California (one using rice straw, one using wood waste, and one using a combination of both), one in Louisiana (using sugarcane bagasse), and one in New York (using MSW). Analyses are also being conducted for other plants in South Dakota and Alaska as well. While the untimely MTBE debate inadvertently extended the construction schedules for most of these plants, we feel that investors' uneasiness will soon be put to rest, but we need your help.

Congress fell well short of providing the Department of Energy's biomass research and commercialization programs with the Administration's allocation request. Biomass ethanol actually received a reduction of several million dollars from last year, ending up at \$39,500,000 versus the request of \$53,441,000 - almost \$14,000,000 below the request. While biomass power received an increase from last year at \$32,500,000, it is still about \$6,000,000 below the request of \$38,950,000.

A commitment to the Executive Order's goal by the Administration will help spur investment in these biomass ethanol plants, making us well on our way to achieving your 2010 goal. *We therefore respectfully request that during any omnibus negotiations with Congress that the Administration consider increasing both the biomass ethanol and power figures now contained in the Energy and Water Appropriations bill to as close to the Administration's request as possible.* Otherwise, we feel it is doubtful we will be able to reach the goal of your EO by 2010.

Sincerely,



Paul Wood
Director of Wood Projects



CALIFORNIA FARM BUREAU FEDERATION

NATIONAL AFFAIRS & RESEARCH DIVISION

2300 RIVER PLAZA DRIVE, SACRAMENTO, CA 95833-3293 • PHONE (916) 561-5610 • FAX (916) 561-5693

October 22, 1999

President William J. Clinton
The White House
1600 Pennsylvania Avenue, NW
Washington, DC 20500

Dear President Clinton,

Recently through an executive order you urged development of programs that will lead to a tripling of our country's reliance on biomass based fuels by the year 2010. California agriculture supports this increased reliance on bioenergy. This emphasis will help us deal with problems such as what to do with our rice straw, tree prunings and wastes generated from timber management practices.

State and federal air quality regulations are forcing us to find alternatives to field burning in very short order. A very promising solution is a proposed biomass to ethanol facility proposed for Northern California, but since this is emerging technology, securing adequate funding is very difficult.

The FY2000 Energy and Water Appropriations bill included funds to aid in the development of such facilities under a grant from the Department of Energy's biomass research and commercialization program. Unfortunately, during congressional budget negotiations those funds were reduced from the levels requested by your administration. In the upcoming budget negotiations, we urge you to press for reinstatement of the biomass funds. We believe the benefits of such a biomass project are very compelling ---a new source of clean burning domestic energy, local jobs and an effective and positive response to California's air quality concerns. These multiple benefits can be derived from a small initial investment.

Thank you for your consideration of this matter.

Sincerely,

California Farm Bureau Federation

American BioEnergy Association



609 2nd Street, NE, Suite #2, Washington, D.C. 20002 ph. 202/467-6540 fax 202/467-6541

TO: Roger Ballentine

FAX: 202/456-1736

DATE: October 21, 1999

FROM: Megan Smith, Executive Director

NUMBER OF PAGES (INC. COVER): 3

MESSAGE:

Attached is a letter for your consideration during ongoing budget negotiations.
Thank you for your support. Please call me with any questions.

Megan Smith

Questions? Call 202/467-6540



3321 E. 26th Street #4
P.O. Box 85102
Sioux Falls, South Dakota 57104
www.ethanol.org

October 25, 1999

President William J. Clinton
The White House
1600 Pennsylvania Ave., NW
Washington, DC 20500

Dear President Clinton:

We wish to thank you for your support in creating a robust biomass ethanol industry in the U.S. and look forward to working with your Administration in the future. We would also like to commend you on your recent Executive Order regarding the "tripling" U.S. use of bio-based products and bioenergy by 2010."

This lofty goal contained in your Executive Order will require much support from both the Administration and Congress to reach fruition. Biomass has much potential throughout the U.S. using what would otherwise be waste in the form of agricultural residues such as switchgrass, sugarcane bagasse and rice/wheat straw, the cellulosic component of municipal solid waste (MSW), orchard and vineyard prunings, and lumber mill waste.

The biomass ethanol industry is now poised to begin building three plants in California (one using rice straw, one using wood waste, and one using a combination of both), one in Louisiana (using sugarcane bagasse), and one in New York (using MSW). Analyses are also being conducted for other plants in South Dakota and Alaska as well. While the untimely MTBE debate inadvertently extended the construction schedules for most of these plants, we feel that investors' uneasiness will soon be put to rest, but we need your help.

Congress fell well short of providing the Department of Energy's biomass research and commercialization programs with the Administration's allocation request. Biomass ethanol actually received a reduction of several million dollars from last year, ending up at \$39,500,000 versus the request of \$53,441,000 – almost \$14,000,000 below the request. While biomass power received an increase from last year at \$32,500,000, it is still about \$6,000,000 below the request of \$38,950,000.

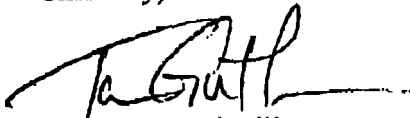
As oil prices stay at high levels, this just exacerbates the problem with our ongoing trade deficit. As a country we need to encourage and incentivize the production and use of all types of alternative energy, especially that energy which is truly renewable. Making fuel and energy from biomass can be done, and we are very supportive of those efforts. Your support and leadership on these issues is making a difference.

Page 2

A commitment to the Executive Order's goal by the Administration will help spur investment in these biomass ethanol plants, making us well on our way to achieving your 2010 goal. We therefore respectfully request that during any omnibus negotiations with Congress that the Administration consider increasing both the biomass ethanol and power figures now contained in the Energy and Water Appropriations bill to as close to the Administration's request as possible. Otherwise, we feel it is doubtful we will be able to reach the goal of your Executive Order by 2010.

Thank you for your consideration.

Sincerely,



Trevor T. Guthmiller
Executive Director



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GEORGE CORIA
LINDA
DELL
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ROGETZ B.

California Plant to Spin Straw Into Environmental Gold

Energy: A factory north of Sacramento will process agricultural waste into ethanol, which may replace unpopular MTBE as a gasoline additive.

By JOHN HOWARD, Associated Press

OROVILLE, Calif.--California's first attempt to turn rice stubble and tree trimmings into ethanol resembles a scene from "Back to the Future," when trash is dumped into Mr. Fusion at one end and pure energy comes out the other.

The proposed "bio-refinery" will convert thousands of tons of rice straw, orchard prunings and other agricultural waste into ethanol, a sort of 200-proof moonshine that state air-pollution fighters hope will soon replace the unpopular additive MTBE in California gasoline.

"We see it as an efficient waste-based ethanol plant that takes advantage of low-cost and no-cost materials," said Stephen J. Gatto, head of Boston-based BC International Corp., which plans to start construction next year south of Oroville, 60 miles north of Sacramento.

Rice farmers see it as a match made in heaven.

Blocked by state air regulators from burning their stubble, the growers disc the hardy straw back into the ground. That costs \$30 an acre, about a fourth of the growers' profits.

About 500,000 acres of rice are grown in the Sacramento Valley, producing about 1.5 million tons of of rice straw.

Rice growers have hunted for ways to use rice straw since new air-quality rules took effect in 1993. House insulation, woven furniture and scaffolding were among the uses tried. None worked out.

Growers believe they've found the answer in ethanol.

"We can get this stuff off the field and at least break even. That's all we really want to do with the rice stubble--break even," said Ken Collins, who farms 1,600 acres of rice near Biggs and plans to ship his rice straw to the new plant.

The Oroville factory will convert about 75,000 tons of rice straw, 125,000 tons of orchard slash and 40,000 tons of other agricultural waste into ethanol each year.

"You're looking at about 900 tons there," Collins said, as his workers tended to a two-story-high mound of baled rice straw culled from his fields. Collins is among a group of growers who have formed a cooperative to feed the new plant.

Ethanol is a familiar product in the Midwest, where factories convert cornstarch into about 1.6 billion gallons annually.

Illinois, South Dakota, North Dakota, Nebraska, Iowa and Minnesota are among states with ethanol factories, providing a market for the states' corn growers and a cleaner mix of fuel for states facing EPA air-pollution-fighting mandates.

A bushel of corn produces about 2.5 gallons of ethanol.

"We're making corn whiskey, is what it amounts to. But ethanol is very clean. It clearly is a benefit to air quality, and it does add octane," said Trevor Guthmiller, executive director of the South Dakota-based American Coalition for Ethanol.

Midwestern ethanol growers see California--and its more than 20 million licensed drivers--as a huge new market. BCI's factory, expected to open by 2001, won't produce enough ethanol to replace all 540 million gallons of MTBE burned annually in the state.

Environmentalists generally supported Gov. Gray Davis' March decision to phase out MTBE, or methyl tertiary butyl ether, noting that MTBE contamination had been reported in lakes and ground water across the state.

U.S. Environmental Protection Agency Administrator Carol Browner said last month that the EPA would seek to reduce the use of MTBE, citing a threat to drinking water.

The Oxygenated Fuels Assn., an Arlington, Va.-based trade association representing MTBE producers, said the compound protects air quality and will prove costly to replace.

"It is the most cost-effective and cleanest source of octane," said Terry Wigglesworth, the group's executive director. "Replace that with something else that's not proven, and you're going to have all kinds of problems."

Ethanol backers say the cost to motorists would be about the same in California as with MTBE. In the Midwest, ethanol has had little effect on pump prices, Guthmiller said. California's gasoline prices already are among the highest in the nation, with unleaded regular averaging about \$1.50 a gallon recently.

Gatto said ethanol has uses beyond gasoline, including mouthwash, aftershave, perfume and solvents.

The Midwestern plants derive sugar from cornstarch to make the ethanol, a relatively simple process. In Brazil, ethanol is made using cane sugar.

BCI's plant, expected to open by 2001, will use new technology to separate cellulose from the "biomass"--wood, straw, leaves, fruit pits and other items--and use that sugar to make the ethanol.

The California Energy Commission is studying the use of ethanol and other compounds as fuel additives.

"Clearly the technology is there, and it's not that difficult to produce ethanol through the conversion process," commission spokeswoman Claudia Chandler said. "The question is, 'Is it economical and is there a market for it?'"

The BCI operation will produce about 22 million gallons of ethanol a year, or roughly 70 to 100 gallons per ton of biomass.

Collins and others believe it's just a start.

"We could use all our rice straw and all our orchard prunings, and we'd still hardly sustain the demand," Collins said.

A similar biomass ethanol plant, also run by BCI, has begun operation in Jennings, La. It produces about 22 million gallons annually. That plant cost about \$90 million, and the Oroville facility is expected to cost about the same, Gatto said.



this way for dream jobs....→

American BioEnergy Association



609 2nd Street, NE, Suite #2, Washington, D.C. 20002 ph. 202/467-6540 fax 202/467-6541

TO: Roger Ballentine

FAX: 202/456-1736

DATE: October 21, 1999

FROM: Megan Smith, Executive Director

NUMBER OF PAGES (INC. COVER): 45

MESSAGE:

Attached is a letter for your consideration during ongoing budget negotiations.
Thank you for your support. Please call me with any questions.

Megan Smith

Questions? Call 202/467-6540

October 20, 1999

President William J. Clinton
The White House
1600 Pennsylvania Ave., NW
Washington, DC 20500

Dear President Clinton:

We wish to thank you for your support in creating a robust biomass ethanol industry in the U.S. and look forward to working with your Administration in the future. We would also like to commend you on your recent Executive Order regarding the "tripling U.S. use of bio-based products and bioenergy by 2010."

This lofty goal contained in your Executive Order will require much support from both the Administration and Congress to reach fruition. Biomass has much potential throughout the U.S. using what would otherwise be waste in the form of agriculture residues such as sugarcane bagasse and rice/wheat straw, the cellulosic component of municipal solid waste, orchard and vineyard prunings, and lumber mill waste.

The biomass ethanol industry is now poised to begin building three plants in California (one using rice straw, one using wood waste, and one using a combination of both), one in Louisiana (using sugarcane bagasse), and one in New York (using MSW). Analyses are also being conducted for other plants in South Dakota and Alaska as well. While the untimely MTBE debate inadvertently extended the construction schedules for most of these plants, we feel that investors' uneasiness will soon be put to rest, but we need your help.

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Thank you for your consideration.

Sincerely,

Arnold R. Klann, CEO
Arkenol, Inc.
Mission Viejo, CA

Stephen Gatto, President
BC International Corporation
Offices in Dedham, MA, Jennings, LA, Denver, CO, and Sacramento, CA

Jack Siverstson, Vice President
Collins Pine Company
Offices in Portland, OR, and Chester, CA

Steven Rothstein, President
Environmental Futures, Inc.
Boston, MA

Thomas Sanford, Mayor Pro-Temp
City of Gridley
Gridley, CA

George A. Craig, President
HFTA
Oakley, CA

Daryl Harms, CEO
Masada Corporation
Birmingham, AL

Robert Loescher, CEO
Sealaska Native Corporation
Juneau, AK

Merlin Fagan, President
MLF Consultants
Sacramento, CA

Loyd Forrest, President
TSS Consultants, LLC
Sacramento, CA

**Megan Smith, Executive Director
American Bioenergy Association
Washington, DC**

cc: Vice President Albert Gore

**Julie Anderson
Roger Ballentine
George Frampton
David Gardiner
Elgie Holstein
Henry Kelly
Jeff Seabright
Todd Stern**



C A L I F O R N I A R I C E C O M M I S S I O N

October 14, 1999

President William J. Clinton
The White House
1600 Pennsylvania Avenue, NW
Washington, DC 20500

Dear President Clinton:

California's rice farmers were extremely pleased with your recent executive order that laid the path for tripling U.S. use of bio-based products and bioenergy by 2010. Today, rice farmers are struggling to find ways to use 1.5 million tons of waste rice straw in lieu of open field burning. We believe ethanol production offers the single greatest promise of economically diverting large volumes of rice straw from costly waste streams.

The biomass-to-ethanol industry is gearing up to build three plants in California, Louisiana and New York. The California facility will convert rice straw and wood waste materials into fuel grade alcohol. Rural counties in Northern California are extremely excited about the prospects of developing year-round jobs in areas where seasonal unemployment often exceeds 30 percent. However, we are very concerned that the \$14 million cut in the Department of Energy's biomass research and commercialization programs could stall or even prevent the actual construction of these badly needed facilities.

The full implementation of DOE's biomass research and commercialization programs will jump-start the biomass-to-ethanol industry in rural areas that have not fully participated in America's economic recovery. These programs will catalyze private investment, create new job opportunities for year-round workers, enhance the financial prospects for family farmers and improve public infrastructure in small towns.

Therefore, we respectfully request that during the omnibus negotiations with Congress that the Administration endeavor to increase the biomass ethanol and power budgets now contained in the Energy and Water Appropriation bill to your original request. Without full funding, it will be difficult to reach the goals for 2010 spelled out in the executive order.

Sincerely;

CALIFORNIA RICE COMMISSION

A handwritten signature in dark ink, appearing to read "Robert E. Herkert", followed by a horizontal line.

By: Robert E. Herkert
Manager of Communications

BIOCYCLE

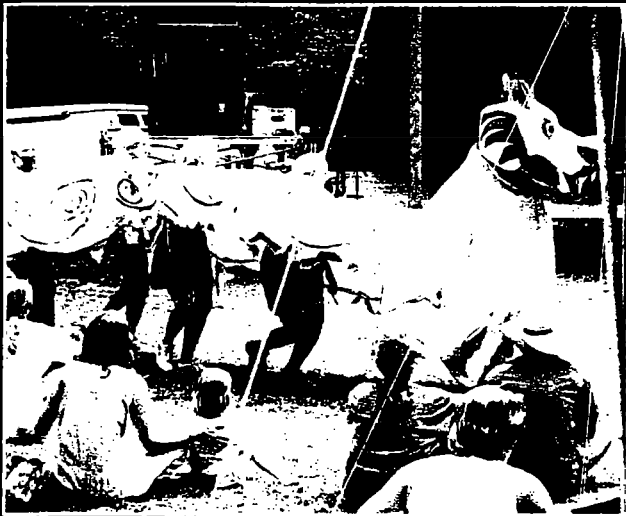
JOURNAL OF COMPOSTING & RECYCLING

SEPTEMBER 1999

ZERO

WASTE

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PROCESSING BIOSOLIDS IN DRY CLIMATES COMPOSTING IN AFRICA
MANURE MANAGEMENT SOLUTIONS TRACKING COMPOST MARKETS IN QUEBEC

EXECUTIVE ORDER AND PROPOSED BILL WILL BOOST BIOBASED PRODUCTS AND BIOENERGY

Initiatives from the federal and legislative branches aim to bring technologies utilizing agricultural and plant-based materials out of the laboratory and into the marketplace.

Dave Block

DEVELOPMENTS in the world of biobased products and bioenergy have flourished in recent years, as reported by sources such as *The Carbohydrate Economy* newsletter, the USDA's Agricultural Research Service, the New Uses Council, and *In Business* magazine, among others. But while each new use for crop residues or another cellulosic ethanol project brings encouragement to sustainability proponents, the biomass and biofuels arena remains small and fragmented compared to the status quo of virgin materials and petroleum-based products.

That may be changing dramatically however, thanks to two recent government initiatives. President Clinton's August 12 Executive Order on Bio-based Products and Bioenergy brings together several federal departments to accelerate support of alternative technologies for generating products based on forestry and agricultural materials, and clean energy sources. A strong influence on the Executive Order was "Biobased Industrial Products," a recently released report by the National Research Council, which concluded that federal support for research is vital to fulfilling the economic and environmental potential of

biobased industries. Leading scientific and industry groups have called for a federal role in transferring these technologies from the laboratory to the marketplace.

The second measure is S.935, which would amend the National Agricultural Research, Extension, and Teaching Policy Act of 1977 to authorize research promoting "the conversion of biomass into biobased industrial products, and for other purposes." Introduced April 30 by Sen. Richard Lugar (R-Indiana) chairman of the Senate Agriculture Committee, the bill was unanimously approved by the Senate Agriculture Committee and is expected to reach the Senate floor early in the fall legislative session. A companion bill is being drafted by Congressman Mark Udall (D-Colorado) in the House of Representatives.

PRESIDENTIAL PUSH

Biobased products are defined as commercial or industrial products — other than food or feed — that use biological, renewable agricultural or forestry materials, including dedicated energy crops and trees, agricultural food and feed crop residues, aquatic plants, wood and wood residuals, and animal wastes. Bioenergy refers to biomass used in the production of energy: electricity; liquid,

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NEW POLICIES COULD SPEED UP THE SHIFT TO COMPOSTING AND ORGANICS RECYCLING

WHEN almost half the states in this nation banned the landfilling of yard trimmings, the impact on companies providing equipment and services that collected, sorted, size reduced, screened and composted those organic residuals was profound. When public agencies establish purchasing specifications for products with high recycled content, that also has a strong impact. When the President of the United States issues an Executive Order to stimulate the early adoption of technologies that make "biobased products and bioenergy cost competitive" in large markets ... "technologies that can create new value-added business opportunities" from renewable farm and forestry

resources, that clearly has the potential to speed up the shift to composting and organics recycling. The question — and the challenge — is: What can we do to make sure the potential is fulfilled?

In addition to the Executive Order issued in August, there was an official announcement in the Federal Register that the U.S. Department of Agriculture will compile a Biobased Products List in the next six months. Once this list has been published, federal agencies "are encouraged to modify their affirmative procurement to give consideration to these products."

The overall goal of these new policies is to develop processing technologies for biomass (organic residues

like yard trimmings, crop wastes, etc.) that can replace petroleum-based energy and products. "Biomass is to the next century what petroleum was to this century," says Carol Browner, Administrator of the Environmental Protection Agency. Tripling use of bioenergy and bioproducts would replace 348 million barrels of imported oil by 2020 and reduce greenhouse gas emissions by 100 million tons. It could also increase the number of successful environmental entrepreneurs whose companies would be commercializing technologies that range from anaerobic digestion, to producing disease suppressant composts and biodegradable plastics from biomass, to marketing the end products. — J.G.

"Farmers are struggling with a glut in world markets. This can increase the number of products and markets by having them get paid for what currently is thrown away as waste."

solid, and gaseous fuels; and heat.

President Clinton has asked for \$242 million in his proposed budget for investments in biomass/biofuels research and development. "We're talking about a tiny fraction of the budget for the combined recommendations we have made that can change the whole future of this country and this world, in the way that the automobile and the perfection of petroleum processing did at the beginning of the century," he explained in a Rose Garden signing ceremony.

President Clinton also has proposed a five-year extension of the current 1.5-cent/kW hour tax credit for electricity produced from biomass. The measure would expand the types of biomass eligible for the credit to include certain forest-related, agricultural and other resources. In addition, a one-cent/kW hour tax credit would be given for electricity produced by cofiring biomass in coal plants.

The Executive Order itself sets a goal of tripling U.S. use of biobased products and bioenergy by 2010. According to the administration, meeting that could create \$15 billion to \$20 billion in new income for farmers and rural America, as well as reduce carbon emissions by the equivalent of taking 70 million cars off the road. The secretaries of Energy and Agriculture were instructed in a separate Executive Memorandum to prepare a report within 120 days that outlines and assesses options for modifying their departments' programs to meet the 2010 target.

"WHOLE NEW DIRECTION"

"This is an important step the administration is taking to say that we need a whole new direction as we enter the next century," says Carol Werner, executive director of the Environment and Energy Study Institute

in Washington, D.C., who serves on the New Uses Council's board of directors and participated in the Department of Energy's Bioenergy Initiative, a group of federal, commercial and nonprofit stakeholders that helped provide input for the Executive Order and the Department of Energy's future plans. She also participated in the signing ceremony for the Executive Order and has worked with the Clinton Administration on revamping the biomass tax credit. "This is what the future will be and what we should be doing to address our problems as we look at helping farmers, rural economic development, the environment and the oil dependency situation," adds Werner.

The Executive Order establishes the Interagency Council on Biobased Products and Bioenergy, with representation from the heads of the federal Agriculture, Commerce, Energy and Interior departments, the Environmental Protection Agency, the Office of Management and Budget, the National Science Foundation and others. The council will prepare an annual strategic plan outlining national goals for development and use of biobased products and bioenergy, as well as how to achieve them. Areas of focus will include rural economic growth, energy security, environmental sustainability and protection, and ensuring safe and affordable supplies of food, feed and fiber.

Strategic plans will cover "biobased products, including commercial and industrial chemicals, pharmaceuticals, products with large carbon-sequestering capacity, and other materials; and biomass used in the production of energy ... these strategic plans shall be based on analyses of the economic impacts of expanded biomass production and uses; and the impacts on national environmental objectives, including

reduction of greenhouse gas emissions." The first annual strategic plan will be due within eight months of the date of the order, describing research, investment and legislative priorities and plans.

Representatives from farm, forestry, chemical manufacturing and other businesses, energy companies, electric utilities, environmental organizations, conservation groups, the university research community and other relevant sectors will serve on an Advisory Committee on Biobased Products and Bioenergy to provide information and advice to the Interagency Council. Among other tasks, it will assess federal agencies' goals for fulfilling the Executive Order, and review proposed research initiatives and demonstration programs.

Additionally, the Secretaries of Agriculture and Energy will establish a joint coordinating office to support implementation of the strategic plans. One of its functions will be to spread information to farm operators, various business sectors, the university community and public interest groups.

CONGRESSIONAL BACKING

Although the President's initiative carries considerable weight, as an Executive Order, funding must come from Congress, where similar goals are being pursued on both sides of the aisle. Sen. Lugar's legislation, "The National Sustainable Fuels and Chemicals Act," is a six-year authorization bill with 15 cosponsors that calls for: Cooperation between the Departments of Agriculture and Energy in the research, development and deployment of new technologies for low-cost conversion of biomass into fuels, chemicals and power; Creation of a Sustainable Fuels and Chemicals Board, consisting of senior officials from several federal bodies, to coordinate federal research and development efforts; Founding of the National Sustainable Fuels and Chemicals Research Initiative, a grant program for biomass conversion research and economic analysis; and Authorization of \$49 million/year for the initiative in fiscal years 2000 through 2005.

One of Lugar's main goals in proposing the bill is to reduce American dependence on imported oil by substituting domestic biofuels, biochemicals and biomaterials. Another aim is to help U.S. farmers. "This would be a huge boon to farmers, and, in broad terms, for rural development," notes Joseph Michels, science policy advisor for Sen. Lugar. "Farmers are struggling with a glut in world markets. This can increase the number of products and markets by having them get paid for what currently is thrown away as waste." A third objective is to introduce environmentally friendly technologies that will decrease impacts on climate change without overhauling the transportation infrastructure. These principles were outlined by Lugar and former CIA director James Woolsey in "The New Petroleum," a well received article cowritten for the January/February, 1999 issue of *Foreign Affairs*.

"I think it's a good bill," says Werner. "It's an important step because of the kind of attention that it calls to this whole area. Forty-nine million dollars/year isn't a big amount, but for the first time, there's a very specific authorization involving interagency effort. It's the first time that there's been this kind of articulation in policy of the need to do this."

Michels believes that there is tremendous potential for furthering the biomass and biofuels marketplace, regardless of future election results. "I think the politics of this are compelling," he says. "During hearings on Senator Lugar's bill, you had administration officials in favor, chemical companies

Meeting the Executive Order's goal could create \$15 billion to \$20 billion in new income for farmers and rural America.



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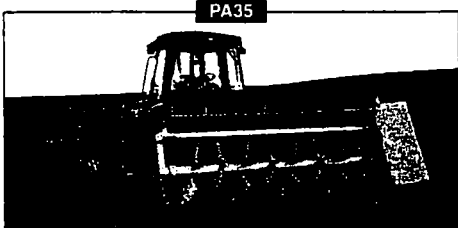


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BIOPRODUCTS AT BIOCYCLE MIDWEST CONFERENCE

THE BioCycle Midwest Conference, set for October 25-27 in Cedar Rapids, Iowa, reflects the growing momentum of biobased products and bioenergy. A session will be held the first day on "Maximizing Potential Of Bioenergy and Bioproducts." Bob Harris of the U.S. Department of Energy will speak on "Bioenergy Initiatives In Federal Agencies," covering the Executive Order, funding opportunities and an overview of technologies. Carol Werner of the Environmental and Energy Study Institute will discuss "Policy And Financial Incentives For Biobased Industrial Products," focusing on government and private sector support for new uses for organic feedstocks, policy integration and the political outlook. Irshad Ahmed of Pure Energy Corp. will talk about "Renewable Fuels And Chemicals From Biomass," discussing biobased businesses and the Carbohydrate Economy, and a case study of manufacturing alternative fuels and chemicals from MSW, as well as evaluating the state of technology and commercial opportunities.

In addition, during the "Organics Management" session on the second day of the conference, Jim Peebles of PMC Marketing Group will speak on "Biodiesel Fuels From Recycled Grease," including a rendering company's experiences, marketing to car fleet owners, and collection and processing of restaurant grease and other feedstocks. Finally, there will be a "Biowaste Processing Workshop" on the third day of the conference. Representatives from private companies, public agencies, research centers and the New Uses Council (a nonprofit group promoting new industrial uses of agricultural materials) will discuss how organic residuals are being processed into biofuels and biodegradable products. For the full conference program, see pages 15-17 in this issue. For more information, call BioCycle at (610) 967-4135.

and some large agriculture interests in favor, and farmers in favor. There are not too many issues where you have that collection of supporters. It cuts across traditional war zones."

PROJECTS

The day after the release of the Executive Order, the U.S. Department of Energy announced the awarding of more than \$13 million in grants to promote the growth of the biomass industry. Like S.935, the awards are aimed at developing technologies to reduce the cost of using biomass to create energy, fuels and products.

For example, Michigan Biotechnology Institute in Lansing will get \$3 million for its partnership with Heartland Grain Fuels in Aberdeen, South Dakota and the Energy and Environmental Research Center in Grand Rapids, North Dakota to further development of biomass technologies for fuels and chemicals. BC International Corp. in Dedham, Massachusetts will receive \$1.4 million toward its pioneering biomass ethanol facility in Jennings, Louisiana, which utilizes sugar cane bagasse. Cargill Polymers, Inc. in Minnetonka, Minnesota and its partners — the National Renewable Energy Laboratory and the Colorado School of Mines — will use a \$1.3 million grant for research on polylactic acid (PLA), an environmentally benign plastic material made from corn with applications in fibers, films, rigid materials and coatings.

BIOENERGY

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Growing an Integrated Industry

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Prospectus

"We are looking forward to a day when a ton of biomass will be traded like a barrel of oil is today."

Assistant Secretary Dan W. Reicher

BIOENERGY

Growing Energy to Power America

A National Partnership for an Integrated Biomass Industry

Vision

BioEnergy is a national partnership to develop an integrated industry to produce power, fuels, and chemicals from crops, trees, and wastes, will help power America by using our most abundant natural resource — biomass. By making a “ton of biomass” a viable market competitor to a barrel of imported oil, BioEnergy will help grow the U.S. economy, strengthen U.S. energy security, protect the environment, reduce greenhouse gas emissions, and revitalize rural America.

Background

Biomass power, fuels, and chemical products already have demonstrated initial success in the marketplace. Bioenergy resources from the nation’s farms, forests, pulp and paper mills, and landfills currently meet more than 3 percent of U.S. heat and electric power needs. In fact, consumption of these biomass resources has been increasing steadily by more than 2 percent annually since 1990 in most regions of the country. The challenge is to build upon these efforts and create new and economically viable options for farmers, foresters, fuels producers, chemical manufacturers, wood products companies, electricity producers, and consumers to use and profit from biomass commodities, products, and services.

Need for an Integrated Industry

There is today inadequate integration across the biofuels, biopower, and bioproducts industries. This lack of integration among technologies, markets, and policies has been a major barrier to industry growth. A more comprehensive and coordinated approach could open opportunities and remove barriers for nascent bioenergy industries. In addition, greater integration across industries could stimulate new and innovative products and increase profitability. Such integration could also enhance development of industrial processes and facilities for biomass that serve multiple uses—the so-called “biorefinery” for example. Furthermore, increased integration of biomass research, development, and deployment programs can reduce the time it takes for improved concepts to make it from the laboratory to the marketplace.

Benefits

The successful integration and market penetration of biomass will yield a number of significant benefits, including:

- Reducing U.S. dependence on foreign oil imports, with enhanced energy security;
- Reducing environmental emissions of NOX, SOX, and other pollutants;

- Decreasing greenhouse gas emissions;
- Increasing profitability for biomass-related commercial activities;
- Revitalizing rural areas with new markets and revenue streams; and
- Providing greater choices of fuel sources for electric power, transportation fuels, and industrial and commercial products.

The Partnership

This initiative will build a new partnership among industries, government agencies, non-governmental organizations, and laboratories. The partnership will foster better collaboration and communication among biomass stakeholders, in order to take advantage of inherent synergies and exploit emerging market opportunities. It will develop a shared vision of the future and reach agreement on the most productive pathways for achieving that vision. It will also address the need for more effective public policies at the federal, regional, and state levels to support a robust biomass industry. Not least, the partnership will help secure the resources required to grow a competitive biomass industry.

TEN POINT ACTION PLAN

1. Establish the Partnership Vision

- Develop a shared vision for the future of biomass fuels, power, and chemicals.
- Establish initial targets and time lines.

2. Develop Roadmaps

- Identify and develop roadmaps to address future needs and pathways for power, fuels, and chemicals.
- Establish priorities for technology development, policy actions, and market mechanisms.

3. Create an Effective Policy Framework

- Assess current biomass-related policies at the federal, regional, and state levels.
- Devise policy options that expand opportunities for biomass production and use.

4. Expand Biomass Markets

- Remove or reduce market barriers.
- Encourage federal procurement.
- Establish biomass quality, performance, and safety standards.
- Promote labeling (e.g., EnergyStar) for biomass products.

5. Conduct Supporting Analysis

- Analyze market potential for production and use of biomass resources.
- Analyze expected performance of process-specific technologies.
- Assess the potential contributions of biomass use in addressing global climate change.

6. Promote Advanced Technologies

- Develop economically viable, dedicated energy crops and trees.
- Demonstrate fully integrated industrial processes for cost-effective co-production of fuels, power, and chemicals.
- Develop profitable, efficient energy conversion processes for waste management.
- Coordinate biomass RD&D with other renewable and fossil energy technology programs.

7. Expand Federal-State Coordination

- Increase the degree of coordination and communication among government agencies.
- Expand technical assistance to state and regional agricultural and forestry programs.

8. Pursue Outreach and Showcase Successes

- Provide information on the benefits of biomass products to states, communities, farms, industries, consumers, and others.
- Organize regional meetings of stakeholders.
- Promote technology demonstrations to exhibit the benefits of biomass.
- Highlight ground breakings, roll-outs, and success stories for the Congress and the White House.

9. Hold Quarterly Progress Meetings

- Review progress toward goals
- Develop strategies and tactics
- Share information

10. Maintain Effective Partnerships

- Annually convene an Integrated Bioenergy Summit.
- Formalize industry consultations with government.
- Develop internal industry coordinating structure to interface with governments.

Statement of Dan W. Reicher
Assistant Secretary for Energy Efficiency and Renewable Energy
U. S. Department of Energy
before the
Committee on Agriculture, Nutrition and Forestry
United States Senate
May 27, 1999

Mr. Chairman, and Members of the Committee, I am pleased to testify today on bioenergy. In my testimony I will address why there is a need—and a great opportunity—for a broadly coordinated initiative in bioenergy at this time. Also, I will provide an overview of what we in the Administration have undertaken, with industry, the national laboratories, universities, state governments, and other stakeholders in the bioenergy arena. Finally, I will comment on S. 935, the National Sustainable Fuels and Chemicals Act of 1999, and suggest some modifications.

The Benefits of Bioenergy Production and Use

Bioenergy resources such as agricultural and forest products and waste residues already meet more than 3% of U.S. energy requirements. Consumption of bioenergy products, particularly electric power and fuels, has been increasing by 2% annually since 1990. However, this growth is not enough—indeed, it is far too slow to meet our fast-growing concerns about air quality, climate change, dependence upon foreign energy supplies, and weakening economic conditions in the nation's farm and forestry sectors. If we are to see a meaningful decline in reliance on fossil fuel use over the next decade and beyond; if we are to lessen our economic and national security vulnerabilities to interruptions in energy supply; if we are to stimulate a whole new arena of agricultural and forestry economics, then we must have a concerted national effort to develop a range of renewable energy sources, with bioenergy as a centerpiece. Biomass resources are an important domestic and renewable source of energy. Moreover, production of energy and chemical products from biomass offers economies of scale that eventually will permit us to supplant fossil energy to a truly significant degree.

The bioenergy industry at the moment, however, remains small and segmented; there is woefully inadequate integration across the biofuels, biopower, and biochemical products industries. Our industry integration meeting in St. Louis in March of this year was one of the few times, if not the first, that senior corporate decision makers from all three industry areas, as well as farmers, have held a common dialogue on the state of the industry and its potential. The lack of integration among technologies, their applications, markets, and policies has been a major barrier to industry growth. More extensive technology integration, along with an integrated strategy for resource development and use,

processing facilities, and product development, would create a strong momentum for both growth and competition within the bioenergy industry. Such integration could stimulate innovative product lines and new markets, while enhancing the development of processes and facilities that use a variety of feedstocks while producing a broad range of products. A long term technical and economic objective is to make a "ton of biomass" a viable market competitor for a barrel of imported oil. That ton of biomass could be processed in a "biorefinery" that can quickly and easily vary its feedstocks and its product mix according to market signals, much as petroleum refineries do with oil today. And not least, integration among biomass research, development, and demonstration programs can shorten the time to move a new process or product from the laboratory to the marketplace.

We at the Department of Energy believe a more focused, visible, and integrated national effort can meet the challenges and make the U.S. the world leader in production of bio-based energy and other products. Some of those challenges lie in improving crop yields; introducing new crop varieties tailored for biorefining; rethinking land use policies to blend resource production with soil and environmental conservation; developing biomass harvesting, distribution, and processing technologies; developing new product opportunities from biochemicals; and building the level of confidence in the investment community that will be needed to finance these undertakings.

A variety of specific advances needed to meet these challenges have already been identified. For instance, in crop feedstocks, near term objectives include development of inexpensive cellulose enzymes having progressively faster specific activity, and new genomic and genetic engineering of cellular wall variability. Longer term work will focus, as an example, on engineering plants with greater carbohydrate composition and specific "designer" properties tailored to reduce the required degree of processing and conversion. In the area of processing, objectives include better separation technologies for easier and more efficient recovery of products, as well as conversion techniques other than catalysis. A major additional challenge lies in developing technological and economic assessments and models for such factors as variability of resource and product mixes for biorefineries, and impacts of bio-based products on markets and pricing of competing products.

Overall, a prediction of costs associated with achieving these objectives would be speculative at this time. We are at the leading edge of much of the R&D and systems integration necessary to grow this industry from one of a few niche products and markets into one that is fully competitive across the board and fully responsive to the whole range of market signals. Since the aims of both the Administration's Bioenergy Initiative and S.935 are in the direction of greater integration, to speed development and enhance synergistic benefits, some additional modest funding may be necessary to achieve those

aims.

The creation of a robust bioenergy industry in the U.S. will have tremendous economic, environmental, national security, and even social benefits. For example, the November 1997 report by the President's Council of Advisors on Science and Technology (PCAST) points out that 4.7 quadrillion BTUs (5% of U.S. energy in 1995) of bioenergy could be available at attractive cost by 2015. Just over half could come from agricultural residues, while just 18 million acres of dedicated energy crops could provide the rest. In one scenario, 31 billion gallons of ethanol could be produced from this biomass, and 12 gigawatts of electricity—as a by-product of making fuel—could be generated in conventional steam plants. That amount of ethanol, powering light-duty vehicles with internal combustion engines, would reduce U.S. requirements for gasoline by as much as 22 percent, and for imported oil by \$10 billion per year. The PCAST report goes on to state that such growth in bioenergy production could, by 2015, reduce U.S. emissions of CO₂ by 6 percent from today's levels. The DOE five-lab study, *Scenarios of U. S. Carbon Reductions*, estimated that biomass resources offer the potential to reduce U.S. carbon emissions by even more, up to 10% of current emissions, by 2010.

Another prime benefit of a fast-growing, robust bioenergy market will be the demand for dedicated energy crops and for agricultural and forest residues of all types, providing new revenue streams for farmers and cash-flow for rural economic development. The present pricing uncertainties faced by the agricultural and forestry sectors due to weather, foreign production, and commodities fluctuations could be greatly alleviated by long-term energy crop contracts to biorefineries. New crops, along with new planting, tillage, and harvesting technologies, can improve the utilization of marginal lands, while better preserving the ecosystem. Better forestry management and harvesting for bioproduction can reduce the danger of forest fires while improving the overall health of forests. And not least, investments made in bioenergy technologies, infrastructures, and market development could increase profitability for U.S. firms competing in global markets, while simultaneously providing for the world's energy needs in an environmentally sustainable way.

A National Bioenergy Initiative

Against this vision of the potential of bioenergy, I want to present a brief view of how the government and industry are currently pursuing opportunities not only to scale up current activities, but to work jointly to develop an integrated bioenergy system—ranging from basic research, through feedstock production and processing, to biobased industrial and consumer products. Such a system will involve integrated teams of researchers and engineers from the public, private, and educational sectors. It will also require interaction among public policy makers, business and financial investment managers, farmers and

foresters, and trade and commodity brokers, as well as the research community. Effective integration of this type is a necessity if we are to make the vision of a bioenergy-based economy a reality.

We have already begun this year to move toward that vision with the formation of an industry-led Bioenergy Industry Vision group, composed primarily of senior corporate leaders from the several sectors of the industry, along with senior Federal and national laboratory officials, grower representatives, and environmental and consumer leaders. Its goal is to develop and adopt a common vision of what the industry could be in the future and what it needs to get there. We hope to have the first draft of that vision ready to release after our next meeting in June. Following extensive industry dialogue and eventual adoption of a vision by the industry as a whole, other industry-led groups will work to draft technology and policy road maps to define the pathways industry and government need to follow to make that vision happen.

The heart of the Bioenergy Initiative undertaken by DOE is this notion of strong industry participation and leadership. Industry leaders are already working closely with DOE and other Federal policy makers and program managers to develop coordinated activities, analytical tools, and assessments of technological, institutional, and infrastructure barriers to bioenergy development. Analyses of policies that help or hinder that development, as well as assessments of market potential for various types of products, is also critically important and will be pursued along with assessments of technology needs.

Along with strong industry leadership, another crucial element of our strategy is the focus on cross-cutting technologies and systems integration. Building and demonstrating the feasibility of multi-product bioenergy facilities is needed to overcome the private sector's inherent reluctance to devote large-scale resources to a new industry in a highly competitive economic arena. This effort will complement ongoing projects in fundamental soil, plant, and ecosystem science, as well as in technology applications for ethanol, biodiesel, gasification, co-firing, biochemicals, and combined-heat-and-power systems. Existing models and analyses will be expanded to study the impact of feedstock options, equipment needs, and product costs of total bioenergy systems on a regional basis. Laboratory-scale R&D will investigate linkages among fuels development, power production, chemical products manufacturing, and agricultural and forest feedstocks and traditional products. Targeted, small-scale demonstrations will focus on enhancing current technology and planned facilities designs to emphasize multiple feedstock utilization and multiple products.

Within my own office at DOE, our primary mission is developing environmentally-sustainable energy resources and technologies, and finding ways to use energy more efficiently. Our current organization of bioenergy-related programs emphasizes

technology development along three pathways: electric power, biofuels—primarily ethanol—and industrial biochemical products. Each program area is making significant progress, in partnership with industry, in technology development and demonstration. For example, we have developed effective methods for converting forest and agricultural residues and dedicated energy crops into cellulosic ethanol, and we are now providing limited, but crucial, financial support to first-generation, commercial-scale demonstration plants. We have also developed, in partnership with industry, technically viable methods of producing biomass gas for power generation. We are now testing a pilot scale gasification system at a commercial electric utility plant, with plans underway to support commercial scale demonstrations in the pulp and paper industry. We have just begun a program to develop small-size, modular biomass processing facilities—taking the processing and conversion to the resources, and greatly reducing transportation costs. We have also recently funded work to produce ethanol from corn stalks and other residues in existing ethanol plants.

However, we now must stretch beyond these niche sectors to realize the vastly greater potential for effective resource use and faster progress that lies in full integration of the industry as a whole. This goal requires a cross-cutting approach to technology development and a recognition of the bioenergy industry as a dynamic, interdependent system. To that end, our Bioenergy Initiative focuses on collaborative planning and resource allocations by DOE headquarters programs, national labs, universities and our industry partners. The aim is to seed the growth of a fully integrated industry where a ton of biomass—like a barrel of oil—will be produced and processed into fuels, power, and/or chemicals in response to market signals and policy drivers. To support this Initiative, we have requested \$6 million in our FY 2000 budget, in addition to our core budget request of about \$117 million that supports ongoing programs in biopower, biofuels, and biochemicals.

Within DOE more broadly, the Office of Science—which funds fundamental plant sciences through its Division of Energy Biosciences—is now an active participant in our Bioenergy Initiative team, and we are devising ways to incorporate its research into our applied technology efforts. We are also discussing with several of our DOE national laboratories the establishment of a National Bioenergy Center. The Center will be a “virtual” lab whose primary functions would be to provide administrative and logistical organization, information and technology sharing, and interactive communications capabilities. It would be the strategic umbrella for project consortia of national, state, university, and private sector researchers and organizations performing integrated bioenergy R&D through competitive solicitations.

With leadership from the White House, we at DOE are now beginning to work with USDA, EPA, the NSF, and other agencies and industry to put together an even broader

strategy. Its aim is to focus the resources and objectives of relevant portions of these agencies on developing the research base, organizational mechanisms and resources need to make substantial advances in bioenergy. At our last Bioenergy Industry Vision meeting in March, two Undersecretaries of Agriculture – Miley Gonzalez and Jill Long Thompson—were active participants. We expect both will be present at our next industry vision meeting in June. Additionally, I will meet with National Science Foundation Director Rita Colwell in the near future to begin discussing how our two agencies can better collaborate.

The reason I have reviewed these developments is to point out that the Administration has recognized, and is beginning to address in concrete ways, the need for a cross-cutting, integrated systems approach to the very complex challenges—and wide range of benefits—of nurturing a bioenergy industry. The support of this Committee—as well as Energy and Natural Resources and both our appropriations committees—is absolutely essential if we are to make serious headway over the next few years in setting the stage for rapid, wholesale advances in utilizing our nation’s biomass resources and capturing the benefits that I have outlined.

S. 935—A First Step

Chairman Lugar’s bill, the National Sustainable Fuels and Chemicals Act of 1999 (S. 935), is an important first step in providing the legislative underpinning for, and direction to, our efforts. The bill’s findings make a compelling case for the need, the benefits, and the urgency of taking actions to stimulate bioenergy production and use. Substantively, the bill’s principal aim—if I have understood it correctly—is threefold:

- to spur closer coordination and cooperation between the USDA and DOE in strategic planning, in use of federal research facilities, and in selection of R&D activities; to that end, the bill authorizes creation of both a Federal policy and oversight board and a non-Federal technical advisory board.
- to establish a mutli-agency, focused program of R&D activities whose objective is a more concerted, faster pace of development of agricultural and forest biomass feedstocks and their processing into power, fuels, and chemicals; and
- to authorize additional Federal resources for competitively-based financial support to a broad spectrum of research entities, preferably in consortia, targeted at: a) biomass conversion; b) biomass products development; and c) sustainability and economic viability of both feedstocks and biobased products.

Obviously, there is a long way to go between S. 935 and final passage of a bioenergy bill,

as well as between authorizing language and actual appropriations to implement it. However, we view this bill as a valuable and complementary legislative foundation for those activities DOE and the Administration have begun to plan and implement -- with industry -- to promote bioenergy integration.

While the bill overall appears to be in line with what we at DOE would like to see, I would like to point out where we believe some changes could improve the bill. First, the title--The National Sustainable Fuels and Chemicals Act of 1999--does not give sufficient recognition to the role of biomass power, or to the tremendous benefits in better air quality and lower greenhouse emissions that will be achieved as electric power producers introduce biomass into their fuel supplies, whether as co-fired material along with coal, or as biomass gas supplied to turbine units. As electric utility restructuring proceeds nationally, we expect to see many utilities facing the choice of what types of facilities to build, what types of equipment to install, and what types of fuel to use for generation. We would like to see more emphasis in this bill on biomass resource and technology development aimed at encouraging these utilities to move toward biomass power. This would not only be a great boon to biomass feedstock producers, primarily farmers and foresters, but is also a natural complement to an integrated biorefinery concept in which the lignin in biomass is fully utilized as a part of the multi-product mix of a biorefinery. Therefore, we would like to see the bill's title include the term "power," or even better, to see it titled "The Bioenergy Integration and Organization Act." ("The BIO Act").

Another change we would hope to see is a less prescriptive approach to collaboration between USDA and DOE, and among the several other federal agencies mentioned. Given periodic changes in internal agency organizations and senior personnel, as well as changes to mission roles within agencies, we feel that the designation of "points of contact" and their precise duties would be more effectively left to executive directives by the President and/or the Cabinet Secretaries rather than be enacted into law.

In the section dealing with "Uses of Grants, Contracts, and Financial Assistance," we would prefer again to see language that is somewhat less prescriptive. At the least, we would prefer greater latitude for the agencies in selecting which fields of R&D are to be emphasized. We feel that, over time, results of R&D and/or changes in market economics may lead to emphasis on priorities--or even new areas of research--that are not reflected in the bill. R&D priorities, we believe, can best be set by scientists and technologists who are closest to the moving targets at any given time. Specific R&D objectives written into law could prove cumbersome and awkward to change, especially in light of the possibility of unexpected breakthroughs or dead-ends in the research process.

Overall, however, I want to thank the Committee for having taken a first important step to

address a real and looming need in the form of bioenergy R&D integration, across science and technology boundaries, Federal bureaucracies, and the public-private sector divide. This piece of legislation, if enacted, will be a visible boost to the widespread and valuable benefits of bioenergy.

I look forward to working with the Committee, as the bill moves through the legislative process, to see that it continues to reflect the priorities that the Committee and the Administration have mutually agreed upon. We also anticipate working closely with you in the near future on legislative approaches that will address needs fundamental to the growth of an integrated bioenergy industry in the areas of policy and regulatory matters, tax credits and financing options, land-use policies, and industry-government partnership to tackle non-R&D issues.

Mr. Chairman, thank you for the opportunity to testify. I will be happy to answer any questions you may have.

STATEMENT OF DAN GLICKMAN
SECRETARY
UNITED STATES DEPARTMENT OF AGRICULTURE
BEFORE THE
UNITED STATES SENATE COMMITTEE
ON
AGRICULTURE, NUTRITION, AND FORESTRY

May 27, 1999

Mr. Chairman and Members of the Committee, I am pleased to appear before you today to discuss the future of renewable fuels and bioproducts for American agriculture and for the American economy. The Clinton Administration shares the Chairman's and this Committee's strong commitment to this issue, and I applaud your leadership in continuing to advance these efforts during this Congress.

Mr. Chairman, as you noted in your recent *Foreign Affairs* article, coauthored with former Director Woolsey, biomass crops, such as poplar, willow, and switch grass, and agricultural waste streams could become important feedstocks of electric power, liquid fuel, and chemical production. In addition, biomass feedstocks can offer significant environmental benefits compared to fossil fuels. For example, energy produced from biomass crops does not add greenhouse gasses to the atmosphere during the life cycle of its production use relative to fossil fuels.

Advances in technology in farm production and processing offer enormous market opportunities for the Nation's farmers and hold the potential of transforming a significant portion of our fossil fuel based economy to a biobased economy. The Clinton Administration wants to help encourage that transformation.

In my testimony today, I will provide a brief overview of activities undertaken by the Clinton Administration that are helping to promote the research and development of a renewable fuels and biobased products industry. But I would first like to comment on S. 935, the National Sustainable Fuels and Chemicals Act of 1999.

The National Sustainable Fuels and Chemicals Act of 1999

The Administration strongly supports S.935, the National Sustainable Fuels and Chemicals Act of 1999, but would prefer to see less prescriptive language. While funding provided under the bill's authorization would have to compete with existing programs under discretionary budget ceilings, we do believe that the legislation, by formalizing cooperation and coordination between USDA, the Department of Energy (DOE) and other agencies in sustainable fuels and chemicals research, would help reinforce the commitment of the agencies, in concert with Congress, to match resources and realize the potential of biofuels and bioproducts. In addition to an advisory committee to help focus strategic planning, the development of a joint sustainable fuels and chemicals initiative to carry out research on biobased industrial products will ensure that funds from both departments are efficiently and effectively leveraged.

The Clinton Administration looks forward to working with Congress to enact S. 935. But we also believe we can begin the process of improving cooperation and coordination immediately. To that end, we have been discussing with your staff how we might accomplish a number of the goals of S. 935 through administrative action.

Current USDA Activities

USDA currently spends \$9 million annually on biofuels research and \$63 million annually on research on new industrial uses of biobased products. To better coordinate these activities within USDA, I established the Biobased Products Coordination Council, chaired by Under Secretary of Research, Education and Economics, Dr. Miley Gonzalez. The Council promotes biobased industrial product research, development, and commercialization through information sharing, implementation of strategic planning and providing policy advice for my office. It is currently working on a list of biobased products for use by Federal agencies and their procurement officials as encouraged under Executive Order 13101.

Ethanol research. One of the most promising roles biomass can play is strengthening our energy security. In 1995, USDA released a study on the net-energy balance of corn ethanol that showed that the energy in ethanol is 22 percent greater than the amount of energy used to produce the ethanol. Since then, technological innovations in corn production and ethanol conversion have substantially reduced the energy required to produce corn ethanol. Our most recent estimate is that the energy content of ethanol is 34 percent greater than the energy used to grow, harvest, and transport corn, produce the ethanol, and distribute the ethanol. In addition, a recent study conducted by Argonne National Laboratory with USDA collaboration showed both corn and cellulosic ethanol reduce greenhouse gas emissions considerably relative to petroleum.

Research directed at reducing ethanol production costs can improve the competitiveness of and expand the quality of ethanol demanded as a fuel or fuel additive. USDA analysis suggests that long-term technology improvement strictly devoted to ethanol production might reduce costs by 9 to 15 cents per gallon. Our researchers believe that additional savings of 13 to 18 cents per

gallon may be possible by developing higher value products--called coproducts--from raw material not used up in ethanol production.

To achieve these cost reductions, USDA research is targeting the development of organisms that will convert multiple, mixed substrates; superior product recovery and separation technology; high-value coproducts; more efficient technologies and processes for coproduct recovery and separation; and better fractionation of feedstocks. Developing new varieties of corn that would be easy to mill and provide optimum levels of fermentable substrate and coproducts are also a subject of scientific work.

Research on Biodiesel and Other Biobased Products. Biodiesel, as well as lubricants, chemicals, and solvents produced from agricultural fats and oils, offer another opportunity to supplant petroleum derivatives. In doing so, an expanded market for agricultural fats and oils may develop, providing farmers with high-volume markets for high-valued nonfood products.

Like ethanol, biodiesel has a positive net energy balance. This high-energy efficiency translates to a much lower emission of greenhouse gases compared with petroleum-based fuels. USDA conducted a study with the Department of Energy's (DOE) National Renewable Energy Laboratory that found the use of biodiesel reduces net carbon dioxide emissions by 78 percent relative to petroleum diesel.

Selected niche market opportunities for biodiesel are emerging now. As a result of legislation passed last year, Federal agencies can use biodiesel 20 percent blends as a credit against alternative fuel vehicle purchases.

The major obstacle to the widespread use of fats and oils for biodiesel manufacture is the relatively high cost of biodiesel from food-grade oils. The full production cost of biodiesel is \$2

to \$3 per gallon compared with 50 to 60 cents for petroleum diesel. Tallows, yellow and white greases, often termed waste vegetable oil, and true wastes, such as sewage trap grease, are cheaper to use than food-grade oils.

To create economically viable sustainable fuels and chemicals markets based on renewable fats and oils, a focused research program is critical. USDA's research is aimed at lowering the cost of production, optimizing the properties of biodiesel feedstocks, and developing conversion and utilization technologies which take advantage of the unique properties of the fats and oils.

We can further reduce our dependence on foreign oil if we can use agricultural materials that replace petrochemicals as a source of raw industrial materials. For example, until recently about 98 percent of all plastics were petroleum-based. They are not generally biodegradable either. USDA's biobased products program is designed to expand nonfood markets for agricultural products and provide biorenewable substitutes for petroleum-based plastics, printing inks, paints and other coating lubricants, and intermediate chemical products.

Biobased products from agricultural and forestry resources provide renewable raw materials for the processing and manufacturing of a broad range of nonfood and nonfeed products, such as chemicals, fibers, construction materials, and energy sources. Development and commercialization of such products provide new and expanded markets, accelerate successful market penetration, and diversify agriculture while fostering rural and sustainable development.

Biomass Initiatives. Farmers and processors need to see practical and successful demonstration projects on the ground before they could be expected to participate on a large scale. To that end, USDA is collaborating with DOE on a Biomass Power for Rural Development Initiative. USDA is leveraging its existing programs and authorities with DOE

funding to cost share with the private sector the development of integrated biomass power projects that couple dedicated energy feedstock production with advanced power conversion technologies.

The first award under this solicitation was signed on May 6, 1996, with Niagara Mohawk Power Corporation of Syracuse, New York, representing the Salix Consortium. The Salix Consortium plans to integrate dedicated short- rotation woody crops such as willows with power conversion by cofiring them with coal. A gasification test will be conducted as well. In the initial phase, a total of up to 47 megawatts of biomass power capacity will be produced at the three project sites, with a total of 6,000 acres of land dedicated to supplying willow feedstocks to these applications by 2001.

In Chariton Valley, Iowa, USDA and DOE are working to explore the possibilities of switchgrass as a fuel to make electricity. The Chariton Valley Resource, Conservation and Development Council received a research project waiver to harvest 4,000 acres of switchgrass from land enrolled in the Conservation Reserve Program and supply it to the power plant for cofiring with coal. A small-scale gassifier will also be investigated in the project.

Last fall BC International broke ground in Jennings, Louisiana to become the first commercial cellulosic ethanol plant. This DOE-supported plant is also receiving help to further advance the cellulosic ethanol conversion technology from USDA through Cooperative State Research, Education, and Extension Service (CSREES) research grants.

Renewable Portfolio Standard. Recently, the Administration proposed the Comprehensive Electricity Competition Act which featured a Renewable Portfolio Standard (RPS). The RPS would require that 7.5 percent of U.S. electricity be generated from renewable sources by 2010.

Improvements in the technology of biomass for electricity could help make biomass an important means to meet the RPS or any similar standard that might be adopted.

Conclusion

The development and expansion of a renewable fuel and biobased products industry founded on a strong agricultural and forestry sector can play an increasingly important role in enhancing energy security, cleaning our environment, and promoting farm and rural economic growth. Petroleum and fossil fuel prices, feedstock costs, coproduct markets, energy and environmental policies, and advances in technology are all critical determinants of market growth for biofuels and biobased products. The Clinton Administration will work with Congress and others to advance the technology and improve the economics of producing and marketing biofuels and new biobased products from agricultural commodities.

That completes my testimony, Mr. Chairman. I am happy to respond to any questions.

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Biobased Industrial Products

Executive Summary

Committee on Biobased Industrial Products

Board on Biology
Commission on Life Sciences
National Research Council

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BIOBASED INDUSTRIAL PRODUCTS

Executive Summary

Biological sciences are likely to make the same impact on the formation of new industries in the next century as the physical and chemical sciences have had on industrial development throughout the century now coming to a close. The biological sciences, when combined with recent and future advances in process engineering, can become the foundation for producing a wide variety of industrial products from renewable plant resources. These "biobased industrial products" will include liquid fuels, chemicals, lubricants, plastics, and building materials. For example, genetically engineered crops currently under development include rapeseed that produces industrial oils, corn that produces specialty chemicals, and transgenic plants that produce polyesters. Except perhaps for large-scale production of bioenergy crops, the land and other agricultural resources of the United States are sufficient to satisfy current domestic and export demands for food, feed, and fiber, and still produce the raw materials for most biobased industrial products.

During this century petroleum-based industrial products gradually replaced similar products that once were made from biological materials. Now, biobased industrial products are beginning to compete with petroleum-derived products that once displaced them. This progress has been made possible by the wealth of knowledge on the scientific basis for conversion of biomass to sugars and other chemicals, particularly the knowledge of biochemical and fermentation fundamentals, and related progress in process technology and agricultural economics. New discoveries occurring in microbial, chemical, and genetic engineering research, in particular, could lead to technological advances necessary to reduce the cost of biobased industrial products. Near-term strategies may be dominated by fermentation of sugars through microbial processes for production of commodity chemicals. In the long-run, similar processes may be used for large-scale conversion of biomass to liquid fuel. In the future, novel chemicals and materials that cannot be produced from petroleum may be directly extracted from plants. Today only a small fraction of available biomass is used to produce biobased chemicals due to their high conversion costs. The long-term growth of biobased industrial products will depend on development of cost-competitive technologies and access to diverse markets.

There remains an open question as to the size of petroleum reserves and the future cost of petroleum products. Current oil reserves are substantial and exploration continues to open new petroleum supplies for the world market (e.g., Caspian Sea). Experts estimate that two thirds of the world's proven reserves are located in a single geographic region, the Persian Gulf, and this area will continue to serve as a dominant source for oil exports (USDOE, 1998). According to the American Petroleum Institute, there are approximately 43 years of reserves remaining as of 1997 (API, 1997), an increase from the 34 years prevailing before the first Organization of Petroleum Exporting Countries (OPEC) crisis of 1973. However, some geologists report that oil reserves could be depleted within 20 years (Kerr, 1998). While this Committee believes there is a need to make a transition to greater use of renewable materials as oil and other fossil fuels are gradually depleted, we cannot predict with any accuracy the availability and cost of future supplies of petroleum.

to the nation's liquid transportation fuel needs. Productivity of U.S. farms and forests has been rising to meet domestic and export demands for traditional food, feed, and fiber products, as well as biobased raw materials. Approximately 35 million acres of marginal cropland in the Conservation Reserve Program (CRP) could provide additional land to grow biomass crops. If approximately half of the land set aside for the CRP could be harvested in a judicious manner (to minimize risks of soil erosion or loss of wildlife), approximately 46 million tons of additional biomass feedstock would become available. This figure assumes very low yields of biomass (2.5 tons/acre) and could increase four-fold (up to 10 tons/acre) with some crops (e.g., switchgrass). The total biomass is sufficient to easily meet current demands for biobased industrial chemicals and materials.

The amount of land that actually will be used for biobased crops will depend on future demands for the final products, and the inputs used to make that product must be competitively priced. High-value novel chemicals are not expected to require large acreages. While biobased materials such as lumber, cotton, and wool do have substantial markets, these products now compete successfully for land resources. However, the current demand for many biobased chemical products is small. For example, as of 1996/1997 marketing year, industrial uses of corn accounted for approximately 7% of the nation's corn grain production (ERS, 1997).

Coproduction of human food and animal feed products such as protein with biobased materials, fuels and chemicals is expected to help prevent future conflicts between production of food and biobased products. Corn-based refineries, for example, yield protein for animal feed and oil, starch, fiber, and fuel alcohol products. In the case of pulp and paper mills, pulp, paper, lignin by-products, and ethanol can be produced while recycling waste paper in a single system. If demand for liquid fuel increases beyond capacity for coproduction of food and liquid fuel, then biobased production may compete for land with food production. This report describes some opportunities for coproduction of food, feed, liquid fuels, organic chemicals, and materials.

The Committee recognizes that an abundant supply of food at a reasonable price is a national goal. If the oil supply does diminish without available substitutes, then oil prices could rise. At that point, policy makers may decide to convert land from food to fuel production. This could create competition for scarce resources and subsequent conversion of U. S. crop land to energy crops could lead to higher food prices. The Committee estimates that by-products of agriculture could provide up to 10% of liquid transportation fuel needs. The amount of land devoted to crops for biobased industries will be determined by economics, as tempered by agricultural policies.

The raw materials for biobased industrial production are supplied by plants as plant parts, separated components, and fermentable sugars. For the immediate future, the raw material sources most likely to be used for producing industrial materials and chemicals in the United States are starch crops like corn and possibly waste biomass. Over the long term, as the demand for biobased products expands and crop conversion technologies improve, this resource base will grow to include lignocellulosic materials from grasses, trees, shrubs, crop residues, and alternative crops custom-engineered for specialized applications.

Many potential biobased products will come from traditional crop plants being put to new uses, for example, grasses and legumes used in paper production. Perhaps more important, however, will be new types of crops or traditional crops that have been genetically engineered. Although a number of barriers can impede the introduction of new crops, the transformation of

be sought for a wide array of plant chemicals (e.g., chiral compounds) not available from petrochemical markets.

Biobased materials represents a significant market with a wide range of products. Lumber, paper, and wood products traditionally have been a large market with annual sales of approximately \$130 billion in the United States. Several other biobased materials have established uses that are likely to grow as technological advances reduce costs. Examples include starch-derived plastics, biopolymers for secondary oil recovery, paper, and fabric coatings.

The cost of large-scale production of biobased products depends on two primary factors: 1) cost of the raw material, and 2) cost of the conversion process. The industries for producing chemicals and fuels from petroleum are characterized by high raw material costs relative to processing costs while, in the analogous biobased industries, processing costs dominate. Therefore, similar percentage improvements in processing costs have much more impact on biobased industries. Also, the cost per ton of biomass raw materials generally is comparable (e.g., corn grain) or much less (e.g., corn stover) than the cost per ton of petroleum. Thus, there is real potential for biobased products to be cost-competitive with petroleum-based production if the necessary research and development are done to reduce processing costs. Furthermore, because starch and sugar already contain oxygen, and petroleum does not, there is the potential to derive oxygenated intermediate chemicals—such as ethylene glycol, adipic acid, and isopropanol—more readily from biological raw materials than from fossil sources. Production of such oxygenated chemicals by fermentation has the additional advantage of being inherently flexible. The raw materials can vary depending on which local source of fermentable sugars provides the best economic returns. Therefore, economic evaluations should first consider the potential of biobased replacements for the oxygenated organic chemicals of the 100 million metric tons of industrial chemicals marketed each year in the United States.

Other significant opportunities exist to produce a wide range of industrial products from agricultural and forest resources. Many will require investment in basic research as well as process engineering research to ensure commercial viability. These opportunities begin with the plant sources for raw materials. Modern principles of molecular biology and genetic engineering can be used to create agricultural crops that contain desired chemical polymers or polymer intermediates. Additionally, trees and grasses could be genetically engineered to have a structural composition that facilitates and enhances the effectiveness and efficiency of subsequent conversion to desired products.

Combined advances in functional genomics, genetic engineering, and biochemical pathway analysis, sometimes referred to as metabolic engineering, will make it possible to manipulate efficiently the biosynthetic pathways of microorganisms. By increasing chemical yield and selectivity, such manipulations could make microbial production more economically competitive with existing production methods. The combination of modern genetics and protein engineering will provide biocatalysts for improved synthesis or conversion of known products or for reaction routes to new chemicals.

products that oil refineries cannot, including foods, feeds, and biochemicals. These additional capabilities give biorefineries a potential competitive edge and enhanced financial stability.

The processing technologies of refineries tend to improve incrementally over time, eventually causing raw material costs to become the dominant cost factor. In this regard, biorefineries have another potential advantage over petroleum refineries because plant-derived raw materials are abundant domestic resources. The availability and prices of biological raw materials may thus be more stable and predictable than that of petroleum.

An extensive case study in this report examines the potential of converting corn stover (stalks, leaves, cobs, and husks—also known as corn residue) to ethanol. The case study incorporates a model to calculate costs for ethanol processed from corn stover. Today production of corn-starch based ethanol costs approximately \$1.05/gallon. The model indicates that by using corn residue as a feedstock, up to 7.5 billion gallons of ethanol could be produced at a cost potentially competitive with gasoline without subsidies. When the ethanol price is adjusted to account for the fact that a gallon of ethanol will provide less mileage in a conventional gasoline-type engine than will the fuel for which the engine is designed, the price of ethanol equivalent to a gallon of gasoline is \$0.58 per gallon. The U. S. refiner price for motor gasoline in July 1998 reported by the Energy Information Administration was \$0.54 per gallon (Energy Information Administration, 1998). The model assumes that some not yet completely developed technologies are available and use of corn residue makes possible especially low-cost raw materials. As a result, projected costs for ethanol processing could drop significantly from current costs because these residues are co-produced with corn grain. It should be noted that the price of oil could change significantly from today's prices, thus changing the price comparisons between ethanol and gasoline. The opportunities to produce ethanol more efficiently are large. While corn has been the dominant raw material source, other more productive lignocellulosic materials such as switchgrass are being considered as alternative feedstocks.

In many cases, the biorefinery that produces ethanol and other commodity chemicals from biomass requires three major new technologies:

- 1) an effective, economical pretreatment to unlock the potentially fermentable sugars in lignocellulosic biomass or alternative processes that enable more biomass carbon to be available for ethanol or other oxygenated chemical;

- 2) inexpensive enzymes (called "cellulases") to convert the sugar polymers in lignocellulose to fermentable sugars; and

- 3) microbes that can rapidly and completely convert the variety of five- and six-carbon sugars in lignocellulose to ethanol and other oxygenated chemicals.

Other biobased processes under development may not require all these pretreatment processes.

Several lignocellulose pretreatment processes recently have been developed that promise to be technically effective and affordable. Such pretreatments should make it possible to convert a vast array of lignocellulose resources into useful products. Considerable progress has also been made in developing genetically engineered microorganisms, which utilize both five- and six-carbon sugars. Less progress apparently has been made in producing inexpensive cellulases.

Processing technologies that use microbes and enzymes have great promise for the expansion of biobased industries. Unlike thermal and chemical processes, such bioprocesses occur under mild reaction conditions, usually result in stereospecific conversions, and produce only a few relatively non-toxic byproducts. One drawback is that bioprocesses typically yield

industrial products. For example, policy makers may want to accelerate use of renewable biomass to mitigate impacts on the U. S. economy from a disruption in world supplies of oil, or perhaps to reduce impacts on the environment created by possible global warming.

RECOMMENDATIONS

Federal support of research on biobased industrial products can be an effective means to improve competitiveness of biobased feedstocks and processing technologies, as well as diversify the nation's industrial base of raw materials, and provide additional markets for farmers. Policy makers should encourage research and development that would fill important technical gaps in raw material production, storage, and processing techniques. Volatility in petroleum prices is a barrier to the development of these biobased products by the private sector. Policy makers should realize that decades of research investment may be necessary to develop enabling technologies, and considerable lead time will be necessary to implement such research programs and to allow for their adoption by industry.

Research will be a prominent tool in making biobased feedstocks more competitive. The public sector research and development agenda should emphasize major technical and economic roadblocks that impede the progress of biobased industrial products. Research priorities should emphasize development of biobased products that can compete in performance and cost with fossil-based ones. Expansion of biobased industries will require research on the biological and engineering principles that underlie biobased technologies as well as the practical implementation of these technologies through development and commercialization.

The discoveries occurring today in plant and microbial genomics are expected to lead to significant advances in fundamental biological research for many years in the future. The complete genomic sequence is available for some microbial organisms such as *Saccharomyces cerevisiae* (common yeast) and *Escherichia coli* (gram-negative bacteria). Scientific investigations are underway to decipher the entire genetic code of eukaryote organisms such as *Arabidopsis thaliana* (flowering plant of the mustard family) and *Drosophila* (fly). The genetic information collected on these organisms will provide researchers with insights on the genes that control plant traits and microbial cellular processes. In the future, this genomic knowledge will help scientists find new ways to alter microbes and plants that increase the value of biobased raw materials and improve the efficiency of the conversion processes.

Specific recommended research priorities for biology include:

- the genetics of plants and bacteria that will lead to an understanding of cellular processes and plant traits;
- the physiology and biochemistry of plants and microorganisms directed toward modification of plant metabolism and improving bioconversion processes;
- protein engineering methods to allow design of new biocatalysts and novel materials for the biobased industry; and
- maximization of biomass productivity.

Recommended research priorities for engineering include:

costs of financing some of these incentives are not well known, government agencies will need to obtain comprehensive cost-benefit data for their decision-making. Incentive programs should be cost-effective with endpoint provisions to evaluate program utility. In the long term, development of biobased products that can compete in an open market without incentives is key to sustaining a strong biobased industry.

Although policy changes would go a long way in encouraging the development of U.S. biobased industries, they will not be sufficient alone. The current technology base for biobased industries is incomplete. Advances in agriculture have stressed crop production technologies without a comparable interest in conversion technologies to produce biobased industrial products. Likewise, education and research resources in the fields of chemistry and process engineering will need to put more emphasis on biobased processing. Careful integration of relevant science and engineering is essential to reduce the cost of processing abundant raw materials into value-added biobased products.

This report takes a broad look at current and potential biobased industries. It identifies key opportunities for products derived from renewable resources and the industry and public policy actions that could facilitate the research, development, and commercialization of biobased industrial products. With a vigorous commitment from all parties, the United States will be well positioned to reap the benefits of a strong biobased industry.

BIOENERGY

Growing Energy to Power America

A National Partnership for an Integrated Biomass Industry

Vision

BioEnergy is a national partnership to develop an integrated industry to produce power, fuels, and chemicals from crops, trees, and wastes, will help power America by using our most abundant natural resource — biomass. By making a “ton of biomass” a viable market competitor to a barrel of imported oil, BioEnergy will help grow the U.S. economy, strengthen U.S. energy security, protect the environment, reduce greenhouse gas emissions, and revitalize rural America.

Background

Biomass power, fuels, and chemical products already have demonstrated initial success in the marketplace. Bioenergy resources from the nation’s farms, forests, pulp and paper mills, and landfills currently meet more than 3 percent of U.S. heat and electric power needs. In fact, consumption of these biomass resources has been increasing steadily by more than 2 percent annually since 1990 in most regions of the country. The challenge is to build upon these efforts and create new and economically viable options for farmers, foresters, fuels producers, chemical manufacturers, wood products companies, electricity producers, and consumers to use and profit from biomass commodities, products, and services.

Need for an Integrated Industry

There is today inadequate integration across the biofuels, biopower, and bioproducts industries. This lack of integration among technologies, markets, and policies has been a major barrier to industry growth. A more comprehensive and coordinated approach could open opportunities and remove barriers for nascent bioenergy industries. In addition, greater integration across industries could stimulate new and innovative products and increase profitability. Such integration could also enhance development of industrial processes and facilities for biomass that serve multiple uses—the so-called “biorefinery” for example. Furthermore, increased integration of biomass research, development, and deployment programs can reduce the time it takes for improved concepts to make it from the laboratory to the marketplace.

Benefits

The successful integration and market penetration of biomass will yield a number of significant benefits, including:

- Reducing U.S. dependence on foreign oil imports, with enhanced energy security;
- Reducing environmental emissions of NOX, SOX, and other pollutants;

- Decreasing greenhouse gas emissions;
- Increasing profitability for biomass-related commercial activities;
- Revitalizing rural areas with new markets and revenue streams; and
- Providing greater choices of fuel sources for electric power, transportation fuels, and industrial and commercial products.

The Partnership

This initiative will build a new partnership among industries, government agencies, non-governmental organizations, and laboratories. The partnership will foster better collaboration and communication among biomass stakeholders, in order to take advantage of inherent synergies and exploit emerging market opportunities. It will develop a shared vision of the future and reach agreement on the most productive pathways for achieving that vision. It will also address the need for more effective public policies at the federal, regional, and state levels to support a robust biomass industry. Not least, the partnership will help secure the resources required to grow a competitive biomass industry.

TEN POINT ACTION PLAN

1. Establish the Partnership Vision

- Develop a shared vision for the future of biomass fuels, power, and chemicals.
- Establish initial targets and time lines.

2. Develop Roadmaps

- Identify and develop roadmaps to address future needs and pathways for power, fuels, and chemicals.
- Establish priorities for technology development, policy actions, and market mechanisms.

3. Create an Effective Policy Framework

- Assess current biomass-related policies at the federal, regional, and state levels.
- Devise policy options that expand opportunities for biomass production and use.

4. Expand Biomass Markets

- Remove or reduce market barriers.
- Encourage federal procurement.
- Establish biomass quality, performance, and safety standards.
- Promote labeling (e.g., EnergyStar) for biomass products.

5. Conduct Supporting Analysis

- Analyze market potential for production and use of biomass resources.
- Analyze expected performance of process-specific technologies.
- Assess the potential contributions of biomass use in addressing global climate change.

6. Promote Advanced Technologies

- Develop economically viable, dedicated energy crops and trees.
- Demonstrate fully integrated industrial processes for cost-effective co-production of fuels, power, and chemicals.
- Develop profitable, efficient energy conversion processes for waste management.
- Coordinate biomass RD&D with other renewable and fossil energy technology programs.

7. Expand Federal-State Coordination

- Increase the degree of coordination and communication among government agencies.
- Expand technical assistance to state and regional agricultural and forestry programs.

8. Pursue Outreach and Showcase Successes

- Provide information on the benefits of biomass products to states, communities, farms, industries, consumers, and others.
- Organize regional meetings of stakeholders.
- Promote technology demonstrations to exhibit the benefits of biomass.
- Highlight ground breakings, roll-outs, and success stories for the Congress and the White House.

9. Hold Quarterly Progress Meetings

- Review progress toward goals
- Develop strategies and tactics
- Share information

10. Maintain Effective Partnerships

- Annually convene an Integrated Bioenergy Summit.
- Formalize industry consultations with government.
- Develop internal industry coordinating structure to interface with governments.

Statement of Dan W. Reicher
Assistant Secretary for Energy Efficiency and Renewable Energy
U. S. Department of Energy
before the
Committee on Agriculture, Nutrition and Forestry
United States Senate
May 27, 1999

Mr. Chairman, and Members of the Committee, I am pleased to testify today on bioenergy. In my testimony I will address why there is a need—and a great opportunity—for a broadly coordinated initiative in bioenergy at this time. Also, I will provide an overview of what we in the Administration have undertaken, with industry, the national laboratories, universities, state governments, and other stakeholders in the bioenergy arena. Finally, I will comment on S. 935, the National Sustainable Fuels and Chemicals Act of 1999, and suggest some modifications.

The Benefits of Bioenergy Production and Use

Bioenergy resources such as agricultural and forest products and waste residues already meet more than 3% of U.S. energy requirements. Consumption of bioenergy products, particularly electric power and fuels, has been increasing by 2% annually since 1990. However, this growth is not enough—indeed, it is far too slow to meet our fast-growing concerns about air quality, climate change, dependence upon foreign energy supplies, and weakening economic conditions in the nation's farm and forestry sectors. If we are to see a meaningful decline in reliance on fossil fuel use over the next decade and beyond; if we are to lessen our economic and national security vulnerabilities to interruptions in energy supply; if we are to stimulate a whole new arena of agricultural and forestry economics, then we must have a concerted national effort to develop a range of renewable energy sources, with bioenergy as a centerpiece. Biomass resources are an important domestic and renewable source of energy. Moreover, production of energy and chemical products from biomass offers economies of scale that eventually will permit us to supplant fossil energy to a truly significant degree.

The bioenergy industry at the moment, however, remains small and segmented; there is woefully inadequate integration across the biofuels, biopower, and biochemical products industries. Our industry integration meeting in St. Louis in March of this year was one of the few times, if not the first, that senior corporate decision makers from all three industry areas, as well as farmers, have held a common dialogue on the state of the industry and its potential. The lack of integration among technologies, their applications, markets, and policies has been a major barrier to industry growth. More extensive technology integration, along with an integrated strategy for resource development and use,

processing facilities, and product development, would create a strong momentum for both growth and competition within the bioenergy industry. Such integration could stimulate innovative product lines and new markets, while enhancing the development of processes and facilities that use a variety of feedstocks while producing a broad range of products. A long term technical and economic objective is to make a "ton of biomass" a viable market competitor for a barrel of imported oil. That ton of biomass could be processed in a "biorefinery" that can quickly and easily vary its feedstocks and its product mix according to market signals, much as petroleum refineries do with oil today. And not least, integration among biomass research, development, and demonstration programs can shorten the time to move a new process or product from the laboratory to the marketplace.

We at the Department of Energy believe a more focused, visible, and integrated national effort can meet the challenges and make the U.S. the world leader in production of bio-based energy and other products. Some of those challenges lie in improving crop yields; introducing new crop varieties tailored for biorefining; rethinking land use policies to blend resource production with soil and environmental conservation; developing biomass harvesting, distribution, and processing technologies; developing new product opportunities from biochemicals; and building the level of confidence in the investment community that will be needed to finance these undertakings.

A variety of specific advances needed to meet these challenges have already been identified. For instance, in crop feedstocks, near term objectives include development of inexpensive cellulose enzymes having progressively faster specific activity, and new genomic and genetic engineering of cellular wall variability. Longer term work will focus, as an example, on engineering plants with greater carbohydrate composition and specific "designer" properties tailored to reduce the required degree of processing and conversion. In the area of processing, objectives include better separation technologies for easier and more efficient recovery of products, as well as conversion techniques other than catalysis. A major additional challenge lies in developing technological and economic assessments and models for such factors as variability of resource and product mixes for biorefineries, and impacts of bio-based products on markets and pricing of competing products.

Overall, a prediction of costs associated with achieving these objectives would be speculative at this time. We are at the leading edge of much of the R&D and systems integration necessary to grow this industry from one of a few niche products and markets into one that is fully competitive across the board and fully responsive to the whole range of market signals. Since the aims of both the Administration's Bioenergy Initiative and S.935 are in the direction of greater integration, to speed development and enhance synergistic benefits, some additional modest funding may be necessary to achieve those

aims.

The creation of a robust bioenergy industry in the U.S. will have tremendous economic, environmental, national security, and even social benefits. For example, the November 1997 report by the President's Council of Advisors on Science and Technology (PCAST) points out that 4.7 quadrillion BTUs (5% of U.S. energy in 1995) of bioenergy could be available at attractive cost by 2015. Just over half could come from agricultural residues, while just 18 million acres of dedicated energy crops could provide the rest. In one scenario, 31 billion gallons of ethanol could be produced from this biomass, and 12 gigawatts of electricity—as a by-product of making fuel—could be generated in conventional steam plants. That amount of ethanol, powering light-duty vehicles with internal combustion engines, would reduce U.S. requirements for gasoline by as much as 22 percent, and for imported oil by \$10 billion per year. The PCAST report goes on to state that such growth in bioenergy production could, by 2015, reduce U.S. emissions of CO₂ by 6 percent from today's levels. The DOE five-lab study, *Scenarios of U. S. Carbon Reductions*, estimated that biomass resources offer the potential to reduce U.S. carbon emissions by even more, up to 10% of current emissions, by 2010.

Another prime benefit of a fast-growing, robust bioenergy market will be the demand for dedicated energy crops and for agricultural and forest residues of all types, providing new revenue streams for farmers and cash-flow for rural economic development. The present pricing uncertainties faced by the agricultural and forestry sectors due to weather, foreign production, and commodities fluctuations could be greatly alleviated by long-term energy crop contracts to biorefineries. New crops, along with new planting, tillage, and harvesting technologies, can improve the utilization of marginal lands, while better preserving the ecosystem. Better forestry management and harvesting for bioproduction can reduce the danger of forest fires while improving the overall health of forests. And not least, investments made in bioenergy technologies, infrastructures, and market development could increase profitability for U.S. firms competing in global markets, while simultaneously providing for the world's energy needs in an environmentally sustainable way.

A National Bioenergy Initiative

Against this vision of the potential of bioenergy, I want to present a brief view of how the government and industry are currently pursuing opportunities not only to scale up current activities, but to work jointly to develop an integrated bioenergy system—ranging from basic research, through feedstock production and processing, to biobased industrial and consumer products. Such a system will involve integrated teams of researchers and engineers from the public, private, and educational sectors. It will also require interaction among public policy makers, business and financial investment managers, farmers and

foresters, and trade and commodity brokers, as well as the research community. Effective integration of this type is a necessity if we are to make the vision of a bioenergy-based economy a reality.

We have already begun this year to move toward that vision with the formation of an industry-led Bioenergy Industry Vision group, composed primarily of senior corporate leaders from the several sectors of the industry, along with senior Federal and national laboratory officials, grower representatives, and environmental and consumer leaders. Its goal is to develop and adopt a common vision of what the industry could be in the future and what it needs to get there. We hope to have the first draft of that vision ready to release after our next meeting in June. Following extensive industry dialogue and eventual adoption of a vision by the industry as a whole, other industry-led groups will work to draft technology and policy road maps to define the pathways industry and government need to follow to make that vision happen.

The heart of the Bioenergy Initiative undertaken by DOE is this notion of strong industry participation and leadership. Industry leaders are already working closely with DOE and other Federal policy makers and program managers to develop coordinated activities, analytical tools, and assessments of technological, institutional, and infrastructure barriers to bioenergy development. Analyses of policies that help or hinder that development, as well as assessments of market potential for various types of products, is also critically important and will be pursued along with assessments of technology needs.

Along with strong industry leadership, another crucial element of our strategy is the focus on cross-cutting technologies and systems integration. Building and demonstrating the feasibility of multi-product bioenergy facilities is needed to overcome the private sector's inherent reluctance to devote large-scale resources to a new industry in a highly competitive economic arena. This effort will complement ongoing projects in fundamental soil, plant, and ecosystem science, as well as in technology applications for ethanol, biodiesel, gasification, co-firing, biochemicals, and combined-heat-and-power systems. Existing models and analyses will be expanded to study the impact of feedstock options, equipment needs, and product costs of total bioenergy systems on a regional basis. Laboratory-scale R&D will investigate linkages among fuels development, power production, chemical products manufacturing, and agricultural and forest feedstocks and traditional products. Targeted, small-scale demonstrations will focus on enhancing current technology and planned facilities designs to emphasize multiple feedstock utilization and multiple products.

Within my own office at DOE, our primary mission is developing environmentally-sustainable energy resources and technologies, and finding ways to use energy more efficiently. Our current organization of bioenergy-related programs emphasizes

technology development along three pathways: electric power, biofuels—primarily ethanol—and industrial biochemical products. Each program area is making significant progress, in partnership with industry, in technology development and demonstration. For example, we have developed effective methods for converting forest and agricultural residues and dedicated energy crops into cellulosic ethanol, and we are now providing limited, but crucial, financial support to first-generation, commercial-scale demonstration plants. We have also developed, in partnership with industry, technically viable methods of producing biomass gas for power generation. We are now testing a pilot scale gasification system at a commercial electric utility plant, with plans underway to support commercial scale demonstrations in the pulp and paper industry. We have just begun a program to develop small-size, modular biomass processing facilities—taking the processing and conversion to the resources, and greatly reducing transportation costs. We have also recently funded work to produce ethanol from corn stalks and other residues in existing ethanol plants.

However, we now must stretch beyond these niche sectors to realize the vastly greater potential for effective resource use and faster progress that lies in full integration of the industry as a whole. This goal requires a cross-cutting approach to technology development and a recognition of the bioenergy industry as a dynamic, interdependent system. To that end, our Bioenergy Initiative focuses on collaborative planning and resource allocations by DOE headquarters programs, national labs, universities and our industry partners. The aim is to seed the growth of a fully integrated industry where a ton of biomass—like a barrel of oil—will be produced and processed into fuels, power, and/or chemicals in response to market signals and policy drivers. To support this Initiative, we have requested \$6 million in our FY 2000 budget, in addition to our core budget request of about \$117 million that supports ongoing programs in biopower, biofuels, and biochemicals.

Within DOE more broadly, the Office of Science—which funds fundamental plant sciences through its Division of Energy Biosciences—is now an active participant in our Bioenergy Initiative team, and we are devising ways to incorporate its research into our applied technology efforts. We are also discussing with several of our DOE national laboratories the establishment of a National Bioenergy Center. The Center will be a “virtual” lab whose primary functions would be to provide administrative and logistical organization, information and technology sharing, and interactive communications capabilities. It would be the strategic umbrella for project consortia of national, state, university, and private sector researchers and organizations performing integrated bioenergy R&D through competitive solicitations.

With leadership from the White House, we at DOE are now beginning to work with USDA, EPA, the NSF, and other agencies and industry to put together an even broader

strategy. Its aim is to focus the resources and objectives of relevant portions of these agencies on developing the research base, organizational mechanisms and resources need to make substantial advances in bioenergy. At our last Bioenergy Industry Vision meeting in March, two Undersecretaries of Agriculture – Miley Gonzalez and Jill Long Thompson—were active participants. We expect both will be present at our next industry vision meeting in June. Additionally, I will meet with National Science Foundation Director Rita Colwell in the near future to begin discussing how our two agencies can better collaborate.

The reason I have reviewed these developments is to point out that the Administration has recognized, and is beginning to address in concrete ways, the need for a cross-cutting, integrated systems approach to the very complex challenges—and wide range of benefits—of nurturing a bioenergy industry. The support of this Committee—as well as Energy and Natural Resources and both our appropriations committees—is absolutely essential if we are to make serious headway over the next few years in setting the stage for rapid, wholesale advances in utilizing our nation’s biomass resources and capturing the benefits that I have outlined.

S. 935—A First Step

Chairman Lugar’s bill, the National Sustainable Fuels and Chemicals Act of 1999 (S. 935), is an important first step in providing the legislative underpinning for, and direction to, our efforts. The bill’s findings make a compelling case for the need, the benefits, and the urgency of taking actions to stimulate bioenergy production and use. Substantively, the bill’s principal aim—if I have understood it correctly—is threefold:

- to spur closer coordination and cooperation between the USDA and DOE in strategic planning, in use of federal research facilities, and in selection of R&D activities; to that end, the bill authorizes creation of both a Federal policy and oversight board and a non-Federal technical advisory board.
- to establish a mutli-agency, focused program of R&D activities whose objective is a more concerted, faster pace of development of agricultural and forest biomass feedstocks and their processing into power, fuels, and chemicals; and
- to authorize additional Federal resources for competitively-based financial support to a broad spectrum of research entities, preferably in consortia, targeted at: a) biomass conversion; b) biomass products development; and c) sustainability and economic viability of both feedstocks and biobased products.

Obviously, there is a long way to go between S. 935 and final passage of a bioenergy bill,

as well as between authorizing language and actual appropriations to implement it. However, we view this bill as a valuable and complementary legislative foundation for those activities DOE and the Administration have begun to plan and implement -- with industry -- to promote bioenergy integration.

While the bill overall appears to be in line with what we at DOE would like to see, I would like to point out where we believe some changes could improve the bill. First, the title--The National Sustainable Fuels and Chemicals Act of 1999--does not give sufficient recognition to the role of biomass power, or to the tremendous benefits in better air quality and lower greenhouse emissions that will be achieved as electric power producers introduce biomass into their fuel supplies, whether as co-fired material along with coal, or as biomass gas supplied to turbine units. As electric utility restructuring proceeds nationally, we expect to see many utilities facing the choice of what types of facilities to build, what types of equipment to install, and what types of fuel to use for generation. We would like to see more emphasis in this bill on biomass resource and technology development aimed at encouraging these utilities to move toward biomass power. This would not only be a great boon to biomass feedstock producers, primarily farmers and foresters, but is also a natural complement to an integrated biorefinery concept in which the lignin in biomass is fully utilized as a part of the multi-product mix of a biorefinery. Therefore, we would like to see the bill's title include the term "power," or even better, to see it titled "The Bioenergy Integration and Organization Act." ("The BIO Act").

Another change we would hope to see is a less prescriptive approach to collaboration between USDA and DOE, and among the several other federal agencies mentioned. Given periodic changes in internal agency organizations and senior personnel, as well as changes to mission roles within agencies, we feel that the designation of "points of contact" and their precise duties would be more effectively left to executive directives by the President and/or the Cabinet Secretaries rather than be enacted into law.

In the section dealing with "Uses of Grants, Contracts, and Financial Assistance," we would prefer again to see language that is somewhat less prescriptive. At the least, we would prefer greater latitude for the agencies in selecting which fields of R&D are to be emphasized. We feel that, over time, results of R&D and/or changes in market economics may lead to emphasis on priorities--or even new areas of research--that are not reflected in the bill. R&D priorities, we believe, can best be set by scientists and technologists who are closest to the moving targets at any given time. Specific R&D objectives written into law could prove cumbersome and awkward to change, especially in light of the possibility of unexpected breakthroughs or dead-ends in the research process.

Overall, however, I want to thank the Committee for having taken a first important step to

address a real and looming need in the form of bioenergy R&D integration, across science and technology boundaries, Federal bureaucracies, and the public-private sector divide. This piece of legislation, if enacted, will be a visible boost to the widespread and valuable benefits of bioenergy.

I look forward to working with the Committee, as the bill moves through the legislative process, to see that it continues to reflect the priorities that the Committee and the Administration have mutually agreed upon. We also anticipate working closely with you in the near future on legislative approaches that will address needs fundamental to the growth of an integrated bioenergy industry in the areas of policy and regulatory matters, tax credits and financing options, land-use policies, and industry-government partnership to tackle non-R&D issues.

Mr. Chairman, thank you for the opportunity to testify. I will be happy to answer any questions you may have.

STATEMENT OF DAN GLICKMAN
SECRETARY
UNITED STATES DEPARTMENT OF AGRICULTURE
BEFORE THE
UNITED STATES SENATE COMMITTEE
ON
AGRICULTURE, NUTRITION, AND FORESTRY

May 27, 1999

Mr. Chairman and Members of the Committee, I am pleased to appear before you today to discuss the future of renewable fuels and bioproducts for American agriculture and for the American economy. The Clinton Administration shares the Chairman's and this Committee's strong commitment to this issue, and I applaud your leadership in continuing to advance these efforts during this Congress.

Mr. Chairman, as you noted in your recent *Foreign Affairs* article, coauthored with former Director Woolsey, biomass crops, such as poplar, willow, and switch grass, and agricultural waste streams could become important feedstocks of electric power, liquid fuel, and chemical production. In addition, biomass feedstocks can offer significant environmental benefits compared to fossil fuels. For example, energy produced from biomass crops does not add greenhouse gasses to the atmosphere during the life cycle of its production use relative to fossil fuels.

Advances in technology in farm production and processing offer enormous market opportunities for the Nation's farmers and hold the potential of transforming a significant portion of our fossil fuel based economy to a biobased economy. The Clinton Administration wants to help encourage that transformation.

In my testimony today, I will provide a brief overview of activities undertaken by the Clinton Administration that are helping to promote the research and development of a renewable fuels and biobased products industry. But I would first like to comment on S. 935, the National Sustainable Fuels and Chemicals Act of 1999.

The National Sustainable Fuels and Chemicals Act of 1999

The Administration strongly supports S.935, the National Sustainable Fuels and Chemicals Act of 1999, but would prefer to see less prescriptive language. While funding provided under the bill's authorization would have to compete with existing programs under discretionary budget ceilings, we do believe that the legislation, by formalizing cooperation and coordination between USDA, the Department of Energy (DOE) and other agencies in sustainable fuels and chemicals research, would help reinforce the commitment of the agencies, in concert with Congress, to match resources and realize the potential of biofuels and bioproducts. In addition to an advisory committee to help focus strategic planning, the development of a joint sustainable fuels and chemicals initiative to carry out research on biobased industrial products will ensure that funds from both departments are efficiently and effectively leveraged.

The Clinton Administration looks forward to working with Congress to enact S. 935. But we also believe we can begin the process of improving cooperation and coordination immediately. To that end, we have been discussing with your staff how we might accomplish a number of the goals of S. 935 through administrative action.

Current USDA Activities

USDA currently spends \$9 million annually on biofuels research and \$63 million annually on research on new industrial uses of biobased products. To better coordinate these activities within USDA, I established the Biobased Products Coordination Council, chaired by Under Secretary of Research, Education and Economics, Dr. Miley Gonzalez. The Council promotes biobased industrial product research, development, and commercialization through information sharing, implementation of strategic planning and providing policy advice for my office. It is currently working on a list of biobased products for use by Federal agencies and their procurement officials as encouraged under Executive Order 13101.

Ethanol research. One of the most promising roles biomass can play is strengthening our energy security. In 1995, USDA released a study on the net-energy balance of corn ethanol that showed that the energy in ethanol is 22 percent greater than the amount of energy used to produce the ethanol. Since then, technological innovations in corn production and ethanol conversion have substantially reduced the energy required to produce corn ethanol. Our most recent estimate is that the energy content of ethanol is 34 percent greater than the energy used to grow, harvest, and transport corn, produce the ethanol, and distribute the ethanol. In addition, a recent study conducted by Argonne National Laboratory with USDA collaboration showed both corn and cellulosic ethanol reduce greenhouse gas emissions considerably relative to petroleum.

Research directed at reducing ethanol production costs can improve the competitiveness of and expand the quality of ethanol demanded as a fuel or fuel additive. USDA analysis suggests that long-term technology improvement strictly devoted to ethanol production might reduce costs by 9 to 15 cents per gallon. Our researchers believe that additional savings of 13 to 18 cents per

gallon may be possible by developing higher value products--called coproducts--from raw material not used up in ethanol production.

To achieve these cost reductions, USDA research is targeting the development of organisms that will convert multiple, mixed substrates; superior product recovery and separation technology; high-value coproducts; more efficient technologies and processes for coproduct recovery and separation; and better fractionation of feedstocks. Developing new varieties of corn that would be easy to mill and provide optimum levels of fermentable substrate and coproducts are also a subject of scientific work.

Research on Biodiesel and Other Biobased Products. Biodiesel, as well as lubricants, chemicals, and solvents produced from agricultural fats and oils, offer another opportunity to supplant petroleum derivatives. In doing so, an expanded market for agricultural fats and oils may develop, providing farmers with high-volume markets for high-valued nonfood products.

Like ethanol, biodiesel has a positive net energy balance. This high-energy efficiency translates to a much lower emission of greenhouse gases compared with petroleum-based fuels. USDA conducted a study with the Department of Energy's (DOE) National Renewable Energy Laboratory that found the use of biodiesel reduces net carbon dioxide emissions by 78 percent relative to petroleum diesel.

Selected niche market opportunities for biodiesel are emerging now. As a result of legislation passed last year, Federal agencies can use biodiesel 20 percent blends as a credit against alternative fuel vehicle purchases.

The major obstacle to the widespread use of fats and oils for biodiesel manufacture is the relatively high cost of biodiesel from food-grade oils. The full production cost of biodiesel is \$2

to \$3 per gallon compared with 50 to 60 cents for petroleum diesel. Tallows, yellow and white greases, often termed waste vegetable oil, and true wastes, such as sewage trap grease, are cheaper to use than food-grade oils.

To create economically viable sustainable fuels and chemicals markets based on renewable fats and oils, a focused research program is critical. USDA's research is aimed at lowering the cost of production, optimizing the properties of biodiesel feedstocks, and developing conversion and utilization technologies which take advantage of the unique properties of the fats and oils.

We can further reduce our dependence on foreign oil if we can use agricultural materials that replace petrochemicals as a source of raw industrial materials. For example, until recently about 98 percent of all plastics were petroleum-based. They are not generally biodegradable either. USDA's biobased products program is designed to expand nonfood markets for agricultural products and provide biorenewable substitutes for petroleum-based plastics, printing inks, paints and other coating lubricants, and intermediate chemical products.

Biobased products from agricultural and forestry resources provide renewable raw materials for the processing and manufacturing of a broad range of nonfood and nonfeed products, such as chemicals, fibers, construction materials, and energy sources. Development and commercialization of such products provide new and expanded markets, accelerate successful market penetration, and diversify agriculture while fostering rural and sustainable development.

Biomass Initiatives. Farmers and processors need to see practical and successful demonstration projects on the ground before they could be expected to participate on a large scale. To that end, USDA is collaborating with DOE on a Biomass Power for Rural Development Initiative. USDA is leveraging its existing programs and authorities with DOE

funding to cost share with the private sector the development of integrated biomass power projects that couple dedicated energy feedstock production with advanced power conversion technologies.

The first award under this solicitation was signed on May 6, 1996, with Niagara Mohawk Power Corporation of Syracuse, New York, representing the Salix Consortium. The Salix Consortium plans to integrate dedicated short- rotation woody crops such as willows with power conversion by cofiring them with coal. A gasification test will be conducted as well. In the initial phase, a total of up to 47 megawatts of biomass power capacity will be produced at the three project sites, with a total of 6,000 acres of land dedicated to supplying willow feedstocks to these applications by 2001.

In Chariton Valley, Iowa, USDA and DOE are working to explore the possibilities of switchgrass as a fuel to make electricity. The Chariton Valley Resource, Conservation and Development Council received a research project waiver to harvest 4,000 acres of switchgrass from land enrolled in the Conservation Reserve Program and supply it to the power plant for cofiring with coal. A small-scale gassifier will also be investigated in the project.

Last fall BC International broke ground in Jennings, Louisiana to become the first commercial cellulosic ethanol plant. This DOE-supported plant is also receiving help to further advance the cellulosic ethanol conversion technology from USDA through Cooperative State Research, Education, and Extension Service (CSREES) research grants.

Renewable Portfolio Standard. Recently, the Administration proposed the Comprehensive Electricity Competition Act which featured a Renewable Portfolio Standard (RPS). The RPS would require that 7.5 percent of U.S. electricity be generated from renewable sources by 2010.

Improvements in the technology of biomass for electricity could help make biomass an important means to meet the RPS or any similar standard that might be adopted.

Conclusion

The development and expansion of a renewable fuel and biobased products industry founded on a strong agricultural and forestry sector can play an increasingly important role in enhancing energy security, cleaning our environment, and promoting farm and rural economic growth. Petroleum and fossil fuel prices, feedstock costs, coproduct markets, energy and environmental policies, and advances in technology are all critical determinants of market growth for biofuels and biobased products. The Clinton Administration will work with Congress and others to advance the technology and improve the economics of producing and marketing biofuels and new biobased products from agricultural commodities.

That completes my testimony, Mr. Chairman. I am happy to respond to any questions.

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Biobased Industrial Products

Executive Summary

Committee on Biobased Industrial Products

**Board on Biology
Commission on Life Sciences
National Research Council**

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BIOBASED INDUSTRIAL PRODUCTS

Executive Summary

Biological sciences are likely to make the same impact on the formation of new industries in the next century as the physical and chemical sciences have had on industrial development throughout the century now coming to a close. The biological sciences, when combined with recent and future advances in process engineering, can become the foundation for producing a wide variety of industrial products from renewable plant resources. These "biobased industrial products" will include liquid fuels, chemicals, lubricants, plastics, and building materials. For example, genetically engineered crops currently under development include rapeseed that produces industrial oils, corn that produces specialty chemicals, and transgenic plants that produce polyesters. Except perhaps for large-scale production of bioenergy crops, the land and other agricultural resources of the United States are sufficient to satisfy current domestic and export demands for food, feed, and fiber, and still produce the raw materials for most biobased industrial products.

During this century petroleum-based industrial products gradually replaced similar products that once were made from biological materials. Now, biobased industrial products are beginning to compete with petroleum-derived products that once displaced them. This progress has been made possible by the wealth of knowledge on the scientific basis for conversion of biomass to sugars and other chemicals, particularly the knowledge of biochemical and fermentation fundamentals, and related progress in process technology and agricultural economics. New discoveries occurring in microbial, chemical, and genetic engineering research, in particular, could lead to technological advances necessary to reduce the cost of biobased industrial products. Near-term strategies may be dominated by fermentation of sugars through microbial processes for production of commodity chemicals. In the long-run, similar processes may be used for large-scale conversion of biomass to liquid fuel. In the future, novel chemicals and materials that cannot be produced from petroleum may be directly extracted from plants. Today only a small fraction of available biomass is used to produce biobased chemicals due to their high conversion costs. The long-term growth of biobased industrial products will depend on development of cost-competitive technologies and access to diverse markets.

There remains an open question as to the size of petroleum reserves and the future cost of petroleum products. Current oil reserves are substantial and exploration continues to open new petroleum supplies for the world market (e.g., Caspian Sea). Experts estimate that two thirds of the world's proven reserves are located in a single geographic region, the Persian Gulf, and this area will continue to serve as a dominant source for oil exports (USDOE, 1998). According to the American Petroleum Institute, there are approximately 43 years of reserves remaining as of 1997 (API, 1997), an increase from the 34 years prevailing before the first Organization of Petroleum Exporting Countries (OPEC) crisis of 1973. However, some geologists report that oil reserves could be depleted within 20 years (Kerr, 1998). While this Committee believes there is a need to make a transition to greater use of renewable materials as oil and other fossil fuels are gradually depleted, we cannot predict with any accuracy the availability and cost of future supplies of petroleum.

to the nation's liquid transportation fuel needs. Productivity of U.S. farms and forests has been rising to meet domestic and export demands for traditional food, feed, and fiber products, as well as biobased raw materials. Approximately 35 million acres of marginal cropland in the Conservation Reserve Program (CRP) could provide additional land to grow biomass crops. If approximately half of the land set aside for the CRP could be harvested in a judicious manner (to minimize risks of soil erosion or loss of wildlife), approximately 46 million tons of additional biomass feedstock would become available. This figure assumes very low yields of biomass (2.5 tons/acre) and could increase four-fold (up to 10 tons/acre) with some crops (e.g., switchgrass). The total biomass is sufficient to easily meet current demands for biobased industrial chemicals and materials.

The amount of land that actually will be used for biobased crops will depend on future demands for the final products, and the inputs used to make that product must be competitively priced. High-value novel chemicals are not expected to require large acreages. While biobased materials such as lumber, cotton, and wool do have substantial markets, these products now compete successfully for land resources. However, the current demand for many biobased chemical products is small. For example, as of 1996/1997 marketing year, industrial uses of corn accounted for approximately 7% of the nation's corn grain production (ERS, 1997).

Coproduction of human food and animal feed products such as protein with biobased materials, fuels and chemicals is expected to help prevent future conflicts between production of food and biobased products. Corn-based refineries, for example, yield protein for animal feed and oil, starch, fiber, and fuel alcohol products. In the case of pulp and paper mills, pulp, paper, lignin by-products, and ethanol can be produced while recycling waste paper in a single system. If demand for liquid fuel increases beyond capacity for coproduction of food and liquid fuel, then biobased production may compete for land with food production. This report describes some opportunities for coproduction of food, feed, liquid fuels, organic chemicals, and materials.

The Committee recognizes that an abundant supply of food at a reasonable price is a national goal. If the oil supply does diminish without available substitutes, then oil prices could rise. At that point, policy makers may decide to convert land from food to fuel production. This could create competition for scarce resources and subsequent conversion of U. S. crop land to energy crops could lead to higher food prices. The Committee estimates that by-products of agriculture could provide up to 10% of liquid transportation fuel needs. The amount of land devoted to crops for biobased industries will be determined by economics, as tempered by agricultural policies.

The raw materials for biobased industrial production are supplied by plants as plant parts, separated components, and fermentable sugars. For the immediate future, the raw material sources most likely to be used for producing industrial materials and chemicals in the United States are starch crops like corn and possibly waste biomass. Over the long term, as the demand for biobased products expands and crop conversion technologies improve, this resource base will grow to include lignocellulosic materials from grasses, trees, shrubs, crop residues, and alternative crops custom-engineered for specialized applications.

Many potential biobased products will come from traditional crop plants being put to new uses, for example, grasses and legumes used in paper production. Perhaps more important, however, will be new types of crops or traditional crops that have been genetically engineered. Although a number of barriers can impede the introduction of new crops, the transformation of

be sought for a wide array of plant chemicals (e.g., chiral compounds) not available from petrochemical markets.

Biobased materials represents a significant market with a wide range of products. Lumber, paper, and wood products traditionally have been a large market with annual sales of approximately \$130 billion in the United States. Several other biobased materials have established uses that are likely to grow as technological advances reduce costs. Examples include starch-derived plastics, biopolymers for secondary oil recovery, paper, and fabric coatings.

The cost of large-scale production of biobased products depends on two primary factors: 1) cost of the raw material, and 2) cost of the conversion process. The industries for producing chemicals and fuels from petroleum are characterized by high raw material costs relative to processing costs while, in the analogous biobased industries, processing costs dominate. Therefore, similar percentage improvements in processing costs have much more impact on biobased industries. Also, the cost per ton of biomass raw materials generally is comparable (e.g., corn grain) or much less (e.g., corn stover) than the cost per ton of petroleum. Thus, there is real potential for biobased products to be cost-competitive with petroleum-based production if the necessary research and development are done to reduce processing costs. Furthermore, because starch and sugar already contain oxygen, and petroleum does not, there is the potential to derive oxygenated intermediate chemicals—such as ethylene glycol, adipic acid, and isopropanol—more readily from biological raw materials than from fossil sources. Production of such oxygenated chemicals by fermentation has the additional advantage of being inherently flexible. The raw materials can vary depending on which local source of fermentable sugars provides the best economic returns. Therefore, economic evaluations should first consider the potential of biobased replacements for the oxygenated organic chemicals of the 100 million metric tons of industrial chemicals marketed each year in the United States.

Other significant opportunities exist to produce a wide range of industrial products from agricultural and forest resources. Many will require investment in basic research as well as process engineering research to ensure commercial viability. These opportunities begin with the plant sources for raw materials. Modern principles of molecular biology and genetic engineering can be used to create agricultural crops that contain desired chemical polymers or polymer intermediates. Additionally, trees and grasses could be genetically engineered to have a structural composition that facilitates and enhances the effectiveness and efficiency of subsequent conversion to desired products.

Combined advances in functional genomics, genetic engineering, and biochemical pathway analysis, sometimes referred to as metabolic engineering, will make it possible to manipulate efficiently the biosynthetic pathways of microorganisms. By increasing chemical yield and selectivity, such manipulations could make microbial production more economically competitive with existing production methods. The combination of modern genetics and protein engineering will provide biocatalysts for improved synthesis or conversion of known products or for reaction routes to new chemicals.

products that oil refineries cannot, including foods, feeds, and biochemicals. These additional capabilities give biorefineries a potential competitive edge and enhanced financial stability.

The processing technologies of refineries tend to improve incrementally over time, eventually causing raw material costs to become the dominant cost factor. In this regard, biorefineries have another potential advantage over petroleum refineries because plant-derived raw materials are abundant domestic resources. The availability and prices of biological raw materials may thus be more stable and predictable than that of petroleum.

An extensive case study in this report examines the potential of converting corn stover (stalks, leaves, cobs, and husks—also known as corn residue) to ethanol. The case study incorporates a model to calculate costs for ethanol processed from corn stover. Today production of corn-starch based ethanol costs approximately \$1.05/gallon. The model indicates that by using corn residue as a feedstock, up to 7.5 billion gallons of ethanol could be produced at a cost potentially competitive with gasoline without subsidies. When the ethanol price is adjusted to account for the fact that a gallon of ethanol will provide less mileage in a conventional gasoline-type engine than will the fuel for which the engine is designed, the price of ethanol equivalent to a gallon of gasoline is \$0.58 per gallon. The U. S. refiner price for motor gasoline in July 1998 reported by the Energy Information Administration was \$0.54 per gallon (Energy Information Administration, 1998). The model assumes that some not yet completely developed technologies are available and use of corn residue makes possible especially low-cost raw materials. As a result, projected costs for ethanol processing could drop significantly from current costs because these residues are co-produced with corn grain. It should be noted that the price of oil could change significantly from today's prices, thus changing the price comparisons between ethanol and gasoline. The opportunities to produce ethanol more efficiently are large. While corn has been the dominant raw material source, other more productive lignocellulosic materials such as switchgrass are being considered as alternative feedstocks.

In many cases, the biorefinery that produces ethanol and other commodity chemicals from biomass requires three major new technologies:

- 1) an effective, economical pretreatment to unlock the potentially fermentable sugars in lignocellulosic biomass or alternative processes that enable more biomass carbon to be available for ethanol or other oxygenated chemical;

- 2) inexpensive enzymes (called "cellulases") to convert the sugar polymers in lignocellulose to fermentable sugars; and

- 3) microbes that can rapidly and completely convert the variety of five- and six-carbon sugars in lignocellulose to ethanol and other oxygenated chemicals.

Other biobased processes under development may not require all these pretreatment processes.

Several lignocellulose pretreatment processes recently have been developed that promise to be technically effective and affordable. Such pretreatments should make it possible to convert a vast array of lignocellulose resources into useful products. Considerable progress has also been made in developing genetically engineered microorganisms, which utilize both five- and six-carbon sugars. Less progress apparently has been made in producing inexpensive cellulases.

Processing technologies that use microbes and enzymes have great promise for the expansion of biobased industries. Unlike thermal and chemical processes, such bioprocesses occur under mild reaction conditions, usually result in stereospecific conversions, and produce only a few relatively non-toxic byproducts. One drawback is that bioprocesses typically yield

industrial products. For example, policy makers may want to accelerate use of renewable biomass to mitigate impacts on the U. S. economy from a disruption in world supplies of oil, or perhaps to reduce impacts on the environment created by possible global warming.

RECOMMENDATIONS

Federal support of research on biobased industrial products can be an effective means to improve competitiveness of biobased feedstocks and processing technologies, as well as diversify the nation's industrial base of raw materials, and provide additional markets for farmers. Policy makers should encourage research and development that would fill important technical gaps in raw material production, storage, and processing techniques. Volatility in petroleum prices is a barrier to the development of these biobased products by the private sector. Policy makers should realize that decades of research investment may be necessary to develop enabling technologies, and considerable lead time will be necessary to implement such research programs and to allow for their adoption by industry.

Research will be a prominent tool in making biobased feedstocks more competitive. The public sector research and development agenda should emphasize major technical and economic roadblocks that impede the progress of biobased industrial products. Research priorities should emphasize development of biobased products that can compete in performance and cost with fossil-based ones. Expansion of biobased industries will require research on the biological and engineering principles that underlie biobased technologies as well as the practical implementation of these technologies through development and commercialization.

The discoveries occurring today in plant and microbial genomics are expected to lead to significant advances in fundamental biological research for many years in the future. The complete genomic sequence is available for some microbial organisms such as *Saccharomyces cerevisiae* (common yeast) and *Escherichia coli* (gram-negative bacteria). Scientific investigations are underway to decipher the entire genetic code of eukaryote organisms such as *Arabidopsis thaliana* (flowering plant of the mustard family) and *Drosophila* (fly). The genetic information collected on these organisms will provide researchers with insights on the genes that control plant traits and microbial cellular processes. In the future, this genomic knowledge will help scientists find new ways to alter microbes and plants that increase the value of biobased raw materials and improve the efficiency of the conversion processes.

Specific recommended research priorities for biology include:

- the genetics of plants and bacteria that will lead to an understanding of cellular processes and plant traits;
- the physiology and biochemistry of plants and microorganisms directed toward modification of plant metabolism and improving bioconversion processes;
- protein engineering methods to allow design of new biocatalysts and novel materials for the biobased industry; and
- maximization of biomass productivity.

Recommended research priorities for engineering include:

costs of financing some of these incentives are not well known, government agencies will need to obtain comprehensive cost-benefit data for their decision-making. Incentive programs should be cost-effective with endpoint provisions to evaluate program utility. In the long term, development of biobased products that can compete in an open market without incentives is key to sustaining a strong biobased industry.

Although policy changes would go a long way in encouraging the development of U.S. biobased industries, they will not be sufficient alone. The current technology base for biobased industries is incomplete. Advances in agriculture have stressed crop production technologies without a comparable interest in conversion technologies to produce biobased industrial products. Likewise, education and research resources in the fields of chemistry and process engineering will need to put more emphasis on biobased processing. Careful integration of relevant science and engineering is essential to reduce the cost of processing abundant raw materials into value-added biobased products.

This report takes a broad look at current and potential biobased industries. It identifies key opportunities for products derived from renewable resources and the industry and public policy actions that could facilitate the research, development, and commercialization of biobased industrial products. With a vigorous commitment from all parties, the United States will be well positioned to reap the benefits of a strong biobased industry.

Bioenergy: Growing an Integrated Industry



Overview of DOE's Bioenergy Activities and Proposed Plan of Action



Dan Reicher

Assistant Secretary of Energy

Energy Efficiency and Renewable Energy

U.S. Department of Energy

June 1999



Bioenergy: Growing an Integrated Industry



Key Drivers

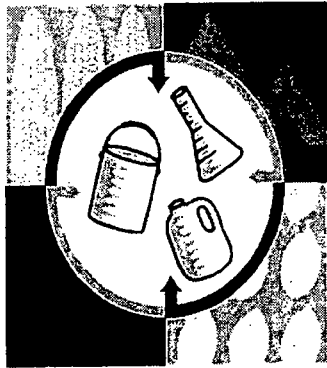
- ↵ Energy Security
- ↵ Economic Competitiveness
- ↵ Electricity Restructuring
- ↵ Environmental Quality
- ↵ Climate Change



Bioenergy: Growing an Integrated Industry



Biomass: The Basic Resource



Chemical
Products



Fuels



Electric Power



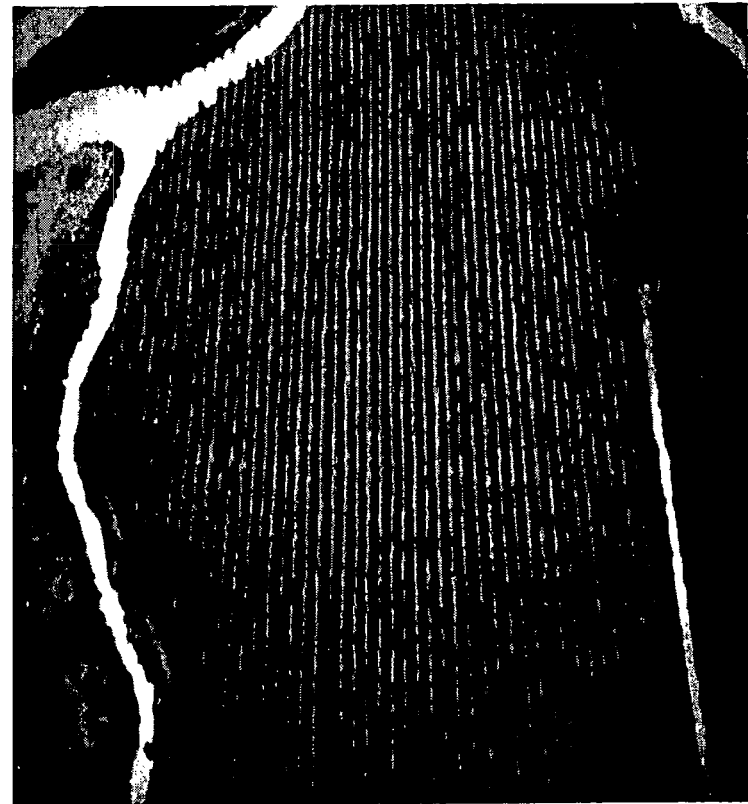
Bioenergy: Growing an Integrated Industry



Feedstock Development

Goals

- ↵ Low cost/high yield
- ↵ Sustainable/widespread availability
- ↵ Develop transport delivery infrastructure



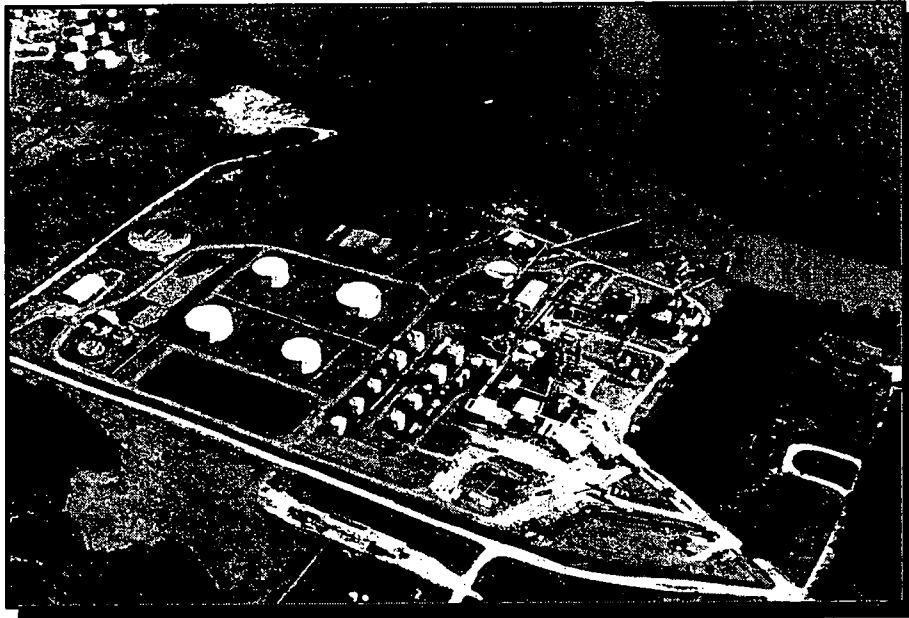
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Bioenergy: Growing an Integrated Industry



Transportation Fuels



BCI Bioethanol Facility

Goals

- └ Produce ethanol at
~75¢/gallon
- └ Develop low-cost
enzymes
- └ Develop co-products
- └ Assist industry through
cost-shared partnerships



Bioenergy: Growing an Integrated Industry



Biomass Power

Goals

- ↵ Become cost competitive
- ↵ Achieve high efficiency
- ↵ Use a variety of feedstocks
- ↵ Co-firing



Vermont Gasifier

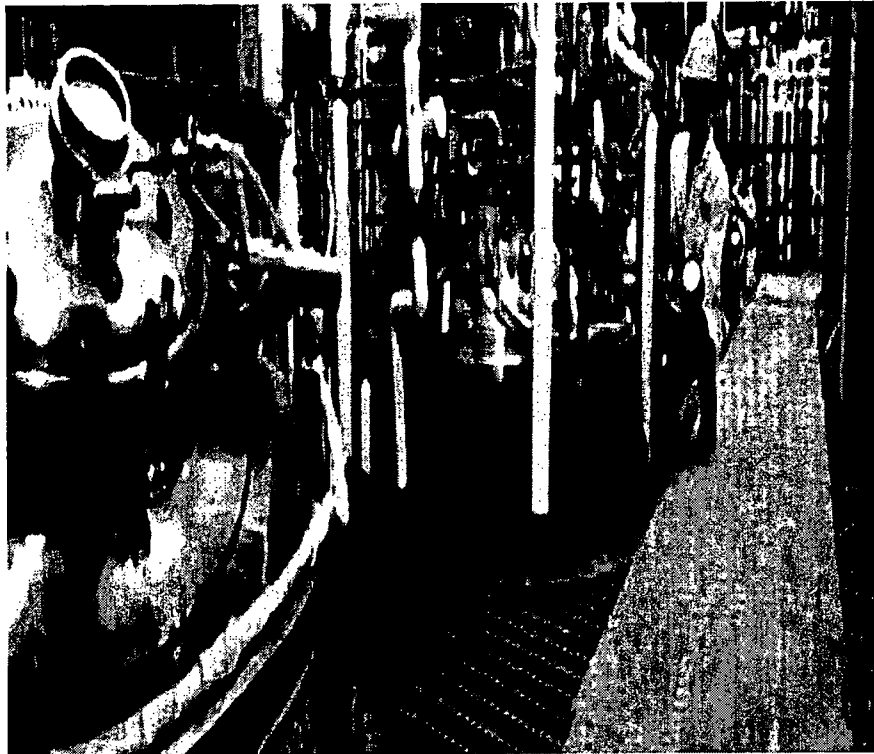


Bioenergy: Growing an Integrated Industry



Bio-Based Products

Goals



- └ 10% of market for chemical feedstocks by 2020
- └ Pursue R&D “hotspots”
 - └ existing crops
 - └ modified plants
- └ Better industry integration



Bioenergy: Growing an Integrated Industry



The Bioenergy Initiative

The Bioenergy Initiative will help power America by using our most abundant natural resource-- biomass. By making a “ton of biomass” a viable market competitor to a barrel of imported oil, the Bioenergy Initiative will help strengthen U.S. energy security, protect the environment, reduce greenhouse gas emissions, and revitalize rural America.



Bioenergy: Growing an Integrated Industry



Ten-Point Action Plan

- ↵ Establish the Partnership Vision
- ↵ Develop Technology Roadmaps
- ↵ Create an Effective Policy Framework
- ↵ Expand Biomass Markets
- ↵ Conduct Supporting Analysis



Bioenergy: Growing an Integrated Industry



Ten-Point Action Plan

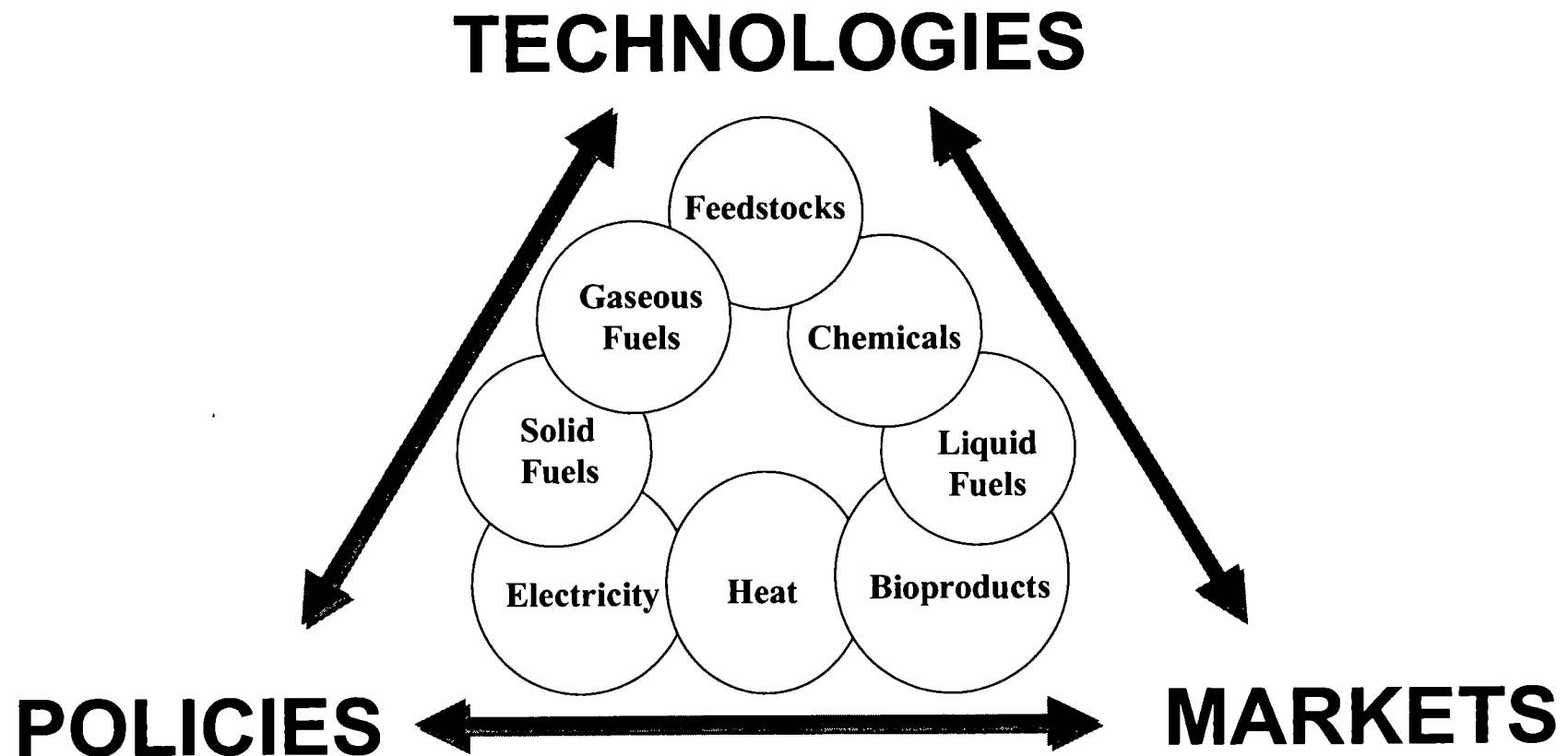
- ↵ Promote Advanced Technologies
- ↵ Expand Federal-State Coordination
- ↵ Carry Out Education and Outreach
- ↵ Maintain Effective Partnerships
- ↵ Showcase Successes



Bioenergy: Growing an Integrated Industry

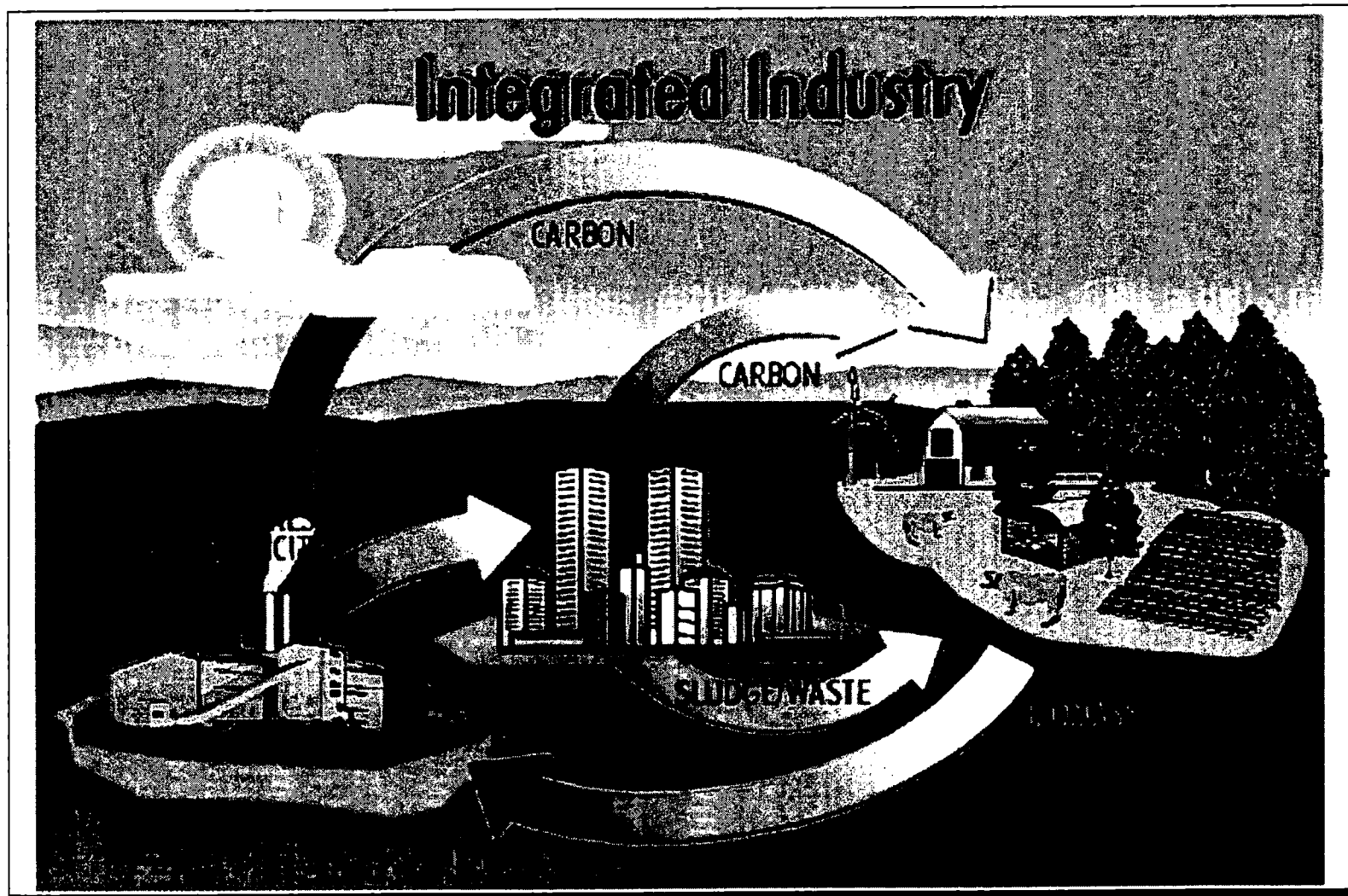


An Integrated Industry





Bioenergy: Growing an Integrated Industry





Bioenergy: Growing an Integrated Industry



Market Challenges

- ↵ Biomass supply and demand
- ↵ Capital costs and investment options
- ↵ Price, quality, availability of power and fuels
- ↵ Replacement costs of facilities and infrastructure
- ↵ Costs of new sales/distribution/service networks
- ↵ Trade opportunities and foreign market access



Bioenergy: Growing an Integrated Industry



Policy Challenges

- └ Tax treatment
- └ Utility restructuring
- └ Environmental regulation
- └ Climate Change
- └ Rural economic development
- └ Government procurement
- └ Trade and developing country assistance



Bioenergy: Growing an Integrated Industry



Technology Challenges

Feedstocks -- Yield, Harvesting, Transportation, Cost

Conversion -- Efficiency, Reliability, Cost

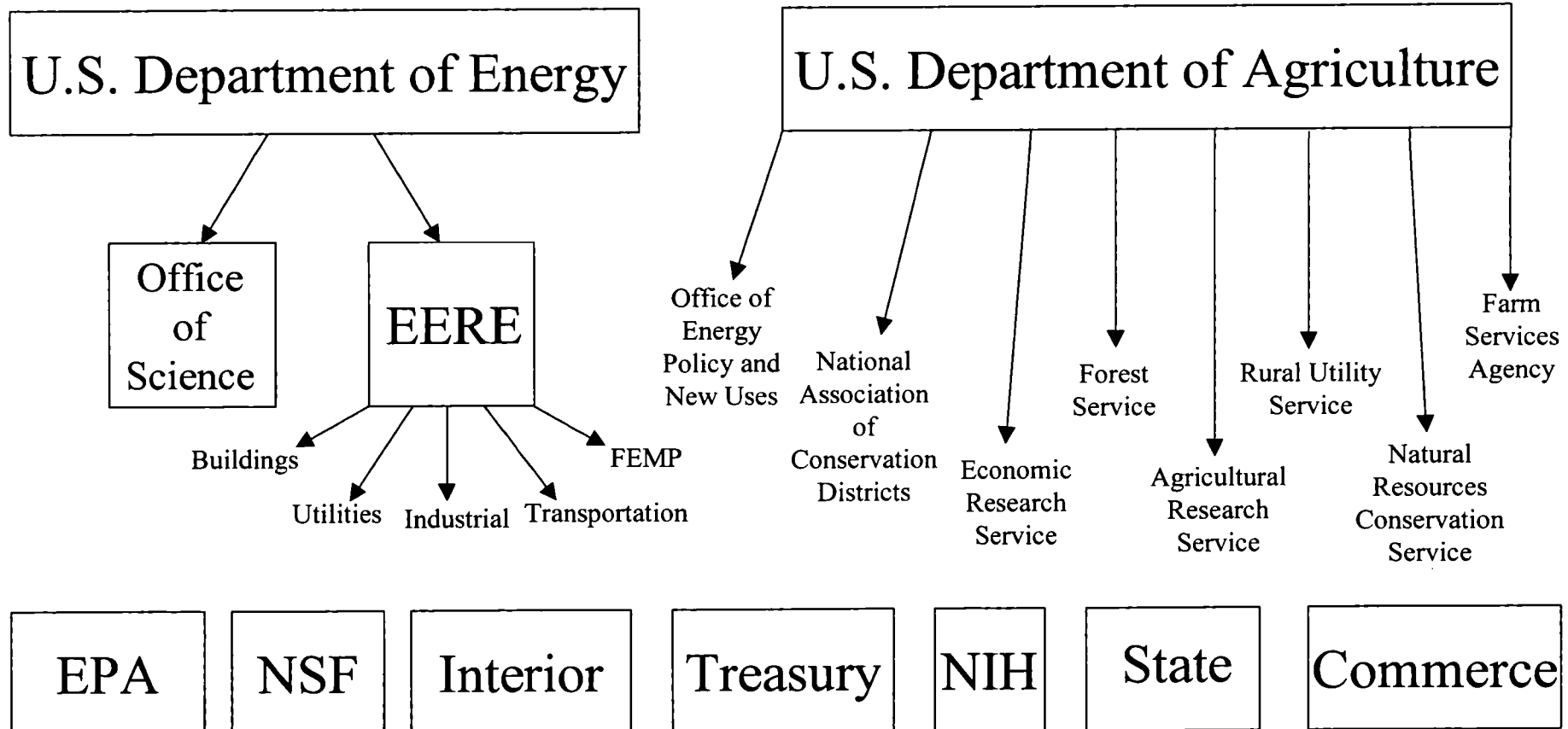
Utilization -- Efficiency, Environmental Impacts, Cost



Bioenergy: Growing an Integrated Industry



Need for Improved Integration





Bioenergy: Growing an Integrated Industry



DOE-Industry Bioenergy Meetings

- ┌ Agricultural Research Institute
- ┌ Archer Daniel Midlands
- ┌ ASERTTI
- ┌ BC International Corporation
- ┌ BD Technologies
- ┌ BF Goodrich
- ┌ BP Amoco
- ┌ Carbona Corporation
- ┌ Cargill
- ┌ Catalytica Combustion Systems, Inc.
- ┌ Champion International Corporation
- ┌ Corn Refiners Association
- ┌ Dow Chemical
- ┌ DTE Biomass Services, Inc.
- ┌ DuPont Corporation
- ┌ Enron Capital and Trade, Inc.
- ┌ Environmental and Energy Study Institute
- ┌ Future Energy Resources Corporation
- ┌ General Electric
- ┌ Georgia-Pacific Corporation
- ┌ Grain Processing Corporation
- ┌ Institute for Local Self Reliance
- ┌ Monsanto
- ┌ NASEO
- ┌ National Biodiesel Board
- ┌ National Corn Growers Association
- ┌ Natural Resources Defense Council
- ┌ Niagara Mohawk Power Corporation
- ┌ NIPSCO, Inc.
- ┌ Northern States Power Corporation
- ┌ NYSERDA
- ┌ Reflective Energies, Inc.
- ┌ Renewable Fuels Association
- ┌ Shell Oil Company
- ┌ Southern Company
- ┌ STM Corporation
- ┌ Tennessee Valley Authority
- ┌ Trigen Biopower Inc
- ┌ Union of Concerned Scientists
- ┌ United Soybean Board
- ┌ United States Department of Agriculture
- ┌ Weyerhaeuser Company
- ┌ Williams Energy Services



BIOENERGY

Agricultural Waste to Ethanol: Sacramento Ethanol Partners



Background

In 1999, Arkenol, a technology and project development company based in Mission Viejo, California, and its partners will build a new biomass-to-ethanol plant near Sacramento. The \$100 million facility will produce 8 million gallons of fuel ethanol and 40 million tons of citric acid from rice straw per year. Key engineering, permitting, and financing activities are under way through a partnership with the U.S. Department of Energy.

Accomplishments

- First facility to use rice straw to produce ethanol and citric acid on a commercial scale.
- Produce precipitated silica and lignin as by-products of the process.
- Obtained process guarantees from Bateman Engineering.

Benefits

- Reduce air pollution and particulate emissions due to rice straw burning, which is being phased out in California.
- Create about 2,000 construction jobs and 105 permanent jobs.
- Ethanol fuel produced will reduce carbon emissions by 12,800 metric tons, equivalent to the carbon emissions from 12,000 cars.

Future Activities

- Demonstrate commercial ethanol production from rice straw.
- Obtain project financing and complete engineering and permitting activities.
- Improve performance and robustness of genetically engineered microorganisms.

Partners in Success

Arkenol, Inc.
Bateman Engineering
University of California-Davis



BIOENERGY

Small Modular Biopower Systems

Objective: To develop small modular biopower systems:

- fuel flexible
- efficient
- simple to operate
- minimum negative impacts on the environment
- power range: 5 kW - 5 MW

Individual Households to Institutions (hospitals, schools) under 100 kW

Developer	Location	Technology
Sunpower	OH	Combustion/Stirling Engine
CPC	CO	Gasification/IC Engine
STM	MI	Gasification/Stirling Engine
Reflective Energies	CA	Gasification/Gas Turbine

Multiphase Project:

- Phase 1: Feasibility Studies
- Phase 2: Prototype Development and Testing
- Phase 3: Integrated Systems Demonstration

Small Villages and Industries 100-300 kW

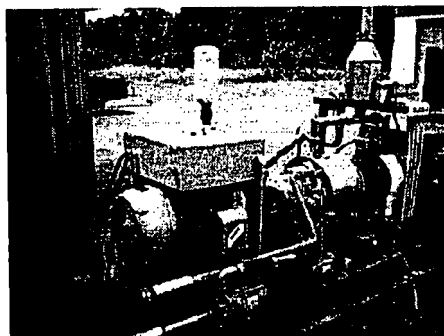
Developer	Location	Technology
Reflective Energies	CA	Gasification/Gas Turbine
Bechtel	VA	Gasifier/Engines/Gas Turbine

Phase I Feasibility Studies:

RFQ Issued	Feb 1998
RFQ Closed	Mar 1998
Technical Review	Apr 1998
Awards	May-Jun 1998

Industries, Mini-grids, Grid Support > 500 kW

Developer	Location	Technology
Agrielectric	LA	Fluid-Bed Combustor/Steam Turbine
Bioten	TN	Direct-Fired Comb. Turbine
Carbona Corp.	GA	Gasification/Steam Turbine
EERE	ND	Fluid-Bed Combustor/Steam Turbine
Niagara Mohawk	NY	Gasification/IC Engine/Gas Turbine



STM's BioStirling™ system is one example of the modular power units being developed under this initiative.



BIOENERGY

Agricultural Waste to Ethanol: BC International



Background

In October 1998, BC International Corporation (BCI) dedicated a former molasses-to-ethanol plant in Jennings, Louisiana, to a new use: it will soon become the world's first facility to produce ethanol from sugar cane wastes and rice hulls. DOE has invested \$11 million toward the renovation cost of approximately \$90 million. The facility will produce 20 million gallons of ethanol per year at first and then expand production to 25 million gallons per year in the future. The ethanol will be used to fuel cars and provide raw materials for the chemical industry.

This facility is a giant step toward alternative fuels that are domestically produced and based on renewable, low-polluting energy sources. We can look forward to a day when a ton of biomass will be traded like a barrel of oil is today.

Bill Richardson
U.S. Secretary of Energy

Accomplishments

- Groundbreaking ceremony on October 20, 1998.
- First facility in the world to produce ethanol from sugar cane wastes and rice hulls instead of more costly feedstocks, such as corn or wheat.
- Uses process based on new genetically engineered bacteria that will allow biofuels to become more cost competitive with fossil fuels.

Benefits

- Create 350 construction jobs and 50 permanent jobs.
- Will displace almost 500,000 barrels of imported oil annually.
- Will reduce carbon emissions by 30,000 metric tons, equivalent to the carbon emissions of approximately 30,000 cars.

Future Activities

- Demonstrate commercial production of ethanol from agricultural residues to lower risk and cost of future facilities.
- Reduce cost of cellulase enzymes to achieve lower cost and higher efficiency.

Partners in Success

BC International
University of Florida
The Industrial Company



BIOENERGY

Integrated Waste-to-Ethanol Facility



Background

Masada Resource Group, based in Birmingham, Alabama, is developing a \$130 million waste disposal and recycling facility in Middletown, New York. On the front end, the plant will recycle plastics, glass, metal, and waste paper. Technology developed in partnership with the Tennessee Valley Authority and the U.S. Department of Energy will also be used to convert the remaining cellulosic refuse into 8 million gallons of ethanol annually. Start-up of the facility is planned in 2000.

Accomplishments

- First proposed biomass ethanol plant to use municipal solid waste (MSW) as a feedstock.
- Contracts negotiated with the surrounding municipalities to accept their MSW.

Benefits

- Use waste that would otherwise be burned or landfilled.
- Eliminate 12,800 metric tons of carbon, equivalent to the carbon emissions of approximately 12,000 cars.
- Displace almost 200,000 barrels of imported oil annually.

Future Activities

- Demonstrate commercial ethanol production from MSW.
- Demonstrate the benefits of co-locating Masada's MSW-to-ethanol technology with coal power plants.
- Complete engineering and permitting activities needed to obtain project financing.
- Improve the performance and robustness of genetically engineered microorganisms used to ferment sugars from biomass to ethanol and chemicals to increase efficiency and yield.

Partners in Success

Harris Group (Seattle)
Masada Resource Group
Tennessee Valley Authority
Stone & Webster Canada, Ltd.
Mississippi State University



BIOENERGY

Biomass Power for Rural Development



Background

Using biomass to generate heat or to drive steam engines is nothing new. Historical methods of burning wood, field residues, or waste were not environmentally sound because they emitted polluting carbons and volatile organic compounds into the air. Today, scientists and engineers are developing several new methods to cleanly and efficiently convert biomass to electricity.

Accomplishments

Coproducts from the Heartland: In Southern Minnesota, alfalfa markets weren't strong enough to justify hauling the crop off the farm—until now. A partnership of the Minnesota Valley Alfalfa Producers cooperative, ENRON Capital and Trade, Carbona, Great River Energy, Westinghouse Electric Corporation, the University of Minnesota and DOE are about to get that alfalfa moving. When they build a planned biomass gasification and power generation

facility in Granite Falls, between 50,000 and 75,000 homes and farms will be served with electricity, and companion products like high-protein feed pellets will be produced. These coproducts will bring new revenues to local farmers. The farmers will get more local control and stability in their business, and there will be beneficial side effects, like an economic cushion against the devastating effects of rain damage to crops.

Switchgrass Binds Prairie: Underutilized, marginal land will be put to work through a public/private partnership to grow switchgrass for energy generation in Iowa. Currently, switchgrass is grown to reduce soil erosion or for feed. By cofiring the switchgrass in existing coal boilers, this native crop can generate about 36 megawatts of electrical power, enough to light some 40,000 homes.

Fourteen organizations, representing a broad cross section of business, community, utility and governmental interests, will work with hundreds of farmers and landowners to develop a biomass power system that will reduce acid rain. The partners plan a 4,000-acre demonstration project that will help farmers achieve a sustainable income as a lasting alternative to traditional Federal farm subsidies. In addition, increased use of homegrown renewable energy will keep more energy dollars in Iowa, concentrating the benefits.

Farmed Trees Grow Energy: In Upper Minnesota, 1,870 acres of hybrid poplar have been established on Conservation Reserve Program land by a consortium led by the WesMin Resource conservation and Development District. These four-year-old trees are being managed and studied extensively by scientists to learn how to grow dedicated crops for future energy uses.



Farmers Dedicate Crops to Energy in New York:

The first dedicated crop for energy production in the United States is growing near Syracuse, New York. Under the care of the Salix Consortium, with 25 university, association, corporate utility and government partners, willow trees are grown on land set aside by 26 farmers and landowners. These trees produce a crop every three years that can be efficiently harvested using existing machinery. Several power plants will participate in this project, cofiring the harvested feedstock with other fuels to produce electricity and reduce emissions. Projections indicate that willow crops like this one could be competitive with coal for producing energy without government subsidies.

Benefits

The U.S. Departments of Energy and Agriculture are partnering to further the development of electricity generation systems that use biomass instead of fossil fuels.

Using biomass, such as energy crops, processing waste, and agricultural residues for energy production is beneficial to the nation, and especially to rural areas. The national benefits include lower acid rain-producing emissions, reductions in greenhouse gas emissions, and less dependence on fossil fuels. Rural

benefits start with new sources of income for farmers, more jobs, and economic development, all achieved while preserving the high quality of life, local control, and lack of pollution that help make rural America a good place to live.

When economic development happens without harming the environment or jeopardizing our children's future well-being, we call it sustainable development. In the four projects established throughout the nation to demonstrate and validate biomass power production, we hope to embody the principles of sustainable development at its best.

Partners in Success

Iowa

Chariton Valley RC&D
Alliant Power
Local Farmers/Landowners
Iowa Farm Bureau
Iowa State University
Iowa Department of Natural Resources
Iowa Division of Soil Conservation
R.W. Beck
NBB/CES
Soil and Water Conservation Districts
U.S. Department of Agriculture

Minnesota

Minnesota Valley Alfalfa Producers
Enron Capital and Trade
Carbona Corporation
Kvaerner Pulping
Siemens Westinghouse
Great River Energy
City of Granite Falls
University of Minnesota
U.S. Department of Agriculture

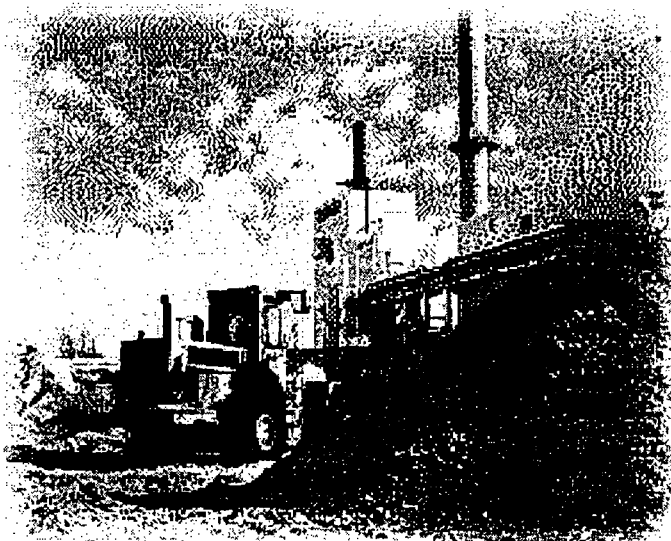
New York

Niagara Mohawk/SUNY
Cornell
New York State Gas and Electric
New York Gas
U.S. Department of Agriculture
NYSERDA
EPRI



BIOENERGY

Biomass Gasifiers: Kindling Biopower Potential



Background

The world's first demonstration of an efficient, low-pressure biomass gasifier capable of producing a high-quality fuel gas is now operating at the Burlington Electric Department's McNeil wood-fired generating station in Burlington, Vermont. The gasifier, developed by Battelle Columbus Laboratories (BCL) and licensed by Future Energy Resources Co. (FERCO) of Atlanta, GA, converts 200 tons of wood chips per day into a gaseous fuel, enough to generate 8 megawatts (MW) of power. The gasifier heats the wood by mixing it with hot sand, causing it to break into its basic chemical components. The resulting fuel gas (with about half of the heat content of natural gas) is separated from the remaining solids—sand and char—and cleaned prior to burning in the McNeil boiler. This very clean fuel gas is also suitable for use in modern power systems, such as combined-

cycle gas turbines. In the near future, a gas turbine will be tested with the gasifier to verify operability and efficiency.

Benefits

The gasifier will significantly improve biomass-to-electricity generating efficiency in stand-alone power generation and in cogeneration. The existing biopower industry is based on conventional combustion/steam turbine technology and has an average plant capacity of 20MW at 20 percent efficiency. This gasifier will allow biomass to be used with standard gas turbines and combined cycles producing advanced power systems with efficiencies that can exceed 35 percent, nearly double that of today's biopower industry. That means twice as much electricity for each pound of biomass converted; or half as much fuel required for each kilowatt of electricity generated.

Because the gas is cleaned before combustion and wood has low nitrogen and sulfur content, controlled emissions (such as SO_x and NO_x) are extremely low. Furthermore, emissions of greenhouse gases (CO_2) are greatly reduced because, when biomass is grown and harvested in a sustainable way, virtually all of the CO_2 that is produced by the power plant is absorbed by the trees and crops when they grow again. In some cases, systems like this can even result in a net removal of CO_2 from the atmosphere.

Future Activities

Commercial development of this gasifier will increase the number and types of biomass fuels suitable for electric generating systems. These fuels could include residues from agriculture, from bioprocessing industries, or eventually energy crops grown specifically for power production. Some of these fuels are difficult to use in existing plants because of their tendency to form deposits in the boilers. One very promising market for the gasifier is in combined heat and power systems in the forest products industry, which already generates a substantial amount of electricity from biomass.

Partners in Success

Battelle Memorial Institute

Bechtel

Burlington Electric Department

Future Energy Resources Corporation

IEA Zurn

National Renewable Energy Laboratory

OEC/Enron

Zurn Industries



BIOENERGY



Background

In November 1994, DOE's Secretary of Energy and the Chairman of the American Forest & Paper Association® signed a compact, establishing a research partnership involving the forest products industry and DOE. A key feature of this partnership was a strategic technology plan—Agenda 2020: A Technology Vision and Research Agenda for America's Forest, Wood and Paper Industry. Agenda 2020

Forest Products and Agenda 2020

includes goals for the research partnership and a plan to address the industry's needs in six critical areas:

- Energy performance
- Capital effectiveness
- Recycling
- Environmental performance
- Sensors and controls
- Sustainable forestry

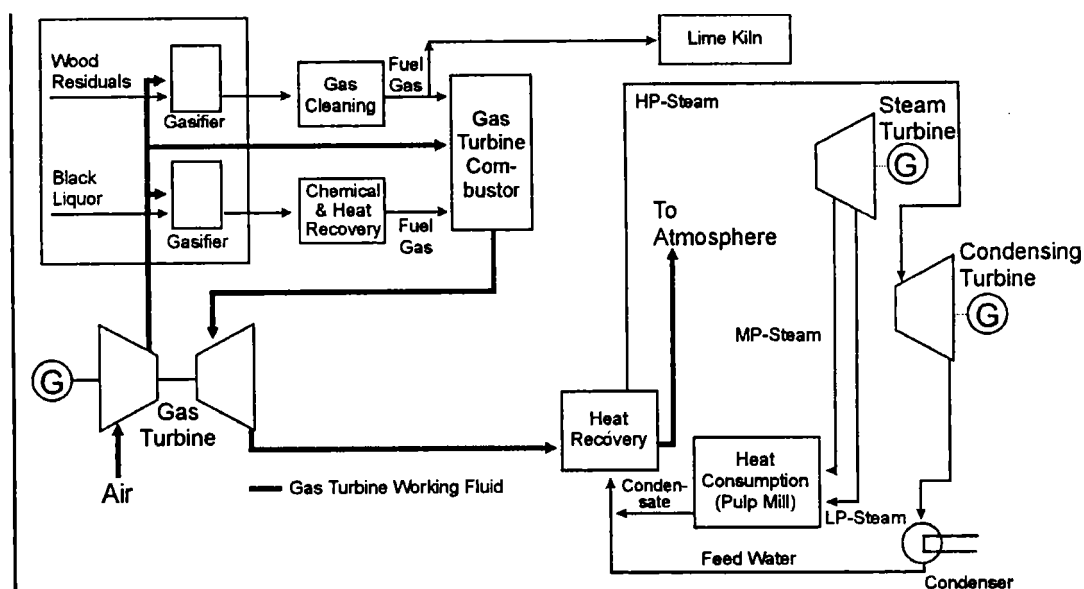
For each area, task groups, including industry, university and government representatives, have developed technology roadmaps—called research pathways—consistent with Agenda 2020's goals.

Black Liquor and Biomass Gasification

Among the highest priority projects identified by the Agenda 2020 process are those related to demonstrating gasification of biomass and black liquor, a by-product of the Kraft chemical pulping process. A large

Power Recovery Island of 2010

One of the many potential configurations generated from Agenda 2020



Source: Adapted from data provided by the Swedish National Board for Industrial and Technical Development

fleet of recovery furnaces and conventional power boilers in pulp and paper plants will need to be replaced or upgraded in the next five to fifteen years. This creates an opportunity for installing new gasification technology in these facilities during the normal capital replacement cycle.

Benefits

- Substantially improve environmental performance: widespread industrial adoption will potentially reduce carbon emissions by more than 30 million metric tons.
- Significantly increase energy efficiency and increased electrical generation from renewables by nearly 30 GW.
- A dramatic shift to increase use of indigenous renewable energy.
- Significant gains in technological leadership.
- The establishment of technologies with crosscutting potential for other industries.

Future Activities

In order to achieve significant energy and environmental benefits, the industry urgently needs to advance gasification technologies which are ready for large-scale demonstration. However, these demonstrations will cost significantly more (40-50%) than subsequent installations, and the industry cannot bear the entire cost alone. DOE participation will not only make the demonstrations possible, it will also accelerate deployment of the technologies in the pulp and paper industry and ensure that results will be shared with other industries and the public.

Related Bioenergy Areas

- Sustainable Forest Management—Advances in sustainable forest management will enable the industry to enhance its existing systems and methods for bolstering productivity while maintaining the biodiversity of intensively managed forests.
- Sensors and Controls—Improved process measurement and control systems hold the key to improving efficiency and cost effectiveness in the forest products industry. With real-time feedback on internal and external environments, process conditions, and product quality, manufacturing systems can optimize energy and materials use.

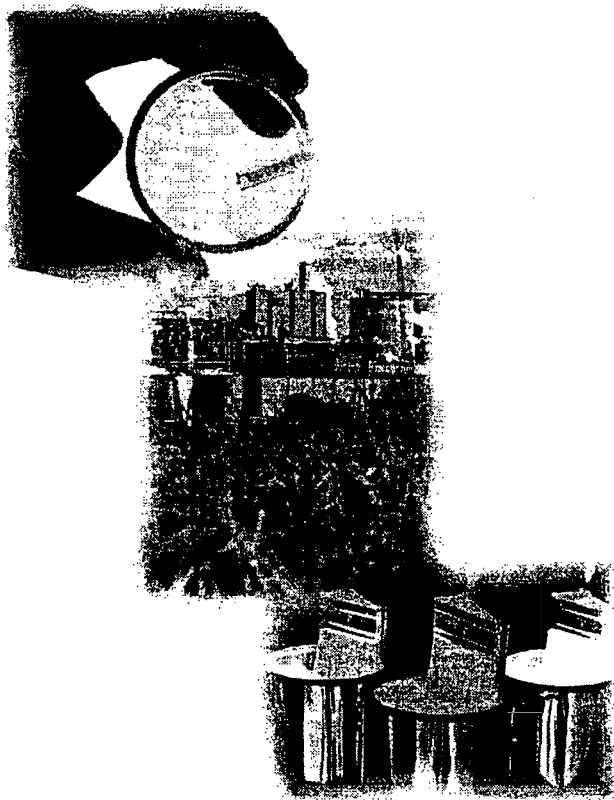
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Plant/Crop-based Renewables Resources 2020 Vision



Background

The U.S. Department of Energy (DOE) through its Office of Industrial Technologies (OIT) supports industries in their efforts to increase energy efficiency, reduce waste and increase productivity. The goal of OIT is to accelerate the development and use of advanced energy efficient, renewable, and pollution prevention technologies that benefit the industry, the environment, and U.S. energy security. The core of OIT is its Industries of the Future program which focuses on basic materials and processing industries such as the Agriculture Industry.

Goals

- Achieve 10 percent of basic chemical building blocks from plant-derived renewable sources (a 5-fold increase from the level today).
- Establish environmentally sensitive manufacturing platforms for renewable plant-based products.
- Build partnerships among industry, growers, academia, and government to develop commercial applications.

Accomplishments

- A strategic vision, "Plant/Crop-Based Renewable Resources 2020," for using crops, trees, and agricultural wastes to manufacture industrial chemicals and a huge range of everyday consumer goods was developed by the U.S. agricultural, forestry and chemical communities.
- Industry has identified the significant barriers that exist in the overall system for conversion of renewable resources into industrial chemicals and everyday consumer goods.

Benefits

- Expand/open new markets to farmers and increase their sales/profits.
- Lessen reliance on imported fossil fuels/improve energy efficiency of products.
- Reduce carbon emissions.

- Establish alternative pathways of making similar or superior products that consumers demand.
- Revitalize the economy in rural regions by co-locating facilities/farm gate.
- Reduce waste generated in the production of chemicals and products.
- Create new opportunities for recycling.

Future Activities

Research and development is being solicited in the high priority areas identified in industry's technology roadmap. Selected high-priority research needs from the technology roadmap include:

Plant Science—Develop understanding of gene regulation and control of plant metabolic pathways, and functional genomics to improve gene manipulation.

Production—Improve production methods (higher plant productivity, more desirable plant components) for an adequate supply of plants for industrial use.

Processing—Improve methods of product separation and develop new, more effective catalysts for creating chemicals and other products from plants rather than hydrocarbons.

Utilization—Develop understanding of the relationships between the structure and functionality of different plant constituents (e.g., proteins, starch) and sound infrastructure and distribution systems to ensure adequate raw materials supply.

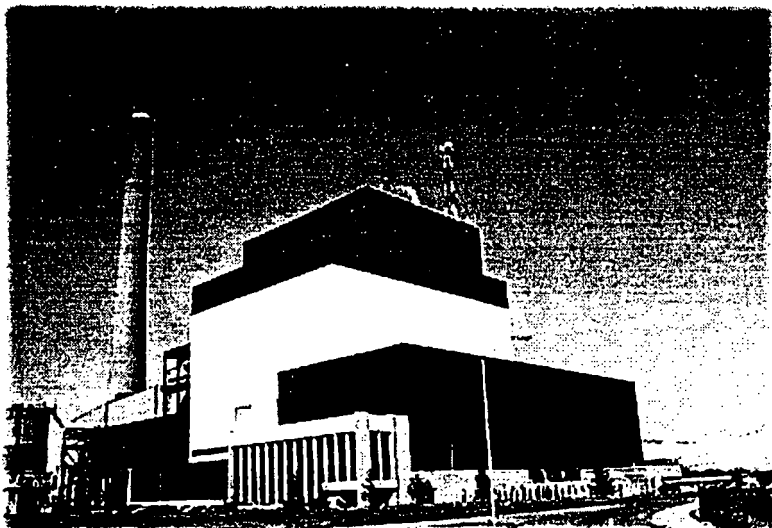
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 Corn Refiners Association
 Genencor International, Inc.
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Biomass Cofiring – A Renewable Alternative for Utilities



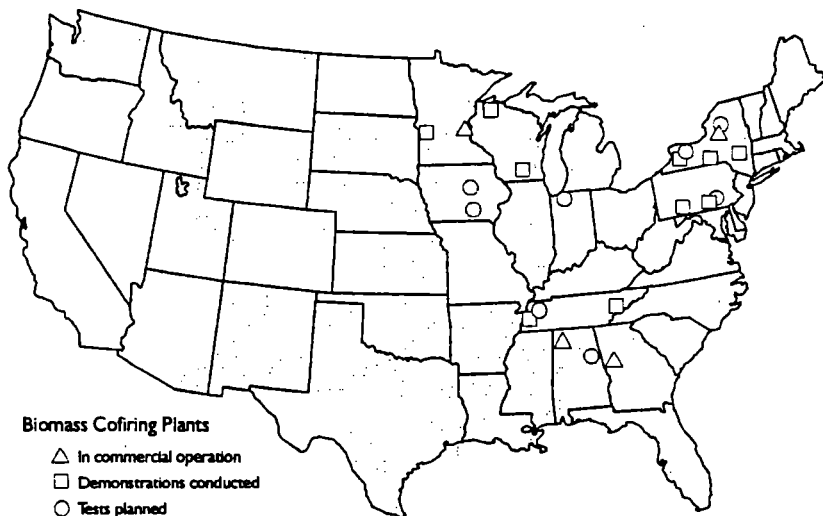
and trials have shown that effective substitutions of biomass energy can be made up to about 15 percent of the total energy input with little more than burner and feed intake system modifications to existing stations. In addition to CO₂ emission benefits, biomass in general contains significantly less sulfur than coal, so there is an SO₂ benefit as well. Early test results also suggest that there is a NO_x reduction potential of up to 30 percent with woody biomass.

Background

Biomass cofiring refers to the practice of introducing biomass as a partial substitute fuel in high efficiency coal boilers. This is the nearest term low-cost option for the efficient conversion of biomass to electricity. Cofiring has been practiced, tested, or evaluated for a variety of boiler technologies. After “tuning” the boiler’s combustion output, there is little or no loss in total efficiency, implying that the biomass combustion efficiency to electricity would be close to the 33-37 percent range. Since large-scale coal power boilers represent 310 GW of generating capacity, there is a substantial opportunity for power generation using biomass cofiring. Extensive demonstrations

Economic Requirements

The economics of cofiring are highly site-specific and depend on power plant layout and type and availability of low-cost biomass fuels. A typical cofire installation includes modification to the fuel-handling and storage system to accommodate biomass. Costs can increase significantly if facilities for wood



drying or size reduction are required, or if a separate feed to the boiler is required. For pulverized-coal boilers, retrofit costs range from \$150 to \$300 per kilowatt (kW) of biomass generation. The lowest cost opportunities are with cyclone boilers, for which costs may be as low as \$50 per kW.

The more important cost factor, however, is fuel supply. Costs for biomass fuels depend on a number of factors such as climate, proximity to population centers, and the presence of industries that handle and dispose of wood. Usually the cost of biomass fuels must be equal to or less than the cost of coal (per MBtu) for cofiring to be economically successful. Some utilities reduce fuel costs by cofiring with biomass; the Tennessee Valley Authority, for example, estimates that it will save \$1.5 million per year in fuel costs by using cofiring at its Colbert plant.

Technical Challenges

Several technical questions having to do with fuel feed, boiler chemistry, and ash deposition and disposal have been defined and are approaching resolution. Losses in boiler efficiency due to cofiring are small and are usually due to higher moisture content in the biomass fuels. A consensus is emerging that cofiring is feasible at the majority of coal-fired power plants. However, many power companies sell fly ash for use in making cement; currently the standard set by the American Society for Testing and Materials requires that only "coal ash" be used in the mixture. Until this standard is changed, cofiring biomass may hinder plant managers from selling ash for use in cement. Several utilities are currently working with the U.S. Department of Energy (DOE) to resolve this issue.

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NYSERDA
Southern Companies
Southern Research Institute
SUNY
Tennessee Valley Authority
University of Toronto
U.S. Department of Agriculture

Oak Ridge National Laboratory	Oak Ridge, TN	\$900,000
Sandia National Laboratory	Albuquerque, NM	\$500,000
National Renewable Energy Laboratory	Golden, CO	\$492,000
University of Washington	Seattle, WA	\$172,500
Sandia National Laboratory	Albuquerque, NM	\$600,000

Sensitivity: None

Closed Loop Biomass Co-Firing and Co-firing Biomass with Lignite Solicitations -

Total to be awarded \$2.5M for cost-shared projects that demonstrate the viability of co-firing biomass with lignite coal for power production, and that develop and validate co-firing technology using the closed loop feedstock supply.

Sensitivity: None

The New Petroleum

Richard G. Lugar and R. James Woolsey

WHY CHANGE?

OIL is a magnet for conflict. The problem is simple—everyone needs energy, but the sources of the world's transportation fuel are concentrated in relatively few countries. Well over two-thirds of the world's remaining oil reserves lie in the Middle East (including the Caspian basin), leaving the rest of the world dependent on the region's collection of predators and vulnerable autocrats. This unwelcome dependence keeps U.S. military forces tied to the Persian Gulf, forces foreign policy compromises, and sinks many developing nations into staggering debt as they struggle to pay for expensive dollar-denominated oil with lower-priced commodities and agricultural products. In addition, oil causes environmental conflict. The possibility that greenhouse gases will lead to catastrophic climate change is substantially increased by the 40 million barrels of oil burned every day by vehicles.

Ethanol has always provided an alternative to gasoline. In terms of environmental impact and fuel efficiency, its advantages over gasoline substantially outweigh its few disadvantages. But until now it has only been practical to produce ethanol from a tiny portion of plant life—the edible parts of corn or other feed grains. Corn prices have fluctuated around \$100 a ton in the last few years, ranging from half to double that amount. Ethanol has thus been too expensive to represent

SENATOR RICHARD G. LUGAR (R-Ind.) is the Chairman of the Agriculture, Nutrition, and Forestry Committee and a member of the Foreign Relations Committee. R. JAMES WOOLSEY, an attorney, was Director of Central Intelligence from 1993 to 1995. He serves on the boards of several corporations, including BC International, which is expected to open the first commercial biomass ethanol plant in the United States in 2000.

cellulosic biomass

The New Petroleum

anything but a small, subsidized niche of the transportation fuel market. In spite of recent reductions in the expense of ethanol processing, the final product still costs roughly a dollar a gallon, or about double today's wholesale price of gasoline.

Recent and prospective breakthroughs in genetic engineering and processing, however, are radically changing the viability of ethanol as a transportation fuel. New biocatalysts—genetically engineered enzymes, yeasts, and bacteria—are making it possible to use virtually any plant or plant product (known as cellulosic biomass) to produce ethanol. This may decisively reduce cost—to the point where petroleum products would face vigorous competition.

The best analogy to this potential cost reduction is the cracking of the petroleum molecule in the early twentieth century. This let an increasingly large share of petroleum be used in producing high-performance gasoline, thus reducing waste and lowering cost enough that gasoline could fuel this century's automotive revolution. Genetically engineered biocatalysts and new processing techniques can similarly make it possible to utilize most plant matter, rather than a tiny fraction thereof, as fuel. Cellulosic biomass is extremely plentiful. As it comes to be used to produce competitively priced ethanol, it will democratize the world's fuel market. If the hundreds of billions of dollars that now flow into a few coffers in a few nations were to flow instead to the millions of people who till the world's fields, most countries would see substantial national security, economic, and environmental benefits.

PAYING FOR ROGUES

ENERGY IS vital to a country's security and material well-being. A state unable to provide its people with adequate energy supplies or desiring added leverage over other people often resorts to force. Consider Saddam Hussein's 1990 invasion of Kuwait, driven by his desire to control more of the world's oil reserves, and the international response to this threat. The underlying goal of the U.N. force, which included 500,000 American troops, was to ensure continued and unfettered access to petroleum.

Oil permeates every aspect of our lives, so even minor price increases have devastating impacts. The most difficult challenge for planners, policymakers, and alternative-energy advocates is the transportation

sector, which accounts for over 60 percent of U.S. oil demand. The massive infrastructure developed to support gasoline-powered cars is particularly resistant to modifications. It precludes rapid change to alternative transportation systems and makes America highly vulnerable to a break in oil supplies. During a war or embargo, moving quickly to mass transit or to fuel-cell or battery-powered automobiles would be impossible.

For most countries, excluding only those few that will be the next century's oil suppliers, the future portends growing indebtedness, driven by increasingly expensive oil imports. New demand for oil will be filled largely by the Middle East, meaning a transfer of more than \$1 trillion over the next 15 years to the unstable states of the Persian Gulf alone—on top of the \$90 billion they received in 1996.

Dependence on the Middle East entails the risk of a repeat of the international crises of 1973, 1979, and 1990—or worse. This growing reliance on Middle Eastern oil not only adds to that region's disproportionate leverage but provides the resources with which rogue nations support international terrorism and develop weapons of mass destruction and the ballistic missiles to carry them. Iraqi vx nerve gas and Iranian medium-range missiles show how such regimes can convert oil revenues into extensive and sophisticated armament programs.

IS OIL RUNNING OUT?

OPTIMISTS ABOUT world oil reserves, such as the Department of Energy, are getting increasingly lonely. The International Energy Agency now says that world production outside the Middle Eastern Organization of Petroleum Exporting Countries (OPEC) will peak in 1999 and world production overall will peak between 2010 and 2020. This projection is supported by influential recent articles in *Science* and *Scientific American*. Some knowledgeable academic and industry voices put the date that world production will peak even sooner—within the next five or six years.

The optimists who project large reserve quantities of over one trillion barrels tend to base their numbers on one of three things: inclusion of heavy oil and tar sands, the exploitation of which will entail huge economic and environmental costs; puffery by OPEC nations lobbying

The New Petroleum

for higher production quotas within the cartel; or assumptions about new drilling technologies that may accelerate production but are unlikely to expand reserves.

Once production peaks, even though exhaustion of world reserves will still be many years away, prices will begin to rise sharply. This trend will be exacerbated by increased demand in the developing world. As Daniel Yergin, Dennis Eklof, and Jefferson Edwards pointed out in these pages ("Fueling Asia's Recovery," March/April 1998), even assuming a substantial recession, increased Asian needs alone will add enough demand by 2010 (9 million barrels per day) to more than equal Saudi Arabia's current daily production.

The nations of the Middle East will be ready to exploit the trend of rising demand and shrinking supply. The Gulf states control nearly two-thirds of the world's reserves; the states bordering the Caspian Sea have another several percent. Barring some unforeseen discoveries, the Middle East will control something approaching three-quarters of the world's oil in the coming century.

A WHOLE NEW WORLD

IF GENETICALLY engineered biocatalysts and advanced processing technologies can make a transition from fossil fuels to biofuels affordable, the world's security picture could be different in many ways. It would be impossible to form a cartel that would control the production, manufacturing, and marketing of ethanol fuel. U.S. diplomacy and policies in the Middle East could be guided more by a respect for democracy than by a need to protect oil supplies and accommodate oil-producing regimes. Our intrusive military presence in the region could be reduced, both ameliorating anti-American tensions and making U.S. involvement in a Middle Eastern war less likely. Other states would also reap benefits. Ukraine, rich in fertile land, would be less likely to be dominated over time by oil-rich Russia. China would feel less pressure to befriend Iran and Iraq or build a big navy to secure the oil of the South China Sea. The ability of oil-exporting countries to shape events would be increasingly limited.

The recent report by the President's Committee of Advisers on Science and Technology (PCAST) predicted that U.S. oil imports will

approximately double between 1996 and 2030, from 8.5 million barrels per day, at a cost of \$64 billion, to nearly 16 million barrels per day, at a cost of \$120 billion. They estimated, however, that with concentrated efforts in fundamental energy research and investment in renewable fuel technologies, this could be reduced to 6 million barrels per day in 2030. The report concluded,

A plausible argument can be made that the security of the United States is at least as likely to be imperiled in the first half of the next century by the consequences of inadequacies in the energy options available to the world as by inadequacies in the capabilities of U.S. weapons systems. It is striking that the Federal government spends about 20 times more R&D money on the latter problem than on the former.

FUEL FARMERS

CELLULOSIC ETHANOL would radically improve the outlook for rural areas all over the world. Farmers could produce a cash crop by simply collecting agricultural wastes or harvesting grasses or crops natural to their region. Agricultural nations with little to no petroleum reserves would begin to see economic stability and prosperity as they steadily reduced massive payments for oil imports. Even more striking would be the redistribution of resources that would occur if farmers and foresters produced much of the world's transportation fuel. We know from the positive results of micro-credit institutions and other such programs that even small increases in income can be a major boost to a subsistence-level family's prospects. If family income is a few hundred dollars a year, earning an extra \$50-\$100 by gathering and selling agricultural residues to a cellulosic ethanol plant could mean a much improved life. Such added income can buy a few used sewing machines to start a business or a few animals to breed and sell. It can begin to replace despondency with hope.

There are likely to be even larger effects on rural development if biomass ethanol production can lead a shift toward using plant matter for other products as well, such as biochemicals and electrical energy. The cleanliness of renewable fuel technologies makes them particularly attractive to countries that lack a sophisticated infrastructure





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or network of regulatory controls. At least some facilities that process carbohydrates should lend themselves to being simplified and sized to meet the needs of remote communities. If such towns can produce their own fuel, some of their fertilizers, and electricity, they will be far better positioned to make their way out of poverty and to move toward democracy and free enterprise. Local economic development can promote political stability and security where poverty now produces hopelessness and conflict.

A major strength of the new technologies for fermenting cellulosic biomass is the prospect that almost any type of plant, tree, or agricultural waste can be used as a source of fuel. This high degree of flexibility allows for the use of local crops that will enrich the soil, prevent erosion, and improve local environmental conditions.

Finally, as recession and devaluations overseas move the American balance-of-payments deficit from the 1998 level—\$1 billion every two days—toward nearly \$1 billion every day, there will be increased calls for protectionism. The best way to avoid the mistakes of the 1930s is to have a solid economic reason for increasing U.S. production of commodities now bought abroad. The nearly \$70 billion spent annually for imported oil represents about 40 percent of the current U.S. trade deficit, and every \$1 billion of oil imports that is replaced by domestically produced ethanol creates 10,000–20,000 American jobs.

EASY BEING GREEN

TO BE politically and economically acceptable, changes in fuel must be understood by the American public to be affordable and not disruptive. Most other countries require the same tough criteria—U.S. difficulties in convincing developing nations to reduce greenhouse gas emissions are directly related to the cost and the damage this would have on their development plans. But if one of the most effective ways to reduce greenhouse emissions also produced an improved balance-of-payments deficit and opportunities for rural development, economic benefits would suddenly far exceed the costs. The political acceptability of reducing emissions changes substantially when the economics change. A shift to biomass fuels stands out as an excellent way to introduce an environmentally friendly energy technology that has a chance of

both enjoying widespread political and economic support and having a decisive impact on the risk of climate change.

Renewable fuels produced from plants are an outstanding way to substantially reduce greenhouse gases. Although burning ethanol releases carbon dioxide into the atmosphere, it is essentially the same carbon dioxide that was fixed by photosynthesis when the plants grew. Burning fossil fuels, on the other hand, releases carbon dioxide

Any type of plant, tree, or agricultural waste can be used for fuel.

that otherwise would have stayed trapped beneath the earth.

If one looks at the complete life cycle of the production and use of ethanol derived from feed grains, the only addition of carbon dioxide to the atmosphere results from the use of fossil fuel products in planting, chemical fertilizing, harvesting, and processing. But this fossil fuel use can be substantial—up to seven gallons of oil may be needed to produce eight gallons of ethanol. When ethanol is produced from cellulosic biomass, however, relatively little tilling or cultivation is required, reducing the energy inputs. It takes only about one gallon of oil to produce seven of ethanol. There is a virtual consensus among scientists: when considered as part of a complete cycle of growth, fermentation, and combustion, the use of cellulosic ethanol as a fuel, once optimized, will contribute essentially no net carbon dioxide to the atmosphere.

According to a 1997 study done by five laboratories of the U.S. Department of Energy, a vehicle powered by biomass ethanol emits well under one percent of the carbon dioxide emitted by one powered by gasoline. More surprising, however, is that ethanol produced from biomass emits only about one percent of the carbon dioxide emitted by battery-powered vehicles, since the electricity for those is commonly produced by burning fossil fuels at another location. Although local air quality is improved, total carbon dioxide emissions are not curtailed; they are merely exported—for example, from Los Angeles to the Four Corners. Unless the electricity to charge the car's batteries is produced by renewable fuels or nuclear power, electric vehicles are only 20 to 40 percent better as carbon dioxide emitters than gasoline-powered cars. Biomass ethanol beats both by a factor of about 100, fundamentally changing the global-warming debate.

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FRINGE BENEFITS

CELLULOSIC ETHANOL is the only alternative fuel that requires, at most, very modest changes to vehicles and the transportation infrastructure. One need not spend money retooling Detroit, nor spend years awaiting the gradual replacement of older vehicles by those with new technology. Nor does one need to modify or construct pipelines and storage tanks to hold hydrogen as an alternate to petroleum. This compatibility with today's infrastructure saves billions of dollars and not just years, but decades. Moreover, there is nothing incompatible between using ethanol now in internal combustion engines and using it later in more efficient power systems, such as hybrids or fuel cells.

Essentially all automobiles currently on the road can use fuel containing up to ten percent ethanol. But strict fuel economy standards have encouraged the development and production of flexible fuel vehicles (FFVs) that can use up to 85 percent ethanol. FFVs are already in dealers' showrooms, containing (at no added cost to the consumer) the minor engine modifications—a computer chip in the fuel system and a fuel line made out of slightly different material—that make large-scale ethanol use possible. Even pure ethanol vehicles are quite practical. Brazil has 3.6 million on the road.

Corn ethanol will continue to serve an important role as ethanol production shifts to cellulosic biomass. Commercialization of corn ethanol has provided a base of industrial experience, talented people, and infrastructure from which a much larger cellulosic ethanol industry may be launched. For corn farmers, biomass is no threat; it will probably be a boon. Indeed, there is likely to be a continuing, perhaps even an expanding, market for corn ethanol because of the value of its byproducts, such as animal feed. In general, the transition from corn to cellulosic biomass and from a few producers to many is likely to expand opportunities for American farmers.

BIOENGINEERED BUGS

ETHANOL'S ECONOMIC viability depends on making it cheaper to produce. This can be achieved by making it out of cellulosic biomass, which includes essentially anything that grows or has grown: agricultural

and forest residues, prairie grass, kudzu, waste wood, used paper products, even much of urban waste. Last year, about 95 percent of the ethanol produced in the United States came from corn. But agricultural residues and other wastes have low or even negative cost—some you are paid to haul away—while crops like prairie grass cost only a few tens of dollars a ton. This represents a substantial savings in the raw material used in ethanol and puts it within the range of oil, even inexpensive Persian Gulf oil.

Only recently have scientists developed the means to convert cellulosic biomass efficiently into ethanol. The edible portions of corn and other grains easily ferment into ethanol because of their chemical make-up. Most biomass, however, consists of more recalcitrant hemicellulose and cellulose, requiring both the breaking up of these two fibers as well as the fermenting of both five- and six-carbon sugars. This all happens in nature, but two parts of it—fermenting five-carbon sugars and breaking up cellulose quickly—are technically challenging. The first is now done by genetically engineered microorganisms; this tool and other new techniques are now being brought to bear on the second problem.

How far along are these developments? The current efficiency of ethanol processing is somewhat analogous to that of petroleum refining in the early 1900s: after the invention of thermal cracking made it possible to use a major share of the petroleum molecule for gasoline production but before the invention of catalytic cracking opened up an even larger share of petroleum to exploitation. In short, we have come a long way, but still have some inventing to do. The new, genetically engineered microorganisms have already taken us far toward the fermentation of ethanol from a wide range of plant material, laying the groundwork for reductions in processing costs as well.

The new microorganisms, combined with other improvements in processing, fundamentally change the equation for considering ethanol a major transportation fuel. According to a recent study by Dartmouth engineering professor Lee Lynd, utilizing only some of the nation's agricultural and forest residues, with no additional land use, could supply over 15 billion gallons of ethanol a year—more than ten times the amount now produced from corn, and enough to replace around eight percent of the nation's gasoline. (Not all residues would

The New Petroleum

be used, of course, since some must be left for long-term fertility.) Lynd also calculated that taking a little over half of the 60 million acres of cropland historically idled by federal programs for conservation and other purposes, and using for ethanol production the mown grasses with which much of this acreage is ordinarily planted, would produce enough ethanol to fulfill around 25 percent of the country's annual gasoline needs. These calculations use current automobile mileage. Lynd notes that further mileage improvements, achieved through a shift to hybrids or fuel cells, could obviate the need for gasoline entirely, without taking land from food crops or nonagricultural uses. The coproduction of animal feed and biomass residues from alfalfa and switchgrass is especially promising. There is, in short, no basis for the argument that America does not have the land to produce enough ethanol to make a very large dent in U.S. gasoline consumption.

Biofuels must be produced in ways that enhance overall environmental quality. Sound land-use policies certainly must be followed, to protect wildlife habitat and address other environmental concerns. But professional land-use techniques should readily accomplish this. Alternative fuels are often seen as an unpalatable necessity representing a retrenched standard of living, forced upon us in an age of limits. The opposite may be true. Utilization of renewable fuels will make it possible for us to continue enjoying the freedom afforded by private cars, even as the production of petroleum begins to decline.

THE RIGHT STUFF?

EARLY THIS century, Henry Ford expected that ethanol, not gasoline, would be the fuel of choice for automobiles. His reasons are evident. The two fuels can be compared by examining three basic parameters—energy content, octane, and vapor pressure. Pure ethanol contains 69 percent of the energy of gasoline. A lower energy content translates into fewer miles to the gallon; in order to travel the same range, about a 30 percent larger fuel tank is needed (as is used in Brazil). Many scientists believe that optimizing engines for ethanol use will largely compensate for this difference, in part because ethanol is a simple combination of carbon, hydrogen, and oxygen. It is vastly less complex than gasoline, which means that

fine-tuning an engine to squeeze every last drop of energy from ethanol is potentially easier.

Octane is the measure of a fuel's ability to oxidize hydrogen and carbon molecules within a fraction of a second. When the reaction is not simultaneous, "engine knock" and inefficient combustion result. Ethanol has an octane rating 15 percent higher than gasoline's. In the 1920s ethanol was briefly considered as a large-scale additive to gasoline to stop the knocking of the new higher compression engines. However, to the detriment of public health, ethanol lost out to highly toxic tetraethyl lead, for three reasons: in contrast to ethanol, only a small amount of lead was needed as an additive; some were concerned that corn-derived ethanol would compete for land and threaten the feed grains market; and since Prohibition was in effect, many were also worried about the security problems associated with maintaining large volumes of what is essentially 200-proof vodka. Ethanol's ability to be an effective fuel, however, was never an issue.

A third important fuel measurement is vapor pressure, or how readily a liquid evaporates. A fuel's vapor pressure is directly linked to the quantity of vehicle emissions, since over 40 percent of automobile emissions result from evaporation, not tailpipe emissions. Substituting ethanol for gasoline in any amount reduces tailpipe emissions and thus reduces urban smog. Pure ethanol, and any gasoline-ethanol mixture that is more than 22 percent ethanol, has a lower vapor pressure than gasoline and would therefore reduce the amount of evaporative emissions.

Somewhat confusingly, however, blends of ethanol and current gasoline have a slightly higher vapor pressure than pure gasoline when the mixture contains less than 22 percent ethanol, because of the unique mixing properties of the liquids. Some studies show that low-level blends of ethanol and gasoline (like gasohol, which is ten percent ethanol) can actually worsen local air pollution, especially the formation of low-level ozone. Consequently, in cities in the Northeast and California, proposals to encourage the use of ethanol blends have often fallen on deaf ears. Some environmentalists see them as camouflaged subsidies for Midwestern corn growers at the expense of the cities.

But although low-level ethanol blends present complex issues, blends with more than 22 percent ethanol—which can be used in FFVs—do not have the vaporization problem. Moreover, with different approaches to

refining and blending gasoline, a solution to the vaporization problem may well exist even at mixtures below 22 percent. Finally, ETBE—an oxygenate made from ethanol that improves gasoline combustion—improves air quality both in tailpipe emissions and vaporization, although its use means the fuel contains five to ten percent ethanol.

Choosing to use cellulosic ethanol is not a choice to forsake more advanced automobile propulsion technologies, such as hybrids and fuel cells. Ethanol is compatible with both. Jeffrey Bentley, vice president of Arthur D. Little, Inc., a company recently honored by the U.S. government for its novel fuel-cell technology, stated that “ethanol provides higher efficiencies, fewer emissions, and better performance than other fuel sources, including gasoline. . . . Where ethanol is available, it will be the fuel of choice by consumers.” As both hybrids and fuel cells continue to improve, automobiles powered by them may dramatically reduce air pollution. Ethanol’s compatibility with both makes moving toward cellulosic ethanol as a transportation fuel much more desirable.

If government policies promote FFVs, moreover, a large fleet of ethanol-compatible vehicles will be available much earlier than would otherwise have been feasible. This is because FFVs can burn gasoline now but can use cellulosic ethanol as it becomes available. Introducing FFVs into the national fleet differs radically in timing from other changes in transportation. Even if an ideal hybrid or fuel-cell vehicle came on the market, the slow rate of turnover in the nation’s cars would mean that it would be many years before its introduction would make a dent in overall fuel use. But moving now to substantially increase the number of FFVs being produced would create the capability to shift to cellulosic ethanol as soon as it is available at attractive prices.

In addition, insofar as U.S. security and environmental concerns are more with the consumption of problem-causing petroleum fuel than with fuel in general, substituting cellulosic ethanol for gasoline improves relevant “mileage” radically, even in internal combustion engines. For example, an average automobile gets approximately 17 miles per gallon and is driven approximately 14,000 miles per year, thus using 825 gallons of gasoline annually. Suppose that same automobile were an FFV using a mixed fuel containing 85 percent cellulosic ethanol. Because of ethanol’s lower energy content, it would use about

1,105 gallons of fuel, but only 165 would be gasoline. Such a vehicle could be said to be getting, in a sense, over 80 miles per gallon—of national-security-risk-increasing, carbon-dioxide-producing gasoline.

The one remaining barrier to widespread replacement of gasoline with ethanol is production cost. Relying on feed grains makes this cost comparatively high and volatile, since corn is subject to the caroming behavior of feed markets. In 1995, its price of \$100 a ton nearly doubled, forcing a sharp curtailment in ethanol production. A partial shift to biomass should circumvent such instabilities. Over the past 15 years, the cost of producing a gallon of ethanol has been cut in half, to just over \$1 a gallon wholesale. If, as predicted, the new biocatalysts, low and steady raw material costs, and improved processing let costs fall another 50 percent or so, ethanol could compete with gasoline at today's prices. If oil prices rise in the next century, gasoline could actually be at a substantial price disadvantage.

Such a reduction of ethanol cost is entirely plausible for two reasons. First, a simple comparison of energy content reveals that a dry ton of biomass crops—\$40 is a reasonable current average cost—is comparable to oil at \$10–13 a barrel. Agricultural wastes, in many cases, are considerably cheaper than either: many are free or have negative cost. So the overall costs of cellulosic biomass are likely to at least be in the same ballpark as those of crude oil. Second, further reductions in the cost of processing seem quite achievable. The current cost of processing ethanol is significantly higher than the equivalent price per barrel for oil. But this discrepancy reflects the maturity and sophistication of the petroleum industry, developed over the past century, as compared to the fledgling biofuels effort. Producing ethanol is not inherently more complex than refining petroleum—in fact, just the contrary. The world has simply invested far more effort in the latter.

JUMP-START

WHILE THE private sector will provide the capital and motivation to move toward ethanol, the federal government has a vital role to play. Market forces seldom reflect national security risks, environmental issues, or other social concerns. The private sector often cannot fund long-term research, despite its demonstrated potential for dramatic innovation. Hence, the federal government must increase its investment

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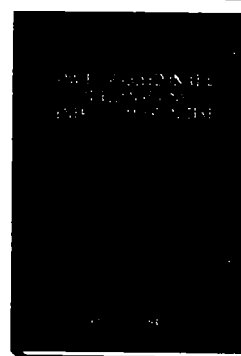
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in renewable energy research, particularly in innovative programs such as genetic engineering of biocatalysts, development of dedicated energy crops, and improved processing. The very small sums previously invested by the Departments of Energy and Agriculture have already spawned dramatic advances. Every effort should be made to expand competitive, merit-based, and peer-reviewed science and to encourage research that cuts across scientific disciplines.

Research is essential to produce the innovations and technical improvements that will lower the production costs of ethanol and other renewable fuels and let them compete directly with gasoline. At present, the United States is not funding a vigorous program in renewable technologies. The Department of Energy spends under two percent of its budget on renewable fuels; its overall work on renewable technologies is at its lowest level in 30 years.

The United States cannot afford to wait for the next energy crisis.

Because private investment often follows federal commitment, industrial research and development has also reached new lows. These disturbing trends occur at a time of national economic prosperity when America has both time and resources for investing in biofuels. The United States cannot afford to wait for the next energy crisis to marshal its intellectual and industrial resources.

Research alone will not suffice to realize cellulosic ethanol's promise. The federal government should also modify the tax code to spur private investment. The existing renewable alcohol tax credits have recently been extended by Congress through 2007—which will help the growth of the new biofuels industry and offer some protection in the transition from grain to cellulosic biomass. But the tax credit structure should facilitate the gradual adoption of cellulosic ethanol—in time, it should not need subsidies. Government incentives to produce FFVS should also be increased.

Finally, there must be a coordinated effort across the many different federal agencies that oversee government laboratories and regulatory agencies. The analogy to the semiconductor industry is instructive. In 1987, Congress authorized the creation of a government-industry partnership, the Semiconductor Manufacturing Technology Association (SEMATECH). Under the direction of the Department of

Defense's Advanced Research Projects Agency, SEMATECH pursued fundamental research in semiconductor components and manufacturing processes. Private firms with innovative ideas were encouraged to devote research dollars to transform the idea into a commercial reality. The few domestic semiconductor manufacturers were brought together in forums where the companies could discuss technical hurdles without sacrificing competitive advantage. Today, the success of SEMATECH is evident, as the high-technology sector demonstrates. Biofuels offer a similar opportunity.

Cellulosic ethanol is a first-class transportation fuel, able to power the cars of today as well as tomorrow, use the vast infrastructure already built for gasoline, and enter quickly and easily into the transportation system. It can be shipped in standard rail cars and tank trucks and is easily mixed with gasoline. Although somewhat lower in energy content, it has a substantially higher octane rating than gasoline, allowing for more efficient combustion. It can radically reduce the emission of global warming gases, help reduce the choking smog of our cities, and improve air quality. It is far less toxic than petroleum, far less likely to explode and burn accidentally, and far simpler physically and chemically, making possible simpler refining procedures. If a second Exxon *Valdez* filled with ethanol ran aground off Alaska, it would produce a lot of evaporation and some drunk seals.

Our growing dependence on increasingly scarce Middle Eastern oil is a fool's game—there is no way for the rest of the world to win. Our losses may come suddenly through war, steadily through price increases, agonizingly through developing-nation poverty, relentlessly through climate change—or through all of the above. It would be extremely short-sighted not to take advantage of the scientific breakthroughs that have occurred and that are in the offing, accelerate them, and move smartly toward ameliorating all of these risks by beginning to substitute carbohydrates for hydrocarbons. If we do, we will make life far less dangerous and far more prosperous for future generations. If we do not, those generations will look back in angry wonder at the remarkable opportunity that we missed.②

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 National Association of State Department of Agriculture
 1890 Institutions
 Corn Refiner Association
 Monsanto
 National Association of Wheat Growers
 National Oilseed Processor Association
 The National Farmers Organization
 The National Sunflower Association
 The National Cattlemen's Beef Association
 The National Pork Growers Association
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 The National Plant Protection Association
 The National Association of Land Grant Colleges and Universities
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 The American Seed Trade Association
 American Dairy Association
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 John Deere
 Case/IH/New Holland ?
 AgCo ?
 National Farmland Trust
 Sierra Club
 National Wildlife Federation
 National Association of Soil Conservation Districts
 National Governors Association (Economic development interest)
 Tribal Governments
 Jeffrey W. Gain, Chairman, AARCC Board
 Ralph Hardy, Ph.D. National Agricultural Biotechnology Council
 Shelby Thames, Ph.D. University of Southern Mississippi
 Mr. William Miller, Jackson, MS
 Pioneer Hi-Bred International, Inc.
 U. S. Grains Council
 Edward J. Daly III , Director, Conservation Alliance
 William E. Mankin, Director, Global Forest Policy Project
 David K. Schorr, Director, World wildlife Fund
 Consumer's Choice Council
 All USDA Bio-based Products Coordination Council Members

DRAFT General Invite List: Agricultural Constituents

**Agricultural Research Institute
American Farm Bureau Federation
American Oilseed Coalition
American Soybean Association/United Soybean Board
National Farmer Cooperatives
Farmland Cooperatives
Ag Processor Coops
National Corn Growers Association
National Farmers Union
National Grange
New Uses Council
Renewable Fuels Association
U.S. Chamber of Commerce
U.S. Feed Grains Council
WIFE
Wheat Gluten Industry Council**

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Alternative auto fuel transforms trash into treasure

By Earle Eldridge
USA TODAY

Grass clippings, leaves, sawdust, cardboard, banana skins, junk mail and other trash could become fuel for the family car.

Pure Energy, a New York-based company working with Princeton University, has created a fuel that's a blend of ethanol, natural gas liquids, a

solvent and up to 70% "cellulosic" wastes — trash with fibers that create energy when burned.

It can be used in flexible-fuel vehicles that can run on gasoline or ethanol. Such vehicles are sold primarily for government and business fleets but also are available for consumers. Models currently available include the Ford Taurus sedan and Ranger pickup and all Chrysler minivans.

Philadelphia has agreed to a one-year test of the fuel, called P-Series, in its municipal flexible-fuel vehicles.

Last year, the Department of Energy approved P-Series as an alternative fuel. Energy Secretary Bill Richardson estimated it could replace about 1 billion gallons of gasoline annually by 2005.

But the company faces several challenges before P-Series is ready

for everyday use.

It would have to build refineries around the nation, each costing \$120 million to \$150 million to build.

And the company would likely need the support of the oil industry to set up pumps at existing gas stations.

Pure Energy says the fuel emits about 35% less hydrocarbons and 15% less carbon monoxide than gasoline. And it's sulfur-free.

Stephen Paul, a Princeton University research physicist who helped develop P-Series, says, "The real issue is the cleanliness of the fuel."

He says the fuel will never replace gasoline because there is not enough trash generated annually. But "we would have a source for some of our energy needs rather than depending on foreign oil."

NATIONLINE

EPA cracks down on use of two popular pesticides

The Environmental Protection Agency set sharp limits on two widely used pesticides Monday and said it will rule by the end of next year on whether to restrict the use of dozens of pesticides suspected of posing health risks to children.

Administrator Carol Browner's decision involves methyl parathion and azinphos-methyl, organophosphates used on apples and other produce. Browner, who said current crops are safe, hailed the rules as "major steps" under a sweeping reassessment of limits on hundreds of pesticides. The 40 or so organophosphates are a priority because overexposure is suspected of causing neurological disorders in children. The restrictions ban methyl parathion for all fruits and many vegetables. They also lower the allowed amount of azinphos-methyl on apples, pears and peaches. The action was reported Friday in USA TODAY.

— Peter Eisler

Withdrawal/Redaction Sheet

Clinton Library

DOCUMENT NO. AND TYPE	SUBJECT/TITLE	DATE	RESTRICTION
001. list	[Personally Identifiable Information] [partial] (1 page)	08/03/1999	b(6)

COLLECTION:

Clinton Presidential Records
Office of Environmental Initiatives
Roger Ballentine
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FOLDER TITLE:

Climate Change Other Bioenergy [2]

2017-1093-F

rs3171

RESTRICTION CODES

Presidential Records Act - [44 U.S.C. 2204(a)]

- P1 National Security Classified Information [(a)(1) of the PRA]
- P2 Relating to the appointment to Federal office [(a)(2) of the PRA]
- P3 Release would violate a Federal statute [(a)(3) of the PRA]
- P4 Release would disclose trade secrets or confidential commercial or financial information [(a)(4) of the PRA]
- P5 Release would disclose confidential advice between the President and his advisors, or between such advisors [(a)(5) of the PRA]
- P6 Release would constitute a clearly unwarranted invasion of personal privacy [(a)(6) of the PRA]

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RR. Document will be reviewed upon request.

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- b(2) Release would disclose internal personnel rules and practices of an agency [(b)(2) of the FOIA]
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- b(9) Release would disclose geological or geophysical information concerning wells [(b)(9) of the FOIA]

Tues Aug 3, 11:30-12:30

Reed
Valerie ~~Harris~~ (586-5656)

BIOENERGY EVENT MEETING

When: Tues August 3, 11:30

Where: OEOB 115

(b)(6)

Janet (cc: Mary)

Julie

Jeff

David G

Paul Bledsoe

Lisa Kountoupes

Beth Viola

Elliot Diring (cc: ~~David Bernell~~)

Pieter Boelhouwer

Tom Kalil

Henry Kelly

Linda Delgado (USDA)

Dan Reicher (DoE)

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Killer (NSF)
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Total Pages: _____

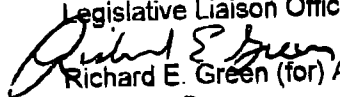
LRM ID: JAB182

**EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF MANAGEMENT AND BUDGET
Washington, D.C. 20503-0001**

Wednesday, July 28, 1999

LEGISLATIVE REFERRAL MEMORANDUM

TO: Legislative Liaison Officer - See Distribution below

FROM:  Richard E. Green (for) Assistant Director for Legislative Reference

OMB CONTACT: James A. Brown
E-Mail: James_A._Brown@omb.eop.gov
PHONE: (202)395-3473 FAX: (202)395-3109

SUBJECT: OMB Request for Views on HR _____ Biomass Research and Development Act of 1999

DEADLINE: 12:00 noon Friday, July 30, 1999

In accordance with OMB Circular A-19, OMB requests the views of your agency on the above subject before advising on its relationship to the program of the President. **Please advise us if this item will affect direct spending or receipts for purposes of the "Pay-As-You-Go" provisions of Title XIII of the Omnibus Budget Reconciliation Act of 1990.**

COMMENTS: Your input is needed for a response to Congressman Udall's request for comments on this draft bill. If your comments are not submitted by the deadline, they may not be submitted to the Congressman in time for consideration before the bill is introduced.

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JUL-28-1999 10:48 TO:277 R BALLANTINE

FROM:M HUNTER

P. 2/19

Julie M. Anderson
Roger S. Ballentine
Stephen Suh
Randolph M. Lyon

LRM ID: JAB182 SUBJECT: OMB Request for Views on HR _____ Biomass Research and Development Act of 1999

RESPONSE TO
LEGISLATIVE REFERRAL
MEMORANDUM

If your response to this request for views is short (e.g., concur/no comment), we prefer that you respond by e-mail or by faxing us this response sheet. If the response is short and you prefer to call, please call the branch-wide line shown below (NOT the analyst's line) to leave a message with a legislative assistant.

You may also respond by:

(1) calling the analyst/attorney's direct line (you will be connected to voice mail if the analyst does not answer); or

(2) sending us a memo or letter

Please include the LRM number shown above, and the subject shown below.

TO: James A. Brown Phone: 395-3473 Fax: 395-3109
Office of Management and Budget
Branch-Wide Line (to reach legislative assistant): 395-3454

FROM: _____ (Date)
 _____ (Name)
 _____ (Agency)
 _____ (Telephone)

The following is the response of our agency to your request for views on the above-captioned subject:

_____ Concur

_____ No Objection

_____ No Comment

_____ See proposed edits on pages _____

_____ Other: _____

_____ FAX RETURN of _____ pages, attached to this response sheet

[DISCUSSION DRAFT]

JULY 13, 1999

106TH CONGRESS
1ST SESSION**H. R. _____**

IN THE HOUSE OF REPRESENTATIVES

Mr. UDALL of Colorado introduced the following bill; which was referred to
the Committee on _____

A BILL

To create an initiative for research and development into
the utilization of biomass for fuel and industrial products.

1 *Be it enacted by the Senate and House of Representa-*
2 *tives of the United States of America in Congress assembled,*

3 **SECTION 1. SHORT TITLE.**

4 This Act may be cited as the "Biomass Research and
5 Development Act of 1999".

6 **SEC. 2. FINDINGS.**

7 Congress finds that—

2

1 (1) several prominent studies, including studies
2 by the President's Council of Advisors on Science
3 and Technology and the National Research Council,
4 support the potential for large research-driven ad-
5 vances in technologies for production of biobased in-
6 dustrial products;

7 (2) if an appropriate research and development
8 effort is undertaken, conversion of biomass into
9 biobased industrial products can lead to enhanced
10 national security, healthier rural economies, im-
11 proved environmental quality, near-zero net green-
12 house gas emissions, technology export, and sustain-
13 able resource supply;

14 (3) additional research and development can
15 help determine whether biomass feedstocks suitable
16 for industrial processing show potential for sustain-
17 able production, improved soil fertility, and carbon
18 sequestration;

19 (4) basic research to understand important
20 mechanisms of biomass conversion processes can be
21 expected to accelerate the application and advance-
22 ment of biomass processing technology by—

23 (A) increasing the confidence and speed
24 with which new technologies can be scaled up;
25 and

1 (B) giving rise to processing innovations
2 based on new knowledge; and

3 (5) it is appropriate for the Federal Govern-
4 ment to provide precommercial investment in basic
5 and applied research in the biomass processing area.

6 **SEC. 3. DEFINITIONS.**

7 For purposes of this Act—

8 (1) the term "Advisory Committee" means the
9 Biomass Technical Advisory Committee established
10 under section 6;

11 (2) the term "biobased industrial product"
12 means any new or improved fuel or chemical product
13 derived from biomass;

14 (3) the term "biomass" means any organic
15 matter that is available on a renewable or recurring
16 basis;

17 (4) the term "Board" means the Biomass Re-
18 search and Development Board established under
19 section 5;

20 (5) the term "Initiative" means the Biomass
21 Research and Development Initiative established
22 under section 7;

23 (6) the term "institution of higher education"
24 has the meaning given that term in section 1201(a)

1 of the Higher Education Act of 1965 (20 U.S.C.
2 1141(a));

3 (7) the term "national laboratory" has the
4 meaning given the term "laboratory" in section
5 12(d)(2) of the Stevenson-Wydler Technology Inno-
6 vation Act of 1980 (15 U.S.C. 3710a(d)(2)); and

7 (8) the term "point of contact" means a point
8 of contact designated under section 4(c).

9 **SEC. 4. COOPERATION AND COORDINATION IN BIOMASS**
10 **RESEARCH AND DEVELOPMENT.**

11 (a) **IN GENERAL.**—The Secretary of Energy and the
12 Secretary of Agriculture shall coordinate policies and pro-
13 cedures that promote research, development, and dem-
14 onstration on the production of biobased industrial prod-
15 ucts.

16 (b) **AREAS.**—In carrying out this Act, the Secretary
17 of Energy and the Secretary of Agriculture shall promote
18 research, development, and demonstration to—

19 (1) ensure full consideration of potential feed-
20 stock resources for energy-efficient, economically
21 competitive, and environmentally sound biobased in-
22 dustrial products; and

23 (2) assess the environmental, economic, and so-
24 cial impact of production of biobased industrial
25 products from biomass on a large scale.

1 (c) POINTS OF CONTACT.—

2 (1) IN GENERAL.—To coordinate research, de-
3 velopment, and demonstration programs and activi-
4 ties relating to biobased industrial products that are
5 carried out by their respective Departments—

6 (A) the Secretary of Energy shall des-
7 ignate, as the point of contact for the Depart-
8 ment of Energy, a high-level officer of the De-
9 partment of Energy; and

10 (B) the Secretary of Agriculture shall des-
11 ignate, as the point of contact for the Depart-
12 ment of Agriculture, a high-level officer of the
13 Department of Agriculture.

14 (2) DUTIES.—The points of contact shall
15 jointly—

16 (A) assist in arranging interlaboratory and
17 site-specific supplemental agreements for re-
18 search, development, and demonstration
19 projects relating to biobased industrial prod-
20 ucts;

21 (B) administer the Initiative; and

22 (C) respond in writing to each rec-
23 ommendation of the Advisory Committee made
24 under section 6.

1 **SEC. 5. BIOMASS RESEARCH AND DEVELOPMENT BOARD.**

2 (a) **ESTABLISHMENT.**—The Secretary of Energy and
3 the Secretary of Agriculture shall jointly establish the Bio-
4 mass Research and Development Board to coordinate pro-
5 grams within and among departments and agencies of the
6 Federal Government for the purpose of promoting the use
7 of biobased industrial products by—

8 (1) maximizing the benefits deriving from Fed-
9 eral grants, research and development agreements,
10 and other assistance; and

11 (2) bringing coherence to Federal planning.

12 (b) **MEMBERSHIP.**—The Board shall consist of—

13 (1) the point of contact of the Department of
14 Energy designated under section 4(c), who shall
15 serve as chairperson of the Board;

16 (2) the point of contact of the Department of
17 Agriculture designated under section 4(c), who shall
18 serve as vice-chairperson of the Board;

19 (3) a senior officer, appointed by the head of
20 the agency, who has a rank that is equivalent to the
21 points of contact, of—

22 (A) the Office of Science and Technology
23 Policy;

24 (B) the National Science Foundation;

25 (C) the Environmental Protection Agency;

26 and

1 (D) the Department of the Interior; and
2 (4) at the option of the Secretary of Energy
3 and the Secretary of Agriculture, other members ap-
4 pointed jointly by those Secretaries (after consulta-
5 tion with members described in paragraphs (1)
6 through (3)).

7 (c) DUTIES.—The Board shall—

8 (1) coordinate research, development, and dem-
9 onstration activities relating to bio-based industrial
10 products—

11 (A) between the Department of Energy
12 and the Department of Agriculture; and

13 (B) with other departments and agencies
14 of the Federal Government; and

15 (2) provide recommendations to the points of
16 contact concerning administration of this Act.

17 (d) MEETINGS.—The Board shall meet at least quar-
18 terly.

19 **SEC. 6. BIOMASS RESEARCH AND DEVELOPMENT TECH-**
20 **NICAL ADVISORY COMMITTEE.**

21 (a) ESTABLISHMENT.—The Secretary of Energy and
22 the Secretary of Agriculture shall jointly establish the Bio-
23 mass Research and Development Advisory Committee
24 to—

1 (1) advise the Secretary of Energy and the Sec-
2 retary of Agriculture concerning—

3 (A) the technical focus and direction of re-
4 quests for proposals issued under the Initiative;
5 and

6 (B) procedures for reviewing the proposals;
7 (2) facilitate consultations and partnerships
8 among Federal agencies, the research community,
9 agricultural producers, industry, consumers, and
10 other interested groups to carry out program activi-
11 ties relating to the Initiative; and

12 (3) evaluate and perform strategic planning on
13 program activities relating to the Initiative.

14 (b) MEMBERSHIP.—The Secretary of Energy and the
15 Secretary of Agriculture shall jointly appoint to the Advi-
16 sory Committee the following members:

17 (1) An individual affiliated with an institution
18 of higher education who has expertise in biobased in-
19 dustrial products.

20 (2) 2 engineers or scientists who have expertise
21 in biobased industrial products.

22 (3) 2 individuals affiliated with environmental
23 or conservation organizations.

24 (4) An individual affiliated with a commodity
25 trade association.

1 (5) An individual affiliated with the biobased
2 industrial products industry.

3 (6) An individual with expertise in energy ac-
4 counting, including the energy inputs of biomass
5 production.

6 (7) An individual with expertise in the econom-
7 ies of biobased industrial products.

8 (8) An individual with expertise in agricultural
9 economics.

10 (9) An individual with expertise relevant to the
11 commercialization of industrial products.

12 (10) Such other members as are appropriate.

13 (c) DUTIES.—The Advisory Committee shall—

14 (1) advise the points of contact with respect to
15 the Initiative; and

16 (2) evaluate whether, and make recommenda-
17 tions in writing to the Board to ensure that—

18 (A) funds appropriated for the Initiative
19 are distributed and used in a manner that is
20 consistent with the purposes described in sec-
21 tion 7(b);

22 (B) the points of contact are funding pro-
23 posals under this Act that are selected on a
24 competitive, peer-reviewed basis as determined

1 by an independent panel of scientific and tech-
2 nical peers; and

3 (C) activities under this Act are carried
4 out in accordance with this Act.

5 (d) COORDINATION.—The Advisory Committee shall
6 coordinate its activities with other Federal advisory com-
7 mittees working in related areas to avoid duplication of
8 effort.

9 (e) MEETINGS.—The Advisory Committee shall meet
10 at least quarterly.

11 (f) FEDERAL ADVISORY COMMITTEE ACT.—The Ad-
12 visory Committee shall not be subject to section 14 of the
13 Federal Advisory Committee Act.

14 **SEC. 7. BIOMASS RESEARCH AND DEVELOPMENT INITIA-**
15 **TIVE.**

16 (a) IN GENERAL.—The Secretary of Energy and the
17 Secretary of Agriculture, acting through their respective
18 points of contact and in consultation with the Board, shall
19 establish and carry out a Biomass Research and Develop-
20 ment Initiative under which competitively awarded grants,
21 contracts, and other financial assistance are provided to,
22 or entered into with, eligible entities to carry out research,
23 development, and demonstration with respect to biobased
24 industrial products.

1 (b) PURPOSES.—The purposes of grants, contracts,
2 and other financial assistance under this section shall be
3 to—

4 (1) stimulate collaborative activities by a di-
5 verse range of experts in all aspects of biomass proc-
6 essing for the purpose of conducting basic and ap-
7 plied research, development, and demonstration with
8 respect to biobased industrial products;

9 (2) enhance creative and imaginative ap-
10 proaches toward biomass processing that will serve
11 to develop the next generation of advanced tech-
12 nologies making possible low-cost biobased industrial
13 products;

14 (3) strengthen the intellectual resources of the
15 United States through the training and education of
16 future scientists, engineers, managers, and business
17 leaders in the field of biomass processing; and

18 (4) promote integrated research partnerships
19 among institutions of higher education, national lab-
20 oratories, Federal research agencies, State research
21 agencies, and the private sector as the best means
22 of overcoming technical challenges that span mul-
23 tiple academic disciplines and leveraging scarce Fed-
24 eral research funds.

25 (c) ELIGIBLE ENTITIES.—

12

1 (1) IN GENERAL.—To be eligible for a grant,
2 contract, or other financial assistance under this sec-
3 tion, an applicant shall be—

- 4 (A) an institution of higher education;
5 (B) a national laboratory;
6 (C) a Federal research agency;
7 (D) a State research agency;
8 (E) a private sector entity; or
9 (F) a consortium of 2 or more entities de-
10 scribed in subparagraphs (A) through (E).

11 (2) UNFAIR COMPETITION PROTECTION.—Be-
12 fore awarding a grant, contract, or other financial
13 assistance under this section, a Federal agency shall
14 issue regulations establishing procedures to ensure
15 that no class of applicants has an unfair advantage
16 in competition for the award.

17 (3) ADMINISTRATION. —After consultation with
18 the Board, the points of contact shall—

19 (A) publish annually a joint request for
20 proposals for grants, contracts, and other finan-
21 cial assistance under this section;

22 (B) provide a preference in grants, con-
23 tracts, and other financial assistance under this
24 section to consortia involving experts from mul-
25 tiple institutions and multiple academic dis-

1 disciplines working on cross-cutting or integrative
2 research, development, and demonstration chal-
3 lenges; and

4 (C) require that grants, contracts, and
5 other financial assistance under this section be
6 awarded competitively after the establishment
7 of procedures that provide for scientific peer re-
8 view by an independent panel of scientific and
9 technical peers.

10 (d) USES OF GRANTS, CONTRACTS, AND ASSIST-
11 ANCE.—A grant, contract, or other financial assistance
12 under this section shall be used to conduct—

13 (1) basic and applied research and development
14 in technologies or processes determined by the Advi-
15 sory Committee to be consistent with the purposes
16 described in subsection (b);

17 (2) research into the long-term environmental
18 impacts and economic viability of the technologies or
19 processes; or

20 (3) pilot projects of processes and technologies
21 that lead to a better understanding of the energy or
22 environmental impacts or performance characteris-
23 ties of a biobased industrial product.

24 Grants, contracts, and other financial assistance shall not
25 be provided under this section for a demonstration project

1 unless at least an equal amount of funding is obtained
2 for such project from non-Federal sources.

3 (e) AUTHORIZATION OF APPROPRIATIONS.—There
4 are authorized to be appropriated to carry out this Act
5 \$49,000,000 for each of the fiscal years 2000 through
6 2005.

7 **SEC. 8. ADMINISTRATIVE SUPPORT AND FUNDS.**

8 (a) IN GENERAL.—To the extent administrative sup-
9 port and funds are not provided by other agencies under
10 subsection (b), the Secretary of Energy shall provide such
11 administrative support and funds of the Department of
12 Energy to the Board and the Advisory Committee as are
13 necessary to enable the Board and the Advisory Commit-
14 tee to carry out this Act.

15 (b) OTHER AGENCIES.—The Secretary of Agriculture
16 and the heads of the agencies referred to in section 5(b)(3)
17 may, and are encouraged to, provide administrative sup-
18 port and funds of their respective agencies to the Board
19 and the Advisory Committee.

20 **SEC. 9. REPORTS.**

21 (a) INITIAL REPORT.—Not later than 6 months after
22 the date of enactment of this Act, the Secretary of Energy
23 and the Secretary of Agriculture shall jointly transmit a
24 report to Congress that—

1 (1) identifies the points of contact, the members
2 of the Board, and the members of the Advisory
3 Committee;

4 (2) describes the status of current biobased in-
5 dustrial product research, development, and dem-
6 onstration efforts in both the Federal Government
7 and the private sector;

8 (3) includes a section prepared by the Board
9 that establishes a metric to assess the potential of
10 biobased industrial products, which shall include for
11 both biomass production and transformation into
12 biobased industrial products an energy accounting,
13 an environmental impact assessment, and an eco-
14 nomic assessment; and

15 (1) describes the research and development
16 goals of the Initiative, including how funds will be
17 allocated in order to accomplish those goals.

18 (b) ANNUAL REPORTS.—For each fiscal year that
19 funds are made available to carry out this Act, the Sec-
20 retary of Energy and the Secretary of Agriculture shall
21 jointly transmit to Congress a detailed report on—

22 (1) the status and progress of the Initiative, in-
23 cluding a report from the Advisory Committee on
24 whether funds appropriated for the Initiative have
25 been distributed and used in a manner that—

1 (A) is consistent with the purposes de-
2 scribed in section 7(b);

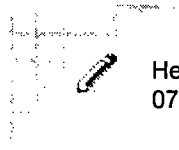
3 (B) uses the metric established under sub-
4 section (a)(3) of this section; and

5 (C) takes into account any recommenda-
6 tions that have been made by the Advisory
7 Committee;

8 (2) the general status of cooperation and re-
9 search, development, and demonstration efforts car-
10 ried out at each agency with respect to biobased in-
11 dustrial products, including a report from the Advi-
12 sory Committee on whether the points of contact are
13 funding proposals that are selected as required by
14 section 7(c)(2)(C); and

15 (3) the plans of the Secretary of Energy and
16 the Secretary of Agriculture for addressing concerns
17 raised in the report, including concerns raised by the
18 Advisory Committee.

July 13, 1999



Henry C. Kelly
07/30/99 10:26:42 AM

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NEWS RELEASE

Senator Dick Lugar

U.S. Senator for Indiana

Contact: Andy Fisher 202-224-2079 or Tiffany Steele
202-224-7435 Date: 7-29-99

MTBE phase-out gives impetus to Lugar's biofuels
initiative

Agriculture Committee approves research bill

An Environmental Protection Agency panel's decision this week that will likely lead to phasing out the use of MTBE (methyl tertiary butyl ether) as a fuel additive, has given new impetus to ethanol and a new biofuels proposal by Sen. Dick Lugar.

Today the Senate Agriculture, Nutrition and Forestry Committee approved Lugar's bill, the National Fuels and Chemicals Act (S. 935), that creates a research initiative focused on producing fuels and chemicals from a wide variety of plants, trees, grasses and agricultural residues.

The EPA Blue Ribbon Panel on Oxygenates in Gasoline report will lead to substantially greater demand for ethanol. This research initiative holds the promise of meeting clean fuel demands by bringing to the market a competitively priced alternative fuel by 2005, Lugar said.

Aggressive development of new biological engineering techniques for producing fuels, chemicals and materials from biomass will help strengthen rural economies, improve America's strategic security and dramatically reduce greenhouse gas emissions that threaten climate stability, Lugar said.

The research into so called biomass technology would develop efficient fuels, notably ethanol, and other

chemicals from virtually any plant or plant product. Although ethanol is more environmentally sound and efficient than gasoline, until now it has only been practical to produce ethanol from a small portion of plant life, such as corn.

Lugar's bill would authorize a \$49 million a year for six years. Given the potential benefits in improved national security, rural development and greenhouse gas reductions, this expenditure represents a wise investment in our future, Lugar said.

The Lugar biofuels initiative has received support from 13 other Senators, the Clinton Administration, the American Farm Bureau, The American Soybean Association, the National Corn Growers Association, the Biotechnology Industry Association, environmental groups, and leading technical experts in biomass.

###

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Deliverables

1. Executive Order and Executive Memorandum

The executive order creates a Cabinet level Council designed to focus the resources of the Departments of Energy, Agriculture, the National Science Foundation and other agencies on the goal of developing economic, environmentally attractive ways to use farm and forestry products as a substitute for fossil fuels. The order calls for a focused research plan and an immediate review of tax and regulatory programs that can be used to encourage expanded use of biological substitutes for the oil, gas, and other fuels now used to produce commodity chemicals, gasoline, electricity, and many other products.

2. Set national Goal of 10% of energy from biomass

Today, biomass used to produce electricity, substitutes for gasoline, and other chemicals and energy products is the equivalent of 3.2 percent of all US energy use. The enterprise we are announcing today makes it possible to set a goal of using renewable biomass products to produce the equivalent of at least 10 percent of US energy use in ten years. Our partners in the private sector will, reacting to the market, will determine whether this material will be used to produce chemicals, fuels, electricity, or other products.

Technology goals:?

Option: Within ten years develop a system which would result in increased income per acre for farmers AND a cost effective substitute for petroleum and other fossil fuels used as feedstock for manufacturing fuels, and other commodity chemicals.

Option: Within five years, make glucose (a critical biochemical feedstock) from wood and other cellulose cheaper than glucose from other sources.

3. List of Bioproducts for Federal use

An executive order {issued in 1998} required the federal government to use recycled products and bioproducts whenever feasible. The Department of Agriculture was charged with developing a detailed list of qualifying bioproducts and that list is being published for public review today.

4. NRC Report]?]

5. Challenge to the Congress on Renewable/Climate Change Budget

The President's budget includes a 33% increase in funding for biomass and other research and incentives programs designed to find economically efficient ways to address the challenge of climate change while creating new business opportunities. The Congress has not only refused to grant these much needed increases but in many

cases cut programs below current funding levels. The President requested an increase of \$87 million for biomass and other renewable energy sources while the House of Representatives cut spending in this area by \$33million below current spending levels. We challenge the Congress to support the President and provide the funding needed to support much needed research.

	1998 Actual	1999 Enacted	2000 Admin. Budget	2000 Latest House Action	2000 Latest Senate Action
DoE					
Biomass and other Renewables ¹	272	350	437	317	339
Energy Efficiency ²	457	552	687	570	557
EPA	90	109	216	105/115?	?
USDA			10	0	0
Tax incentives			(383)		
Total	819	1021	1368		

6. Economic Analysis of Biomass

Ethanol production, wood used to generate electricity in lumber mills, and other applications are already playing a significant role in rural economies supplying over 3% of US energy and producing products valued at over \$3 billion annually. Meeting the goal of using biomass for the equivalent of 10% of all US energy by 2010 would result in \$20-30 billion of new income for farmers and rural communities. New sources of income would also be created be generated for chemical manufacturers able to use new understanding of biological processes to use renewable feedstocks to produce chemicals, glues, paints, and many other materials more efficiently and with vastly reduced pollution.

7. State-by-state income effects

For example, meeting the 2010 Goal would mean that in Iowa:

- Value of products made from Iowa Biomass: \$4.72 billion
- New income in rural Iowa communities \$2.35 billion
- New Iowa Farm Income: \$0.78 billion

8. Agency Program Announcements

¹ Energy and Water Appropriation

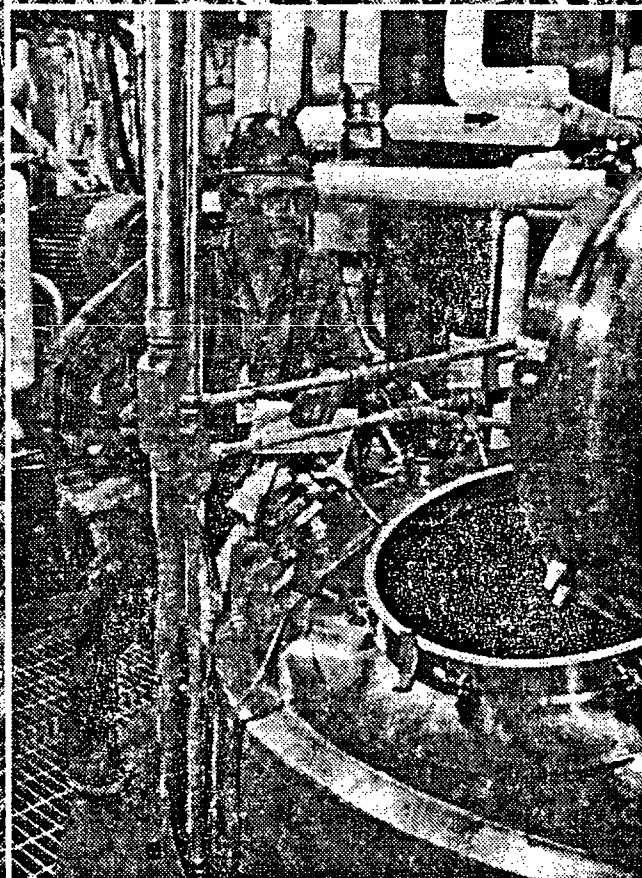
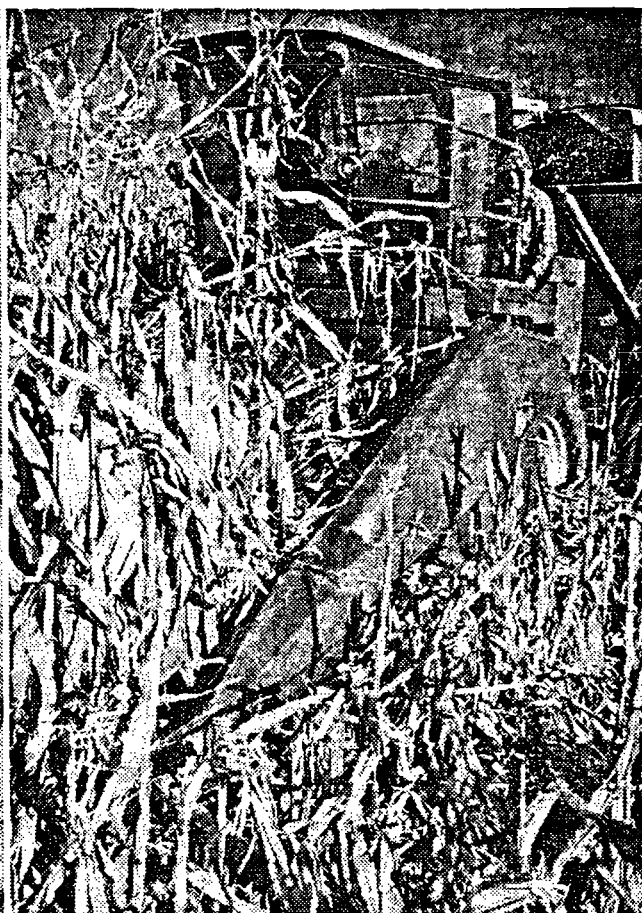
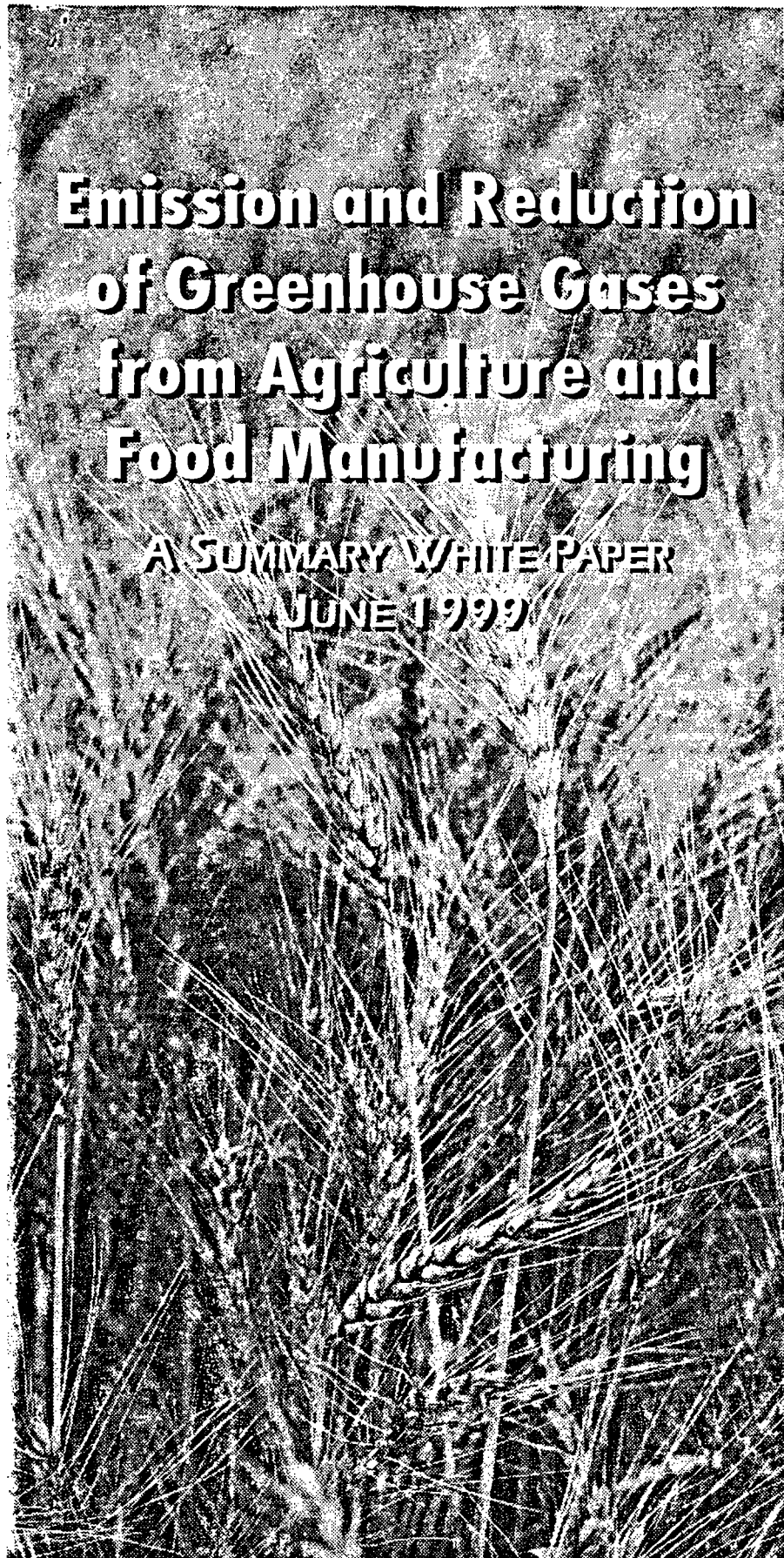
² Interior and Related Agencies Appropriation

HCK 07/30/99

- CCC???? (USDA)
- ***Plant/Crop Based Renewable Resources 2020 Awards:*** Six awards totaling \$4.8 M over 3 years will be announced (DoE)
- ***Black Liquor Gasification Awards*** \$1.75M each to Champion International and Georgia Pacific Corporation to use waste products from papermaking to produce electricity and valuable chemicals.(DoE)

Emission and Reduction of Greenhouse Gases from Agriculture and Food Manufacturing

A SUMMARY WHITE PAPER
JUNE 1999



U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Office of Industrial Technologies





Department of Energy

Washington, DC 20585

LETTER TO THE READER

One of the least understood links affecting global climate change is the one between the broad agricultural and energy sectors. America's farmers use many different forms and amounts of energy to grow our food and fibers. Those bountiful harvests can also be used in bioenergy applications: transportation fuels, electricity, and industrial chemicals and materials, and all of these processes have some kind of impact on the production of greenhouse gases.

This white paper—Emission and Reduction of Greenhouse Gases from Agriculture and Food Manufacturing—summarizes the current scientific and technological knowledge about greenhouse gas emissions from various agricultural practices and the manufacturing of food. In addition, the study, which was commissioned from SC Johnston Associates, Inc., also provides estimates that compare agriculture-related alternatives for reducing greenhouse gas emissions.

Although the paper is only a first step in understanding the complex issues regarding greenhouse gases and agriculture, a few conclusions emerged that may have significant implications for future public policy. First, while agriculture, broadly defined for all energy inputs, contributes 9% of the total U.S. greenhouse gas emissions, technologies and practices exist today that could significantly reduce these emissions both in the United States and worldwide. Second, emerging technologies in this industry hold the promise of even greater emissions reductions nationally and globally. The level of carbon dioxide emissions from the food manufacturing industry, broadly defined for all energy inputs, is similar to agriculture; and this industry too possesses opportunities for technology-driven emissions reductions. Finally, further analyses must be conducted in order to fill in the many gaps in knowledge regarding these issues.

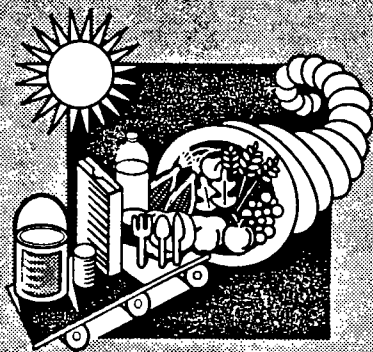
This paper complements another study recently issued by the Pew Center on Global Climate Change. "Agriculture and Global Climate Change" looked primarily at how greenhouse gas buildup in the atmosphere could affect the U.S. agriculture industry. The report noted that a shift to plants as an alternative source of energy could offer new economic opportunities for farmers and also help ameliorate the overall greenhouse gas buildup.

We at the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy are now seeking to contribute to the integration and development of the emerging bioenergy industry. Together with our public and private sector partners we are working to help reduce U.S. greenhouse gas emissions and strengthen the American economy. Through our new Bioenergy initiative, an annual investment of more than \$100 million will be designated for research, development, and deployment in this area. This will be an integrated effort to pursue a more focused national effort to accelerate the development of bio-based technologies.

So, we view this white paper as presenting both an opportunity and a challenge. Tremendous potential exists to reduce our growing reliance on imported oil and thus to transform the economies of the next century. But, we also know that much remains to be done before the country will see the full benefits of this transformation to bio-based industries. We look forward to working with our industry, university, and laboratory partners in order to meet this goal.

Assistant Secretary for Energy Efficiency and Renewable Energy
Dan W. Reicher





AUTHOR'S NOTES

As we developed this paper, we encountered many challenges in gathering data. The paucity of data in some areas and inconsistencies in the way data were collected and reported in other areas led us to make the following considerations in the preparation of this paper.

In some cases, we have extended published data by calculating new quantities from those data to reveal trends of current interest. An example is the estimate of carbon dioxide emission from knowledge of the energy consumed by a particular process or technology, such as food manufacturing. Estimates of potential future emissions reductions were based either on previous studies or on estimates of potential future energy reductions that were converted to emissions reduction. Also considered were the effects of fuel shift on carbon emissions for the food manufacturing and agriculture industries. Only human-caused emissions are considered—the impacts on atmospheric greenhouse gas inventories caused by natural processes are excluded.

We did not, however, address scientific, technological, or policy issues of global climate change. These topics have been extensively covered in the literature and are the subject of worldwide debate.

The inconsistency of greenhouse gas emissions data reported in the literature did, however, present some difficulty in the preparation of this white paper. We made no attempt here to resolve those differences—rather, we merely noted them in our data tables. Also, no attempt was made to normalize data to a single year. After comparing data from different years within the past decade we observed that, for the most part, for the purpose of this study, there were no significant differences among data separated by a span of 10 years. This was not the case for nitrous oxide, however; the inclusion of new anthropogenic sources of soil nitrogen, as noted in a recent U.S. Environmental Protection Agency (EPA) study, resulted in a large increase in estimates of nitrous oxide emissions by U.S. agriculture. Further, we used mid-range values of data estimates of past and future greenhouse gas emissions and reductions only up to the year 2010.

We obtained most of our data from the following sources: *Preparing U.S. Agriculture for Global Climate Change*, published in 1992 by the Council for Agricultural Science and Technology (CAST), supported by a grant from the U.S. Department of Agriculture; various publications of the Intergovernmental Panel on Climate Change; *The Potential of U.S. Cropland to Sequester Carbon and Mitigate the Greenhouse Effect*, Lal, et al. 1998; publications of the Energy Information Administration (EIA) of the U.S. Department of Energy (DOE); EPA publications; and, in the private sector, an energy consumption study of the food industry prepared by Energetics, Inc., for DOE. Data formatting followed the CAST report (which was updated using EIA 1997, EPA 1998, and Lal, et al. 1998) because it was the only publication that reported carbon dioxide emissions for the agriculture industry. This database served as the basis for further calculations, from which trends were identified and conclusions drawn.

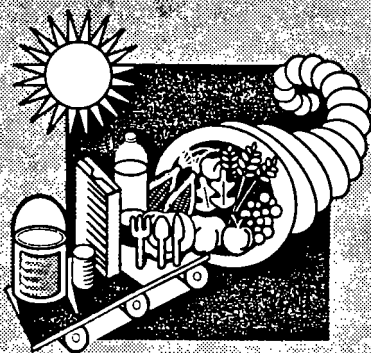
Sheridan Johnston
SC Johnston Associates, Inc., Danville, California

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Cover photo credits: Warren Gretz, NREL.

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EXECUTIVE SUMMARY

Agriculture is unique among the world's industries in that its own carbon dioxide emissions are low, and it has the potential for removing and sequestering large amounts of carbon dioxide from the atmosphere.

On a global scale, all of the world's agriculture accounts for about one-fifth of the annual human-caused increase in greenhouse gas emissions, and most of this is due to methane and nitrous oxide. World agriculture contributes about 4% to global carbon dioxide emissions (See Summary Graphic A). However, agriculture plays an important role as a carbon sink by sequestering large amounts of carbon in vegetation, soil, and long-lived commercial goods produced from plants.

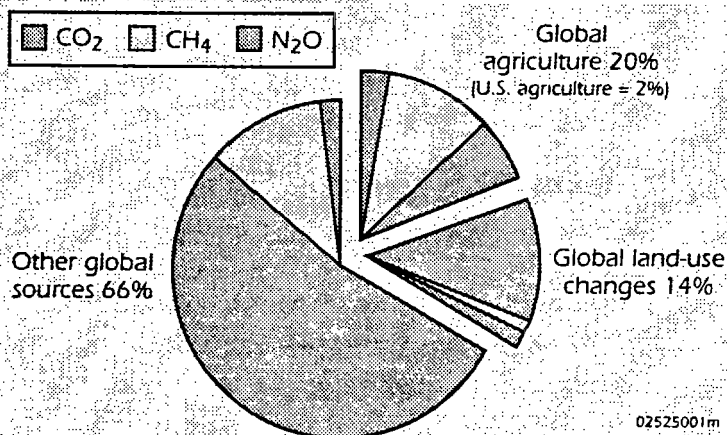
Globally, agriculture in the United States contributes about 2% of the gases that lead to the greenhouse effect (Summary Graphic B). In the United States, agriculture contributes about 9% of the total amount of gases emitted that could lead to greenhouse gas warming

(Summary Table 1). The largest fraction of that 9% is attributable to methane and nitrous oxide emissions rather than carbon dioxide emissions. Moreover, U.S. agriculture has the capacity for making significant reductions in U.S. atmospheric carbon emissions.

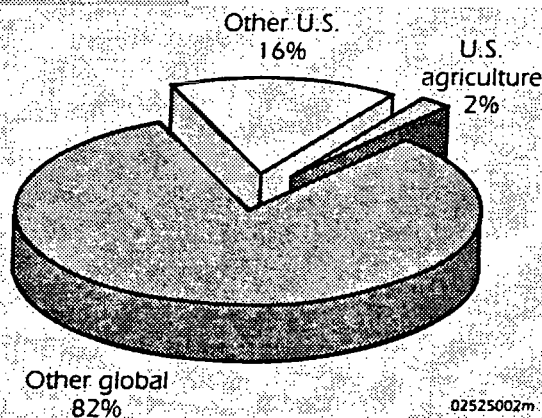
In recent years, domestic manufacturing of food and kindred products generated about two-thirds as much carbon dioxide as all U.S. agricultural sources, and does not generate significant levels of methane or nitrogen oxides.

Summary Graphic C gives estimates of potential reductions in global and U.S. carbon emissions using a variety of mitigation options available to U.S. agriculture. This chart uses essentially all of the information contained in this white paper that relates to reduction, or estimates of reduction, in greenhouse gas emissions. In producing Summary Graphic C, all greenhouse gas emissions were reduced to a common denominator—their carbon equivalent, which is a standardized measure of carbon emission to the atmosphere for all greenhouse gases. The resulting carbon-equivalent reductions are presented in this graph, which shows food manufacturing's and agriculture's options for reducing greenhouse gas emissions. Since the values are not absolute, they can only provide indications as to areas where potential impacts could be made in the near term (i.e., by 2010). An understanding of the real impact, now and in the future, awaits further research and development.

The information displayed in Summary Graphic C highlights two facets of agricultural and food manufacturing technologies. First, there are technologies and practices that are being used to differing degrees today that could quickly impact greenhouse gas emissions—improved cropping systems, improved irrigation and water management, and conservation tillage. There are other technologies and practices—biobased products, biofuels/biopower, and afforestation—that could potentially have a major impact once the needed research and development to implement them has been fully undertaken. Second, there are advanced technologies and



Summary Graphic A: Percent contributions to the annual increase in the greenhouse gases carbon dioxide, methane, and nitrous oxide, based on global warming potential. U.S. agriculture emissions are 2% of the carbon equivalent emissions of the three greenhouse gases shown. Global land-use changes are agriculture related. Source: IPCC 1996.



Summary Graphic B: U.S. contributions to the greenhouse gas emissions of carbon dioxide, methane, and nitrous oxide, based on global warming potential. Source: Table 2.

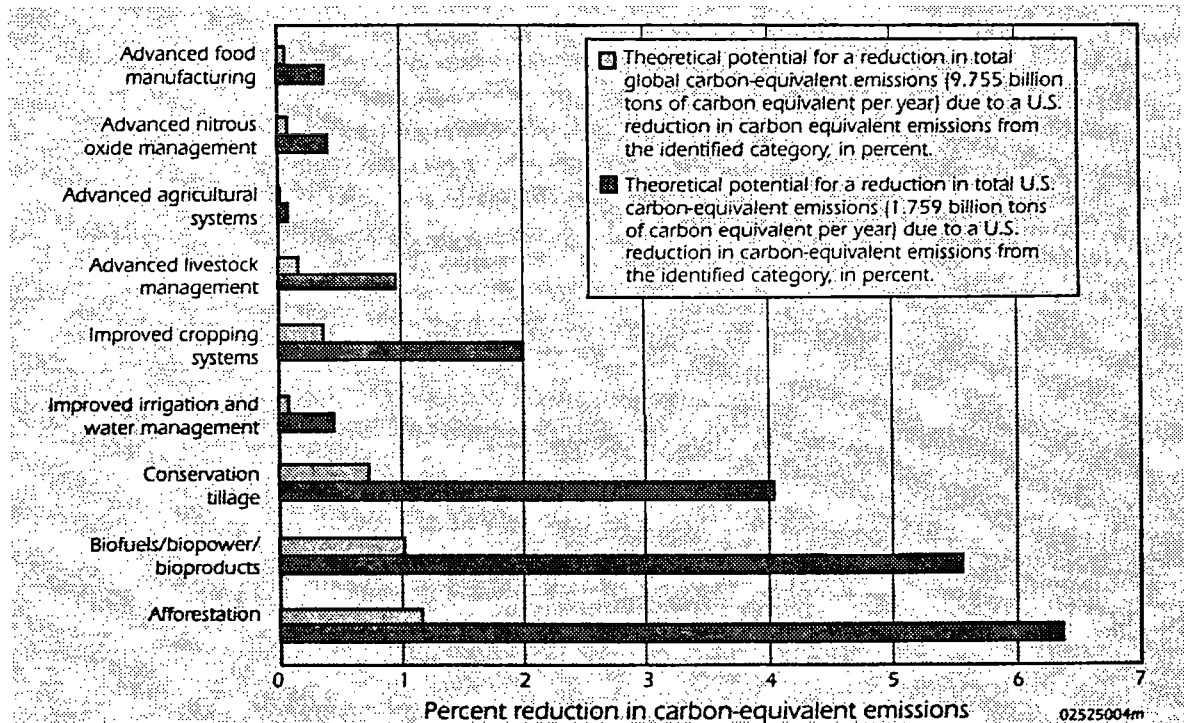
Summary Table 1. Greenhouse gas emissions attributable to U.S. farming, based on global warming potential¹

	Carbon dioxide (%)	Methane (%)	Nitrous oxide (%)	All three gases (%)
As % of Global	1	3	12	2
As % of U.S.	3	30	70	9

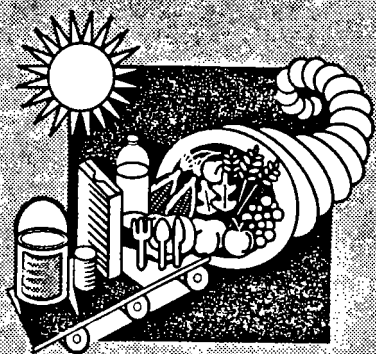
¹ Values were rounded.

Source: This information was obtained from Table 2 by taking vertical ratios.

practices, which in aggregate could provide a 1%-2% reduction in U.S. carbon-equivalent emissions. These include emerging and advanced practices in technologies such as food manufacturing, nitrous oxide management, agricultural systems, and livestock management.



Summary Graphic C: Theoretical potential for annual reduction of human-caused greenhouse gas emissions from agriculture and food manufacturing, expressed in percent reduction in total carbon or carbon equivalent emitted to the atmosphere from three greenhouse gases (carbon dioxide, methane, and nitrous oxide). It is not possible to simultaneously achieve both the afforestation and biofuels/biopower/bioproducts reductions because each has been estimated assuming exclusive use of all idle U.S. farmland. The biofuels/biopower/bioproducts and afforestation reductions may be decreased by climatological and ecological factors, as well as by economic efficiencies. In the future, there will be a competition for land for the production of food, feed, fiber, and industrial-agricultural products, as well as for social uses. Source: Appendix C.



1. THE GREENHOUSE EFFECT

GREENHOUSE GASES

The Earth's atmosphere acts much like a greenhouse, where average temperature is a result of incoming and outgoing radiation. Much of the short-wavelength radiation from the sun passes through the atmosphere, strikes the Earth, and warms it. This energy is redistributed by circulation in the atmosphere and oceans and then re-radiated at longer, infrared wavelengths to space by the Earth's surface and clouds. On average, for the Earth as a whole, the incoming solar energy is balanced by outgoing long-wavelength radiation. However, certain gases in the atmosphere called greenhouse gases transmit sunlight but absorb the outgoing, long-wavelength radiation, much like the glass in a greenhouse does. It is this molecular absorption of infrared radiation by greenhouse gases that is directly responsible for the greenhouse effect (IPCC 1990). The effect can vary from one greenhouse gas to another because of differences in their molecular absorption of infrared radiation.

The greenhouse effect has operated in the Earth's atmosphere for billions of years due to naturally occurring greenhouse gases such as water vapor, carbon dioxide (CO₂), ozone (O₃), methane (CH₄), and nitrous oxide (N₂O). However, human activity is changing the atmospheric concentrations and distribution of greenhouse gases and small particulates, called aerosols. These changes reduce the efficiency with which the Earth can cool to space. The net effect is a trapping of part of the absorbed energy and a tendency to warm the lower atmosphere and surface of our planet.

Three greenhouse gases are associated with agriculture: carbon dioxide from the burning of fossil fuels and decaying organic matter; methane from wetlands and ruminant animals; and nitrous oxide from fertilizer. Table 1 summarizes information about these gases.

Table 1. Selected greenhouse gases that have been affected by human activity

	Carbon dioxide	Methane	Nitrous oxide
Preindustrial concentration	278 ppmv	700 ppbv	275 ppbv
Concentration in 1994	358 ppmv	1720 ppbv	312 ppbv
Percent change from Preindustrial times to 1994*	29%	146%	13%
Rate of concentration change**	1.6 ppmv/yr 0.4%/yr	8 ppbv/yr 0.6%/yr	0.8 ppbv/yr 0.25%/yr
Global emissions to the atmosphere by human activity	26,030 MMT	400 MMT	6 MMT

Sources: Intergovernmental Panel on Climate Change (IPCC) 1996a, U.S. Department of Energy/Energy Information Administration (DOE/EIA) 1997, and Lal, et al. 1998.

1 ppmv = 1 part per million by volume of gas

1 ppbv = 1 part per billion by volume of gas

1 MMT = one million metric tons of gas (10¹² grams of gas)

* Prior to 1850

** Averaged over the decade 1984–1994

AEROSOLS

In addition to the gases listed in Table 1, aerosols can alter the radiation received by the sun. Aerosols are a suspension of ultramicroscopic solid or liquid particles in the troposphere that are derived naturally from sources such as the oceans (dimethyl sulfide) or terrestrial vegetation (non-methane hydrocarbons). These particles are then oxidized in the troposphere. Aerosols are derived anthropogenically from the emission of sulfur dioxide from burning fossil fuels or biomass. Aerosols can both absorb and reflect solar radiation, and they can alter cloud properties by increasing cloud droplet concentration in the lower atmosphere; they can also increase ice formation in the upper atmosphere (*Science* May 1997). However, in most cases, aerosols tend to act in an opposite manner than greenhouse gases and cool the atmosphere. They also disappear far faster than greenhouse gases through sedimentation and atmospheric precipitation.

RADIATIVE FORCING AND GLOBAL WARMING POTENTIAL

Anything that alters the radiation received from the sun or lost to space, or which alters the redistribution of energy within the atmosphere—or between the atmosphere, land, and ocean—can affect climate. A change in the energy available to the global Earth/atmosphere system is called radiative forcing. (It is important to consider radiative forcing here in order to compare the relative warming effects of the greenhouse gases.)

One characteristic of greenhouse gases is that an increase in their concentrations in the atmosphere reduces the efficiency with which the Earth cools to space. This results in a positive radiative forcing, which tends to warm the lower atmosphere and surface of the Earth. On a per-unit-mass basis, methane is 58 times as effective in warming the atmosphere as is carbon dioxide, and nitrous oxide is 206 times as effective in warming the atmosphere as is carbon dioxide. In other words, it takes a smaller amount of methane or nitrous oxide to have the same warming effect as carbon dioxide. This is why methane and nitrous oxide are important, even though their absolute emissions to the atmosphere (in tons of gas) are considerably less than those for carbon dioxide.

Another important characteristic of a greenhouse gas is its lifetime in the atmosphere; that is, how long the radiative forcing by the gas will go on. Methane remains in the air for a much shorter time than either carbon dioxide or nitrous oxide, and a unit of methane will cause radiative forcing about one-tenth as long as carbon dioxide.

The characteristics of radiative forcing and lifetime combine into a single index that shows the potential of a unit of each gas for warming the Earth. This global warming potential (GWP) is the cumulative radiative forcing over a specified time horizon resulting from the emission of a unit mass of gas relative to some reference gas (IPCC 1994). Although GWPs are quoted as single values, the typical uncertainty is $\pm 35\%$. (See Appendix D for a more complete discussion of GWP.) The GWPs of the three agricultural greenhouse gases are given in the third line of Table 2. At the current rate of emission of methane and nitrous oxide into the atmosphere, these gases would not be important if it were not for their considerable global warming potentials.

GLOBAL CARBON INVENTORIES AND TRANSPORT

The Earth's atmosphere holds an inventory of about 775 gigatons of carbon (GTC) (Climate Change Technology Strategy [CCTS] 1997), and each year the inventory increases about 3.5 GTC (See Figure 1). Natural processes dominate the carbon dioxide budget, accounting for 97% or more of all sources and sinks. Biota on the Earth holds an inventory of about 610 GTC, and soil and detritus hold about 1580 GTC. Thus, there is more carbon in the atmosphere than there is in the entire world's plant life and 2–3 times as much carbon in the surface soils of the world than in its plants.

Approximately 61.7 GTC pass into plants annually on the land via photosynthesis. Respiration, which occurs in living things and the organisms responsible for plant-matter decay, emits about 60 GTC back to the atmosphere. About 6 GTC are released to the atmosphere from burning fossil fuel, and about 1.4 GTC stream into the atmosphere from changes in land use (primarily deforestation).

About 50% of the initial uptake of carbon through photosynthesis is used by plants for growth and maintenance (gross primary production). The remaining carbon is called net primary production (60 GT/yr). Part of this is shed as litter and enters the soil, where it decomposes, releasing nutrients to the soil and CO_2 to the atmosphere. The carbon remaining (10 GT/yr) after these emissions is net ecosystem production. Much of this is lost by nonrespiratory processes such as fire, insect damage, and harvest. The remaining carbon (1–2 GT/yr) is called net biome production and is a small fraction of the initial uptake of CO_2 from the atmosphere. Net biome production can be positive or negative; at equilibrium it would be zero. Net biome production is the critical factor to consider in long-term terrestrial carbon storage (*Science* May 1998).

Table 2. Human-caused greenhouse gas emissions from global, U.S., and U.S. agricultural sources for three greenhouse gases, 1996

	Carbon dioxide	Methane	Nitrous oxide	All three gases
Radiative forcing, per unit mass relative to CO ₂	1	58	206	
Mean atmospheric lifetime (years)	125	12	120	
GWP ¹ , 100 years relative to CO ₂	1	21	310	
Emissions of gas in gigatons ² (GT)				
All global sources	26.03 ^A	0.375 ^B	0.006 ^C	
All U.S. sources	5.49 ^D	0.0309 ^E	0.00101 ^F	
All U.S. agricultural sources	0.163 ^G	0.0094 ^H	0.000713 ^I	
Emissions of carbon dioxide equivalent ³ , in GTCO ₂ E				
All global sources	26.03	7.88	1.86	35.8
All U.S. sources	5.49	0.649	0.314	6.45
All U.S. agricultural sources	0.163	0.197	0.221	0.581
Emissions of carbon equivalent ³ , in GTCE				
All global sources	7.10	2.15	0.507	9.76
All U.S. sources	1.50	0.177	0.086	1.76
All U.S. agricultural sources	0.044	0.054	0.060	0.158
Emissions, percent of total global carbon equivalent ⁴				
All global sources	72.8	22.0	5.20	100
All U.S. sources	15.3	1.81	0.88	18.0
All U.S. agricultural sources	0.45	0.55	0.62	1.62

Sources: Adapted from DOE/EIA 1997; Lal, et al. 1998; and EPA 1998. Data in Table 2 refer to only three (of several) greenhouse gases emitted from anthropogenic terrestrial sources, and thus do not represent the global carbon cycle, which is shown in simplified form in Figure 1.

¹ Global Warming Potential (GWP) is the radiative forcing of a unit of gas emitted, multiplied by its concentration in the air integrated for 100 years, where radiative forcing is a change in the energy available to the global Earth/atmosphere system. IPCC reported these results to be preliminary because of the uncertainties regarding the lifetime of methane, the single lifetime specified for CO₂ (despite greatly different rates of its transfer amongst different reservoirs), and the assumption that lifetimes of trace gases remain constant during the integration period (CAST 1992).

² 1 gigaton = 10⁹ metric tons = 10¹⁵ grams = 10³ teragrams (Tg)

³ Carbon dioxide equivalent is the concentration of carbon dioxide that would cause the same amount of radiative forcing as a given mixture of carbon dioxide and other greenhouse gases. Carbon dioxide equivalents are computed by multiplying the amount of the gas of interest by its estimated global warming potential. From the carbon dioxide equivalent it is possible to define a "carbon equivalent," which is the carbon dioxide equivalent multiplied by the molecular weight ratio of carbon to carbon dioxide (i.e., 12/44).

⁴ Total global carbon equivalent of all three greenhouse gases (carbon dioxide, methane, and nitrous oxide) is 9.755 GTCE.

^A Total global carbon emissions from carbon dioxide emissions = 26,033 MMTCO₂ x 12/44 = 7100 MMTC, from DOE/EIA 1997, Table 2, p. 4.

^B DOE/EIA 1997, Table 2, p. 4.

^C DOE/EIA 1997, Table 2, p. 4.

^D Total carbon emissions from U.S. carbon dioxide emissions = 5485 MMTCO₂ x 12/44 = 1496 MMTC, from DOE/EIA (1997), Table ES1, p. x. There is a slight discrepancy between the DOE/EIA value of 5485 MMTCO₂ and the EPA value of 5394 MMTCO₂.

^E DOE/EIA 1997, Table ES1, p. x. There is agreement between the DOE/EIA value of 30.9 MMTC₄ and the rounded EPA value of 30.9 MMTC₄.

^F This figure was obtained using the DOE/EIA (1997) value of 0.446 MMTC₄ and adding to that the difference between the EPA 1998 value for agriculture (0.713 MMTC₄, from Table 7, ANNEX N: IPCC Reporting Tables) and the DOE/EIA (1997) value for agriculture (0.1462 MMTC₄, from page 39), which equals 0.5668 MMTC₄, yielding (0.446 + 0.5668) = 1.0128 MMTC₄. This procedure accounts for the effects of the increased agricultural component in the EPA (1998) data for the United States. (See Footnote I below for details.) Assessments of the other components of U.S. N₂O emissions in EPA (1998) are ongoing and therefore were not used here. No adjustments were made to global N₂O estimates because of the uncertainty of enhanced N₂O emissions from countries other than the United States, and because the estimate given in Table 2 (0.006 GTN₂O) is within the range of values given by DOE/EIA (1997), which were obtained from IPCC (1996a).

^G This figure was obtained by taking the Lal, et al. (1998) value, which was based on DOE/EIA (1996) data, and scaling it to DOE/EIA (1997) data = (157 MMTCO₂) x (5485/5297) = 163 MMTCO₂. Lal, et al. (1998) was used because neither DOE/EIA (1997) nor EPA (1998) separately identified carbon dioxide emissions for agriculture.

^H EPA (1998), Table 7, ANNEX N: IPCC Reporting Tables; or it can be closely approximated by taking the Lal, et al. (1998) value, which was based on DOE/EIA (1996) data, and scaling to DOE/EIA (1997) data = (9 MMTC₄) x (30.9/30.93) = 9 MMTC₄.

^I EPA (1998), Table 7, ANNEX N: IPCC Reporting Tables. The EPA 1998 data source was used here rather than the DOE/EIA or Lal, et al. data sources because it alone contains the inclusion of new anthropogenic sources of nitrogen as recommended in the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC/United Nations Environment Programme [UNEP]/Organization for Economic Cooperation and Development [OECD]/IEA/UNEP 1997). Previous estimates of N₂O emissions from agricultural soils included only those that result from the application of synthetic and organic fertilizer nitrogen. The new estimates include livestock waste management and volatilization and subsequent atmospheric deposition of ammonia (NH₃) and oxides of nitrogen (NO_x) that originate from the application of fertilizers and the production of livestock wastes, both of which result in further additions through surface runoff and leaching of nitrogen. Inclusion of these new sources results in N₂O soil emission estimates that are about 225% higher than previous soil emission estimates, according to EPA (1998).

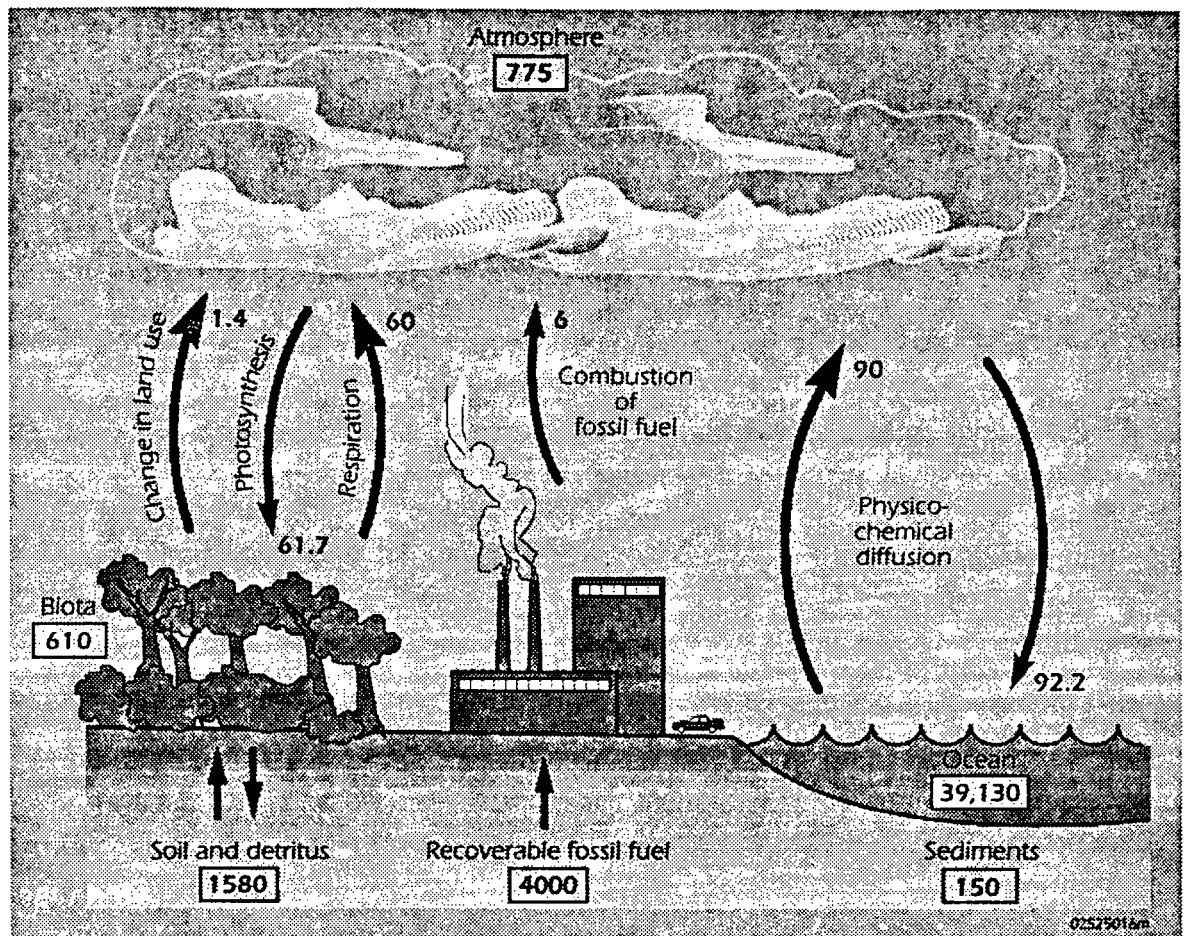


Figure 1. Simplified Global Carbon Cycle with major reservoirs in gigatons of carbon (GTC) and fluxes in GTC/year.

The net annual increase in atmospheric carbon is about 3.5 GTC.

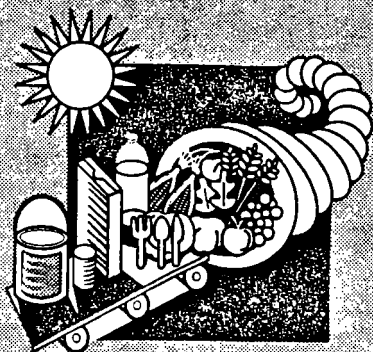
Biota is the total flora and fauna; detritus are small pieces of dead and decomposing plants and animals.

Source: Adapted from IPCC 1996a, CCTS 1997, and Moore and Bolin 1986

Because the inventory of carbon in living and dead things on the land plus the soil is about 2190 GTC, this inventory would only have to be increased by 0.16% ($3.5/2190$) per year to arrest the annual 3.5 GTC rise in the atmospheric inventory. Or, the net flux of carbon from the atmosphere to living things would only have to be increased 6% ($3.5/61.7$) to arrest the annual rise in atmospheric carbon.

Although there is a high degree of uncertainty in estimates concerning both flux rates and carbon storage capacity, these simple reckonings show that moderate changes in total photosynthesis, less respiration and decay on land, could dramatically slow, or accelerate, CO₂ enrichment of the atmosphere (Follett 1993).

However, for the United States, where deforestation is not a critical issue, two significant agriculture-related actions that could reduce atmospheric greenhouse gas inventories are possible. One involves sequestering carbon in soils and trees or in highly durable products made from trees. The second involves displacing fossil fuel utilization with biomass that can be used for energy supply and industrial products.



2. AGRICULTURAL EMISSIONS

GREENHOUSE GAS EMISSIONS: INTRODUCTION

Based on the combined carbon equivalent of carbon dioxide, methane, and nitrous oxide, the United States emits about 18% of the global emissions of these three gases (See Figure 2), whereas U.S. agriculture emits about 2% of these greenhouse gases. Thus, although it is important for U.S. agriculture to reduce greenhouse gas emissions, the impact of doing so on the atmospheric inventory will be small.

On a global scale, agriculture accounts for one-fifth of the annual increase in the radiative forcing due to greenhouse gas emissions (See Figure 3). Most of this is due to CH₄ and N₂O; agriculture produces about 50% and 70%, respectively, of their human-activity-related emissions. World agriculture contributes about 4% to global emission of carbon

dioxide (See Figure 3). All of the activity in the United States taken together emits 21% of the global CO₂, but smaller percentages of methane (8.2%) and nitrous oxide (16.9%). Greenhouse gas emissions from U.S. farming, based on global warming potential, are given in Table 3. The last column of Table 3 reveals that when the three greenhouse gases are taken together, U.S. farming emits about 2% of the global and about 9% of the U.S. emissions of the three gases combined.

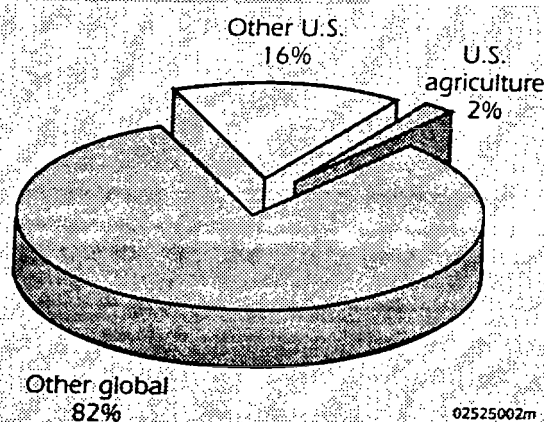


Figure 2. Percent contribution of U.S. agriculture to global greenhouse gas emissions of carbon dioxide, methane, and nitrous oxide, based on global warming potential. Source: Table 2.

POTENTIAL FOR REDUCTION

Carbon Dioxide

Carbon dioxide mitigation options in agriculture include reducing agricultural emissions, sequestering carbon in soils and trees, and utilizing biomass for the production of fuels and products.

Since the 1970s production agriculture in the United States has undergone a significant decline in emission of carbon dioxide from fossil fuels. This is the result of dramatic decreases in both gasoline and diesel fuel use, shifts from gasoline-powered engines to more fuel-efficient diesel-powered engines, and technology (See Figure 4). Examples where fossil fuel use

by agriculture can be further reduced are conservation tillage, irrigation scheduling, solar drying of crops, and improved fertilizer management.

Carbon dioxide emissions associated with soil erosion, the manufacture of agricultural equipment and agrochemicals, and with fuel use on farms is about 3% of all other U.S. emissions of carbon dioxide (See Table 2; Duxbury and Mosier 1993; Stiles 1998).

Finally, it should be noted that there is a high degree of uncertainty in estimates concerning both flux rates and carbon storage capacity, as well as in the level at which various mitigation options could be implemented.

Forestation

Forests are comprised of four interrelated carbon storage pools that include trees, understory, the forest floor, and soil, which act together to form a complex ecosystem. Biological processes in forests (e.g., growth and mortality) and anthropogenic activities (e.g., harvesting, thinning, and replanting) cause carbon to be continuously cycled through the forest ecosystem, as well as between the forest ecosystem and the atmosphere.

As trees age, they continue to accumulate carbon until they reach maturity, at which point they are relatively

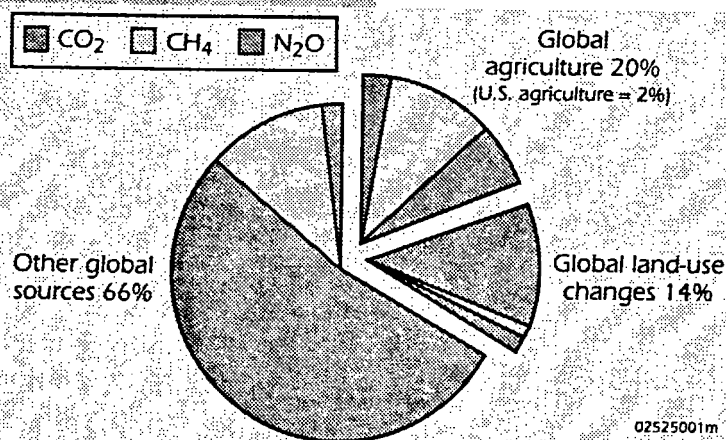


Figure 3. Percent contributions to the annual increase in the greenhouse gases carbon dioxide, methane, and nitrous oxide, based on global warming potential. U.S. agriculture emissions are 2% of the carbon equivalent emissions of the three greenhouse gases shown (see Table 3). Global land-use changes are agriculture related. Source: IPCC 1996.

Table 3. Greenhouse gas emissions attributable to U.S. farming, based on global warming potential¹

	Carbon dioxide (%)	Methane (%)	Nitrous oxide (%)	All three gases (%)
As % of Global	1	3	12	2
As % of U.S.	3	30	70	9

¹ Values were rounded.

Source: This information was obtained from Table 2 by taking vertical ratios.

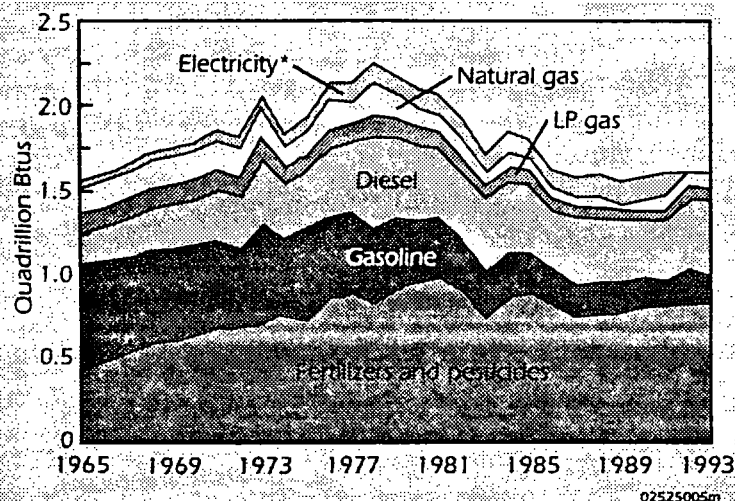


Figure 4. Energy use in production agriculture, 1965-93. *No data on electricity use since 1991. Source: Shapouri 1998 (Redrawn with permission of the USDA).

constant carbon stores. As trees die and deposit litter and debris on the forest floor, decay processes release carbon to the atmosphere and increase soil organic carbon. The net change in forest carbon is the sum of the net changes in the total amount of carbon stored in each of the four carbon pools over time (EPA 1998).

Recent evidence suggests that forests store much more carbon than had been previously thought. Previous estimates indicated that they take up about as much carbon dioxide during photosynthesis as they give off during respiration—resulting in little net carbon flow into or out of forests. But new results, some from reanalyses of old data and others from field studies, indicate that forests, and the carbon they sequester, have been undervalued (*Science* July 1997).

Earlier, widely cited studies focused on old-growth forests, in which carbon flux is typically in equilibrium (Bowyer 1993). Several earlier studies had neglected to include the huge amounts of carbon stored in peat and other organic matter in soils—now estimated to account for about two-thirds of the total carbon sequestered, primarily in high-latitude forests

(*Science* May 1998). In the United States, revised estimates indicate that the net CO₂ uptake from forests was about 171 MMTC for 1996 when all four carbon storage pools identified above are considered (EPA 1998). This is about 11% (171/1496) of the total CO₂ emitted by the United States in 1996.

In addition, it is now recognized that young, relatively fast-growing forests sequester carbon much more rapidly than they release it (Bowyer 1993).

The new picture of forest dynamics may help solve a long-standing enigma: When researchers estimate annual carbon dioxide releases and compare those figures to actual carbon dioxide concentrations in the atmosphere and known sinks, such as the oceans, they typically come up short by about 1 billion to 2 billion metric tons. In other words, roughly 20% of the total CO₂ released each year is apparently missing. But the forest studies suggest where at least part of this carbon dioxide could be going. Terrestrial ecosystems, including forests and their soils and agriculture, can account for some of the missing carbon (*Science* July 1997).

The Intergovernmental Panel on Climate Change suggests that improved use of forests worldwide could store enough carbon in soils, trees, and other vegetation between 1995 and 2050 to offset 12% to 15% of fossil fuel emissions during that period.

In the United States, the amount of forestland (737 million acres) has remained fairly constant over the past several decades, with an annual average fluctuation of about 0.1% per year. Improved forest management practices, reforestation, and timber harvesting and use have resulted in a net annual uptake of carbon (EPA 1998).

Forest harvesting for wood products or energy alters the natural cycle of carbon between forest ecosystems and the atmosphere. Most of the timber that is harvested from U.S. forests is used in wood products that are eventually disposed of by landfilling, rather than by incineration. Thus, significant quantities of harvested carbon are transferred to long-term storage pools (e.g., the timber used to construct a house) rather than immediately being released to the atmosphere (e.g., combustion as a fuel). As global human population has increased, the size of these long-term storage pools has steadily increased as well. Estimates of the net-annual harvested carbon that has been transferred to the long-term storage pools of wood products and landfilled wood are 18 and 20 MMTC, respectively, for 1996, giving a total carbon sequestration of 209 MMTC (765 MMTCO₂), including forest carbon pools (EPA 1998).

A computer-modeling effort at Oak Ridge National Laboratory (*Science* July 1997) suggests that planting and harvesting fast-growing forests can tie up even more carbon than mature, protected forests that are

left alone. Studies in New Zealand involving *Pinus radiata* found that a radiata pine plantation that is replanted each time it is harvested sequesters 112 metric tons of carbon per hectare over the 26 years it takes a tree to mature, or 4.3 TC/ha/yr (1.7 TC/acre/yr) (Marland 1998).

In the United States, carbon emissions to the atmosphere from forest harvest and the use of wood products was about 140 MMTC in 1990, the year of the most recent wood product survey. Regrowth of forests offsets a large proportion of the emissions from harvested wood and thus reduces overall emissions from the forest products sector, making most developed countries a net carbon (C) sink (Winjum, Brown, and Schlamadinger 1998).

Idle cropland in the United States totaled about 56 million acres in 1992. If an area this size were planted in trees (afforestation), and if an average net weight of about 2.0 TC/acre (Follett 1998; Birdsey 1998; Sampson 1998) were stored each year, the total carbon uptake would be about 112 MMTC/yr, or about 8% of total U.S. carbon dioxide emissions in 1992 (Follett 1993). Thus, afforestation in the United States could theoretically increase by about two-thirds (i.e., 112/171) the carbon that is now sequestered in U.S. forests.

It is anticipated that even if all the idle cropland in the United States were available for afforestation, climate and economic, social, and ecological factors would reduce the actual number of hectares that could be converted to forest. For example, many of the idle hectares of U.S. cropland are in regions with insufficient rainfall to grow trees. (Western Kansas is a good example.) However, it might be feasible to grow perennial grasses (e.g., switchgrass) on such semi-arid land, which would enhance carbon sequestration (Kuch 1998).

Some fraction of the 591 million acres of pastureland and rangeland in the United States could be used for afforestation (Kuch 1998). A discussion of the potential for carbon sequestration on revegetated or set-aside land, degraded land, pastureland, and rangeland is given by Bruce, et al. (1998).

In balance, the estimates given in this section are possibly high for this carbon removal and sequestration option.

Biomass-Derived Fuels, Power, and Products

Another way to reduce carbon dioxide emissions is to displace some of the carbon that is now emitted to the atmosphere from the combustion of fossil fuels with carbon derived from renewable resources. Reports indicate that only a very small net atmospheric buildup occurs in biomass combustion (for example, power generation) when the biomass is grown sustainably because released carbon dioxide is largely compensated for by that withdrawn from

the atmosphere during photosynthesis (Mann and Spath 1998; Hart 1997; Shapiro and Magretta 1997). Displacing a unit of energy from gasoline with a unit of energy from ethanol in light-duty vehicles results in a 90% reduction in carbon emissions. Similar reductions can be expected from other biofuels, such as methanol and biodiesel (CCTS 1997).

Plant matter is associated with three basic crops: cellulosic crops (wood, cotton); starch crops (corn); or oil crops (soybeans). Starch has the same chemical formula as cellulose ($C_6H_{10}O_5$), and both are polymers of glucose, a simple sugar (See Appendix A). The difference between starch and cellulose is the way the glucose units are joined; 1,4- α -D-linked in the case of starch and 1,4- β -D-linked in the case of cellulose (Shoemaker 1998). This difference makes cellulose a much more compact structure and much more difficult to break down, compared to starch (Morris and Ahmed 1992). This is also why fuel-grade ethanol produced from cellulosic biomass is not yet commercial, whereas fuel-grade ethanol produced from corn is a 1.5-billion-gal/yr industry. Large-scale displacement of petroleum will rely primarily on low-cost cellulosic feedstocks: starch crops such as corn will play an important transitional role (CCTS 1997). Potential cellulosic biomass sources include municipal solid waste, industrial and agricultural residues, forests, and energy plantations for crops such as switchgrass and hybrid poplar.

Such biomass sources have a distinct potential for renewable energy and bioproduct production even using just a fraction of available land. For example, on a global scale, biofuel production on 10%–15% of the land area currently in agricultural use or in agricultural set-asides could substitute for about 784 MMTC/yr of fossil fuel carbon. Substitution estimates are based on assumptions for energy conversion and degree of substitution (energy substitution factor of 0.7 used) for fossil C (IPCC 1996). This estimate does not include the indirect CO_2 offsets of biofuel production through increasing C storage in standing woody biomass, and possibly by increased soil C sequestration. (See Table 5 for an estimate.) Recovery conversion of crop residues could substitute for an additional 150 MMTC/yr of fossil fuel carbon (IPCC 1996). These mid-range values sum to 934 MMTC/yr of fossil fuel carbon that could be displaced by biofuels for the entire globe. Based on the U.S./global cropland ratio, this roughly translates to 121 MMTC/yr of fossil fuel carbon that could be displaced from U.S. sources.

Another way to determine the dedicated energy crop potential for the United States is as follows: For the United States, dedicated energy crop yields of about 5 TC/ha/yr currently are achievable from good cropland (IPCC 1996), where ha denotes a hectare

and is equal to 2.47 acres. If the approximately 56 million acres (22.6 Mha) of idle cropland in the United States in 1992 (12% of total U.S. cropland) were used to plant energy crops, this would yield 113 MMTC/yr fossil fuel carbon offset. Assuming the same ratio of crop residue availability as for global production, the residue is 21 MMTC/yr, yielding a total of 134 MMTC/yr. Applying an energy substitution factor of 0.7, this is about 94 MMTC/yr, or 94/7100, or about 1.3% of the global carbon-offset potential and 94/1496, or about 6.3% of total 1996 U.S. carbon emissions (from carbon dioxide).

The above estimates are made without specification as to how the energy crops are to be utilized: whether they would be used to generate electricity by substituting biomass for coal in existing power plants; used alone in power plants that displace new fossil fuel-fired plants; used in gasified form to produce power from advanced gas turbines; or used to produce liquid transportation fuels for internal combustion engines. Thus, the estimates for carbon-offset potential given here will be reduced further by thermodynamic constraints and by real-world constraints such as market forces (that are influenced greatly by the prevailing price of a barrel of oil), public policy decisions, and the economics of production, including the cropland quality.

In the appendices of CCTS 1997, carbon reduction estimates were made only on ethanol, using switchgrass as a feedstock at 10% and 95% blends, compared with reformulated gasoline, and with market penetration for these blends of 4 billion gallons in 2010 and other projections for future years. Using these parameters and the low projected price of gasoline, CCTS 1997 concluded that neat ethanol is not cost effective enough to use as a transportation fuel during the next 30-year period. For the year 2010, carbon reductions were estimated at 10 MMTC/yr for ethanol, which included biomass-generated electricity returned to the grid from ethanol plants, and 15 MMTC/yr for biopower applications. The sum of these estimates of carbon offset (25 MMTC/yr) is about one-quarter of the estimate based on technical potential as reported in IPCC 1996 and adapted to the United States in this work (94 MMTC/yr).

Yet another way to reduce atmospheric carbon is to produce materials that are made from biomass, which has the effect of directly displacing fossil fuel-derived products and the carbon release that is associated with their production. An associated benefit is that biomass-derived products (e.g., wood products) can typically be produced using much lower energy inputs than traditional alternatives such as those made from metals, cements, or petrochemicals (Bowyer 1993). A further benefit is that the carbon

is sequestered for long periods of time in the bio-products themselves, before it is released back into the atmosphere through biological decay or other oxidative processes. Substitution of bio-based products for fossil fuel-based products has the potential to reduce greenhouse gas emissions by 3.5 MMTC by 2010 (CCTS 1997), which translates to 0.23% of total carbon emissions by the United States and 0.05% total global carbon emissions, based on 1996 carbon emission data.

Another consideration in the economic use of biomass for fuels, power, and products in the United States is that only a fraction of the idle crop land would be available since such crop land is typically found in small parcels that are physically scattered from one another (Follett 1998).

Conservation Tillage

Losses of soil carbon as a consequence of cultivation are ubiquitous and well documented (IPCC 1996). Historical losses of carbon observed in many soils were due, in part, to low production levels, erosion, inadequate fertilization, removal of crop residues and other biomass, and intensive tillage. In general, high residue production, perennial forage crops, elimination of bare fallow, and reduced tillage will promote sequestration of soil organic carbon.

For the first time, U.S. farmers are planting more acres to crops using conservation tillage methods than traditional methods. No-till, mulch-till, and ridge-till systems, which leave at least 30% residue on the land, now account for more than one-third of all U.S. cropland (*The Kiplinger Agricultural Letter* 1998). Although no-till systems are setting the pace, reduced till is also on the rise. This method leaves 15%–30% residue on the land. Increases in the soil organic carbon pool are nonlinear with time, increasing very slowly for several years and then displaying rapid growth over the next several years, increasing over a period of 25 to 50 years (Lal, et al. 1998).

Assuming a recovery of one-half to two-thirds of historic carbon losses as a reasonable upper limit, the global potential for carbon sequestration in cultivated soils over the next 50 years would be approximately 20 GTC (IPCC 1996). Because U.S. cropland area is 13% of the world value (See Table 4), total carbon sequestration over 50 years in the United States would be 2600 MMTC, or an average annual rate of 52 MMTC/yr. A recent estimate focused on U.S. cropland reports this number to be about 71 MMTC/yr, or about 5% of the total U.S. carbon emission in 1996 (Lal, et al. 1998).

Table 4. World and U.S. land area and cropland area

	Land area (millions of acres)	Cropland (millions of acres)
World	32,213	3560
United States	2264	464
U.S. fraction of world (%)	7	13

Source: United Nations 1994.

Table 5. Enhanced carbon sequestration using improved cropping practices

Practice	MMTC/yr
Fertilizer management	12
Organic manures and by-products	6
Rotation and winter cover crops	10
Summer fallow elimination	2
Management of rice straw	1
Idle land conversion to biofuels; increased soil organic carbon	4
Total	35

Source: Lal, et al. 1998.

Improved Cropping Systems

These systems represent current technologies that can be applied more effectively using existing techniques. Adoption of improved cropping systems has vast potential for increased carbon sequestration in agricultural lands already in use. Estimates of the potential for enhanced carbon sequestration achievable using these techniques are given in Table 5.

Improved Irrigation and Water Management

The basic idea of this approach to enhancing soil organic carbon is to convert less-productive soils to economic cropland using irrigation. This practice can result in large increases in biomass production both above and below ground. A good example of this is the irrigated farming practiced in California, Texas, and other arid and semiarid regions. It is estimated that the total potential of irrigated cropland in carbon sequestration is about 4 MMTC/yr in soil carbon sequestration (Lal, et al. 1998).

Opposite to irrigation is the drainage of seasonally wet agricultural land, which leads to a net loss in soil organic carbon. Drained soil has a lower soil organic content than undrained soil for all tillage methods,

but is best managed with conservation tillage. Lal, et al. (1998) estimated that improved management of drained cropland would lead to about a 4 MMTC/yr increase in soil carbon sequestration.

Advanced Agricultural Systems

Agricultural managers have for decades taken advantage of new technologies, including information technologies, that enabled better management decision making and improved economic efficiency of operations. The extent and rate of change now occurring in the development of information technologies have opened the way for significant change in crop production management and agricultural decision making (National Research Council 1997). These technologies represent advanced, site-specific technologies that could be used to improve cropping and other agricultural systems.

One of today's major goals is to optimize nutrient, water, and pesticide inputs to crops. Some components of advanced agricultural systems such as use of global-positioning systems to map yields are in or close to commercial use, whereas others such as real-time monitoring of water and nutrient status are not. Fertilizer delivery and the fate of applied chemicals have been significantly improved over the last 10 years, but advances in areas such as biologically released fertilizers and control of microbial processes still require significant efforts. Detailed real-time and small-area geographic matching of fertilizers and other agricultural chemicals to plant requirements are in the early stages of development. Technologies involving biocontrol of pests are evolving and some are to the point of commercial development.

Estimates derived in the Climate Change Technology Strategy report to the U.S. Department of Energy (CCTS 1997) indicate that by the year 2010 a reduction of about 1.5 MMTC/yr could be achieved through the use of advanced, site-specific information technologies. This translates into about a 0.1% decrease in total carbon emission for the United States and about a 0.02% decrease in global carbon emissions to the atmosphere.

Because agricultural information is so ubiquitous, it is not possible to state with certainty the impact of new information-based technologies on greenhouse gas emissions. Indeed, enhanced information can be used to manage other production systems, such as livestock and forestry, in addition to crop production. Thus, the overall impact of information technologies could be enhanced by their use beyond crop production.

A summary comparing all of the major carbon dioxide mitigation options for agriculture in the United States is given in Table C1 of Appendix C.

Methane

The current global average atmospheric concentration of methane is 1720 ppbv, more than double its pre-industrial value of 700 ppbv. About 70% of global methane production arises from anthropogenic sources and about 30% from natural sources. Agriculture is considered to be responsible for about two-thirds of the global anthropogenic sources of methane (Duxbury and Mosier 1993). In the United States, agriculture contributes about 30% of anthropogenic methane gas emissions. U.S. anthropogenic sources of methane gas emission are shown in Figure 5. The primary sink for methane is oxidation with hydroxyl radicals (OH) in the troposphere; in addition, soil provides an aerobic sink for about 10%–20% of methane emissions.

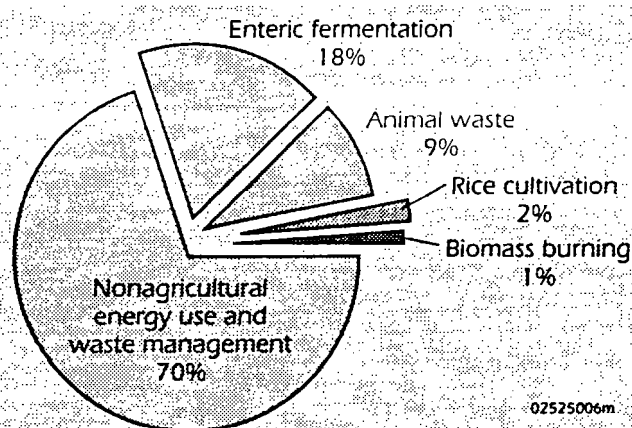


Figure 5. U.S. methane gas emissions from anthropogenic sources. Source: Table 6 [Adapted from DOE/EIA 1997].

Global methane emissions could be reduced by improved nutrition of ruminant animals, which reduces enteric fermentation, and better management of rice-paddy fields. Additional methane decreases are possible by altered treatment and management of animal wastes and by reduction of biomass burning. These combined practices could reduce methane emissions from agriculture by 15%–56% (IPCC 1996). The potential for reducing global methane emission from anthropogenic sources is shown in Figure 6.

Enteric Fermentation

Major sources of U.S. methane emissions are shown in Table 6. The most significant methane reduction opportunities for U.S. agriculture are in emissions from livestock. Technically feasible and cost-effective strategies exist to reduce methane emissions per unit of milk and meat produced in the United States. About one-third of the emissions reduction per unit of product are estimated to be from the dairy industry, whereas two-thirds are from the beef industry (EPA 1993).

Methane is produced when carbohydrates are broken down in the digestive tract of animals. The volume of methane produced from this process, called enteric fermentation, is largest in those animals that possess a rumen, or forestomach, such as cattle, sheep, and goats. The forestomach allows these animals to digest large quantities of cellulose found in plant material. Microorganisms in the rumen, some of which are methanogenic bacteria, accomplish this digestion. These bacteria produce methane while removing hydrogen from the rumen. About 90% of the methane produced by the methanogenic bacteria are released through normal animal respiration and eructation.

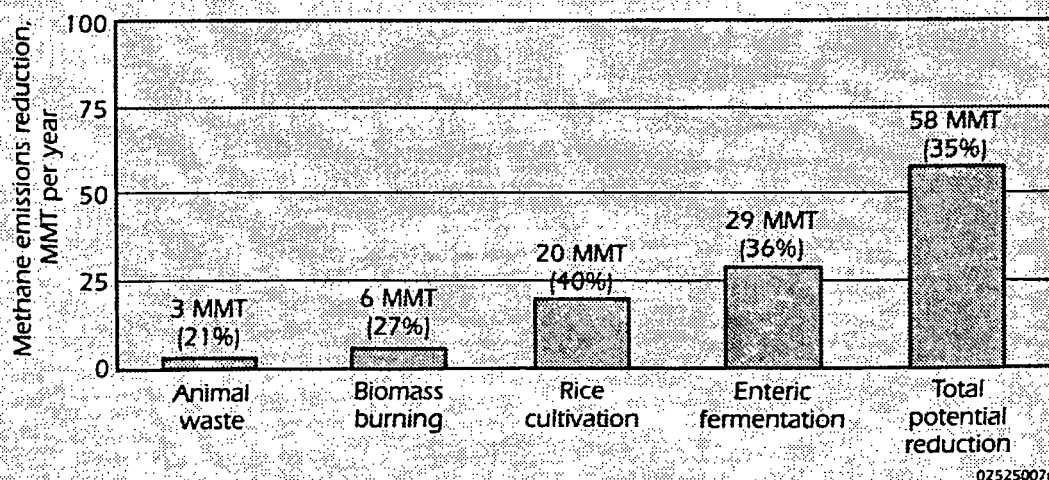


Figure 6. Global comparative estimates of the effect of mitigation options on reducing anthropogenic methane gas emissions (in millions of metric tons of methane gas per year) and their equivalent percentage decrease from current global emission levels for each category. Source: Adapted from IPCC 1996.

Table 6. U.S. methane emission from agricultural sources

Source	Methane emitted (1996)		Carbon dioxide equivalent ¹	Carbon equivalent ²
	Millions of metric tons	% of U.S. total	Millions of metric tons	Millions of metric tons
Enteric fermentation	5.46	18	114.66	31.27 {34.5}
Animal waste	2.76	9	57.96	15.81 {16.6}
Rice cultivation	0.40	2	8.40	2.29 {2.5}
Biomass burning	0.14	1	2.94	0.80 {0.2}
Total agricultural sources	8.76	30	183.96	50.17 {53.7}
Total from all U.S. sources ³	30.90		648.90	176.97 {176.7}

Source: Adapted from DOE/EIA 1997. Numbers in parentheses { } are from EPA 1998.

¹ Carbon dioxide equivalent is calculated by multiplying the source concentration by the global warming potential for 100 years, which, for methane, is 21.

² Carbon equivalent is calculated by multiplying the carbon dioxide equivalent by 12/44.

³ Other U.S. sources of methane emission include energy use and waste management, which contribute approximately equal amounts to the atmospheric methane inventory.

The remainder is released as flatus (DOE/EIA 1996). Biomass burning associated with agriculture also contributes to the global methane budget.

Dairy Industry

Significant improvements in milk production per cow are anticipated in the dairy industry as the result of continued improvements in management and genetics. By increasing milk production per cow, methane emissions per unit of milk produced declines (EPA 1993).

Beef Industry

The main options for reducing methane emissions from the beef industry are the refinements to the marketing system and improved cow-calf sector performance. The refinements to the marketing system are needed to promote efficiency (which will reduce methane emissions by eliminating unnecessary feeding) and shift production toward less methane-emissions-intensive methods. To be successful, the refinements to the marketing system require that the information flow within the beef industry be improved (EPA 1993).

Improvement in the quality of pastureland and grazing lands would yield reductions in methane emission through better digestion, and it would increase the rate of carbon sequestration (Kuch 1998).

Methane emissions from U.S. livestock and profitable emissions reductions are shown in Table 7.

Animal Waste

Methane is produced during the anaerobic decomposition of the organic material in livestock and poultry manure. (Anaerobic decomposition is a

microbiological process that occurs in an oxygen-free environment.) Liquid-based livestock manure systems such as anaerobic lagoons produce about 80% of the total. Methane recovery systems can collect the methane produced by liquid manure management systems so that the methane can be used as a fuel. With methane recovery systems it is technically feasible to reduce total methane emissions from livestock manure by 80% to about 0.6 MMT. Although it is technically feasible for virtually all farms using liquid-based manure management systems, methane recovery systems are only profitable for large farms in warm climates. At these farms, it is profitable to collect the methane and use it to meet a portion of the farm's energy requirements.

Estimates of potential methane emission reduction achievable through application of methane-capture technology are given in Table 8.

Methane emissions reduction from advanced livestock management, which includes methane emissions from livestock and livestock waste, can be calculated in terms of the carbon equivalent of methane. The total methane emission reduction in 2010 is estimated to be 2.9 million metric tons, obtained from the best-case scenarios of Tables 7 and 8. This value was converted to carbon equivalent ($2.9 \times 21 \times 12/44 = 16.6$ MMTCE) and is shown in percentage form in Table C1 of Appendix C.

Nitrous Oxide

Soil Nitrogen

On a global scale, agricultural practices contribute approximately 70% of anthropogenic nitrous oxide emissions (DOE/EIA 1997). These emissions occur

Table 7. Methane emission from U.S. livestock and profitable emissions reduction

Year	Baseline emissions (MMT)		Profitable emissions reduction (MMT) (best case)		Profitable emissions reduction (%) (best case)	
	Low	High	Low	High	Low	High
2000						
Dairy Industry	1.4	2.0	0.3	0.5	21	25
Beef Industry	3.4	5.5	0.8	1.2	24	22
Other	0.2	0.4	0.0	0.0	0	0
Total	5.0	7.9	1.1	1.7	22	22
2010						
Dairy Industry	1.4	2.4	0.4	0.7	30	30
Beef Industry	3.1	5.4	0.7	1.2	23	22
Other	0.2	0.4	0.0	0.0	0	0
Total	4.7	8.2	1.1	1.9	25	23

Source: EPA 1993.

Table 8. Methane emission from U.S. livestock waste and profitable emissions reduction

Year	Emissions without recovery (MMT, best case)			Profitable emissions reductions (MMT, best case)		
	Dairy	Swine	Total	Dairy	Swine	Total
2000	1.7	2.6	5.6	0.4 (24%) ¹	0.4 (15%)	0.8 (14%)
2010	2.0	2.6	6.0	0.5 (25%)	0.5 (19%)	1.0 (17%)

Source: Adapted from EPA 1993.

¹ Numbers in parentheses are the percent reduction based on the corresponding "Emissions Without Recovery" values displayed in the left side of the table.

primarily through decomposing organic matter in soil as it undergoes a series of oxidative and reductive processes, called nitrification and denitrification, respectively (Smith, et al. 1997). However, it is the reductive process, denitrification, that is responsible for the primary loss of gaseous nitrogen (N) compounds to the atmosphere (CAST 1992). In denitrification, nitrate ion (NO₃⁻) is reduced first to nitrite (NO₂⁻), then to nitric oxide (NO), then to nitrous oxide (N₂O), and finally to nitrogen (N₂). In addition to requiring an oxygen-poor environment, denitrification most often also requires effective microbes, reducing agents such as organic carbon, and oxides of nitrogen to proceed (CAST 1992). It is the loss of N as N₂O (and not as N₂) that is of concern, because of the large global warming potential of nitrous oxide. Nitrous oxide is destroyed primarily by photochemical decomposition in the stratosphere (IPCC 1996a).

Anthropogenic activities account for both direct and indirect nitrogen additions to soils. Direct additions occur through cropping practices such as the application of synthetic nitrogen and organic

fertilizers, production of nitrogen-fixing crops, and cultivation of high organic soils, called histols, and through livestock waste management. Previous estimates of N₂O emissions from U.S. soils included only those that result from the application of synthetic and organic nitrogen fertilizer on the soil. More recent estimates (EPA 1998) also include direct soil emissions from animal production (livestock wastes that are spread on cropland and pasture or that are deposited by grazing livestock in pastures and paddocks) and emissions from soils indirectly induced by agricultural activities.

Indirect sources include volatilization and subsequent atmospheric deposition of NH₃ and NO_x that originate from the application of fertilizers and the production of livestock wastes, both of which result in further soil additions through surface runoff and leaching of nitrogen. As a result of these newly considered sources of N, the new estimates of N₂O are significantly higher (by 225%) than previous estimates (EPA 1998).

Estimates of the effects of irrigation, tillage practices, and fallowing of land were not included in EPA 1998 because of the significant uncertainties in N₂O fluxes associated with these practices.

Important variables that control the rates of production of N₂O are soil water content, which regulates oxygen supply; temperature, which controls rates of microbial activity; nitrate or ammonium concentration, which regulate reaction rates; available organic carbon, which is required for microbial activity; and soil pH, which is a controller of both nitrification and denitrification rates and the ratios of N₂O/N₂ (EPA 1998). Because interactions among the physical, chemical, and biological variables are complex, N₂O fluxes from agricultural systems are highly variable in both time and space. Consequently, the prediction of nitrous oxide emissions associated with a unit of N applied to a specific field or fixed by legumes is not yet reliable.

Animal Waste

Another category included in EPA 1998 is N₂O produced as part of the agricultural nitrogen cycle through the denitrification of the organic nitrogen contained in animal manures. This nitrous oxide differs from that discussed in the previous section because it consists of livestock manures that are managed using liquid and slurry systems, as well as manures that are collected and stored, whereas the previous section addressed only unmanaged livestock manures on pastures, ranges, and paddocks.

Biomass Burning

Nitrous oxide is also directly evolved during biomass burning, and is produced in soil after burning. However, in the United States, field burning is not a common method of agricultural residue disposal and N₂O emissions from this source are not significant (<0.1%). (More typically, agricultural residues are plowed back into the field, composted, landfilled,

or collected and used as fuel or as feedstock for the production of chemicals and materials.)

In the United States, most anthropogenic nitrous oxide emissions can be attributed to energy-related and agricultural sources. Agricultural sources account for 70% of the total U.S. emission of nitrous oxide, with energy use and industrial emissions accounting for the remaining 30% (See Figure 7).

Table 9 gives U.S. nitrous oxide emission from agricultural sources and Figure 8 shows the estimated decrease in global N₂O emissions for various mitigation options followed on a worldwide scale.

The underlying concept of limiting N₂O emissions is that if fertilizer N (all N applied to improve crop growth) is utilized better by the crop, the amount of N needed to meet the increasing demand for food will be less. Therefore, less N₂O will be produced and less N will leak from the system (IPCC 1996). Thus, the key to decreasing nitrous oxide emissions is improving the efficiency of utilization of nitrogen fertilizer by plants.

The author did not find estimates of potential reductions in U.S. nitrous oxide emissions while preparing this white paper. However, an estimate of U.S. nitrous oxide reduction potential can be obtained from Table 2 and Figure 8 by taking the ratio of the U.S. agriculture-to-global carbon equivalent emissions shown in Table 2 ($0.06/0.507 = 0.12$), and then multiplying that ratio by the estimated carbon equivalent of total global emission reduction for nitrous oxide ($0.71 \times 310 \times 12/44 = 60.03$ million metric tons) shown in Figure 8. This calculation yields an estimated reduction (admittedly overestimated) of 7.2 million metric tons of carbon equivalent for the United States alone, which is $(7.2)/1759 \times 100 = 0.41\%$ of the total U.S. carbon equivalent emissions for the three greenhouse gases.

In summary, we found that nitrous oxide emissions were the most troublesome ones for which to obtain information. In addition, the information that was obtained is of questionable accuracy. For example, in Appendix C of DOE/EIA (1997), it states that the estimates of nitrous oxide emissions from the application of fertilizer have an uncertainty range of a factor of 10. Similarly, EPA has also estimated an uncertainty range of a factor of 10 for nitrous oxide emissions.

RESEARCH NEEDS

The IPCC (1996) notes that there are deficiencies in our collective scientific understanding of greenhouse gas processes, as well as inadequacies in the information base needed to apply the knowledge that we do have. They conclude that the most pressing problem, however, is not a lack of adequate scientific understanding, but rather a lack of baseline

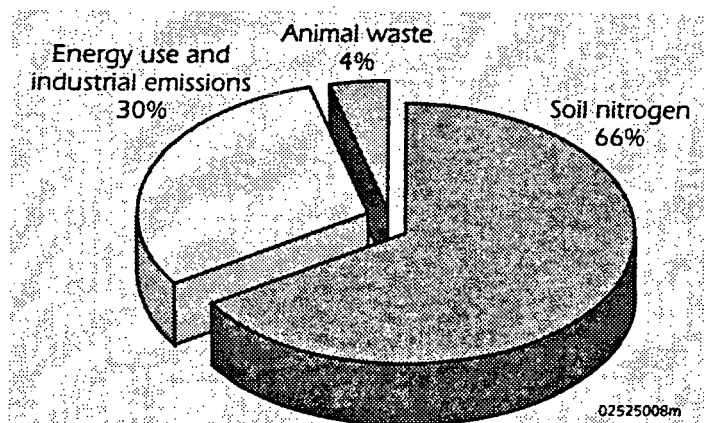


Figure 7. U.S. nitrous oxide emissions from anthropogenic sources, in percent. Source: Table 9.

Table 9. U.S. nitrous oxide emission from agricultural sources in 1996 (MMTCE)

Source	Nitrous oxide emitted (1996)		Carbon dioxide equivalent	
	Thousands of metric tons	Percent of U.S. total	Millions of metric tons	Carbon equivalent Millions of metric tons
Soil nitrogen	668	65.94	207.1	56.5
Animal waste	44	4.34	13.6	3.7
Crop residue burning	1	0.10	0.3	0.1
Total U.S. agricultural sources ¹	713	70.38	221.0	60.3
Total from all U.S. sources ²	1,013		314.0	85.6

Source: Adapted from DOE/EIA 1997 and EPA 1998.

¹ The U.S. agricultural source was obtained from EPA 1998, as described in footnote F of Table 2 of this document.

² Other U.S. sources of nitrous oxide are energy use emissions and industrial emissions. They total 300,000 metric tons of gas based on DOE/EIA 1997. The EPA 1998 value for this sum was still being evaluated at the time this white paper was completed and was not used herein. It may be greater than the DOE/EIA 1997 value by an approximate factor of two.

data in an organized and useable format. With that in mind, they propose the following three major focus areas for compiling and analyzing baseline information.

Bioenergy and Biomaterials Production from Agricultural Land

Research needed to improve assessments of CO₂ mitigation potential through increased use of biomass includes: (1) improved information on the actual carbon feedstock value of forest, agroforestry, and agricultural management systems; (2) better data on energy inputs for the production of plant-derived goods and chemicals; (3) better data on land availability for bioenergy and biomaterials production, including cultural, social, and political factors

that may preclude some lands from use for C offset projects; and (4) better data, including economic analyses, for the use and efficiency of biofuels.

Carbon Sequestration in Agricultural Systems

Elements that are lacking for model-based analysis with global coverage are: (1) spatial databases linking climate, soils, and land use and management, which are needed as model inputs; and (2) reliable experimental data to calibrate and/or verify model predictions.

CH₄ and N₂O Emissions from Agricultural Lands

Improved synthesis and coordination of existing information and additional field measurements are needed.

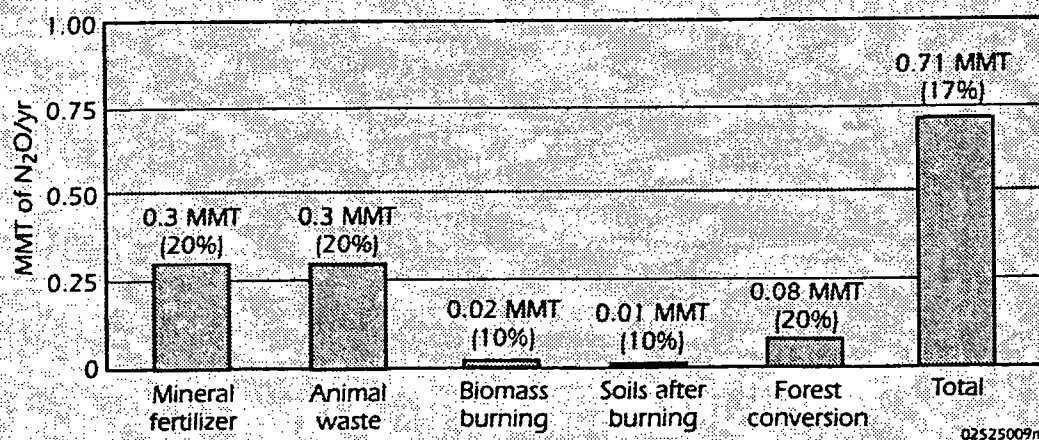
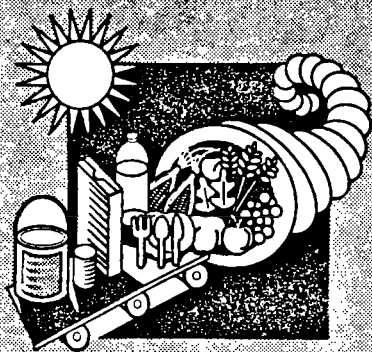


Figure 8. Estimated global mitigation potentials for reducing N₂O emission (in millions of metric tons of N₂O per year) and their equivalent percentage decrease from current global N₂O emission levels in each category. Source: Adapted from IPCC 1996.



3. FOOD-MANUFACTURING EMISSIONS

CARBON DIOXIDE

Over the past few years, food and kindred products generated annually about two-thirds as much carbon dioxide as did all us agricultural sources (Figure 9). In this section, we examine carbon emissions of the food and kindred products sector in more detail.

In our literature search, we did not find specific data on greenhouse gas emissions in the food-manufacturing sector. Extensive data do exist, however, on energy consumed by the food and kindred products sector, through data published by the U.S. Departments of Energy and Commerce. Thus, it was necessary to calculate greenhouse gas emissions from energy consumption data.

Although other greenhouse gases might be emitted to the atmosphere during the manufacturing of food and kindred products, we assumed that the primary greenhouse emission is carbon dioxide. This greenhouse gas is created through the combustion of fossil fuels directly, for example, in pasteurization, heat treatment, evaporation, concentration, or indirectly for the production of electricity used for refrigeration and freezing.

We followed the approach taken by Marland and Pippin (1990), in which the amount of CO₂ emitted to the atmosphere during food manufacturing is estimated by converting fuel consumption data to joules and using "carbon coefficients" in units of kgC/10⁹ joules to estimate carbon dioxide emissions. This requires knowledge of the quantity of fuel burned, the carbon content of that fuel, and the efficiency of combustion. A complete energy balance is required, as is summary data on fuel chemistry, and an estimate of the efficiency of fuel oxidation,

and the fate of unoxidized materials and non-fuel products of fossil fuels. We calculated carbon dioxide emissions for the U.S. manufacturing sector using this procedure. (See Figure 10 for a breakdown of the sources of these emissions.)

Energy sources for the food and kindred products industry include electricity, residual fuel oil, distillate fuel oil, natural gas, liquid petroleum gas (LPG), and coal. We used energy consumption data from the Energetics, Inc., report (1990) for this white paper. Although the historical data contained in that report are now dated, only the projections for the year 2010 were used to estimate carbon emission reduction (Table C1 of Appendix C.)

In Table 10, historical and projected domestic energy consumption data were converted to carbon emissions using the carbon coefficient method outlined above and translated, for our purposes, into MMTC/quad.

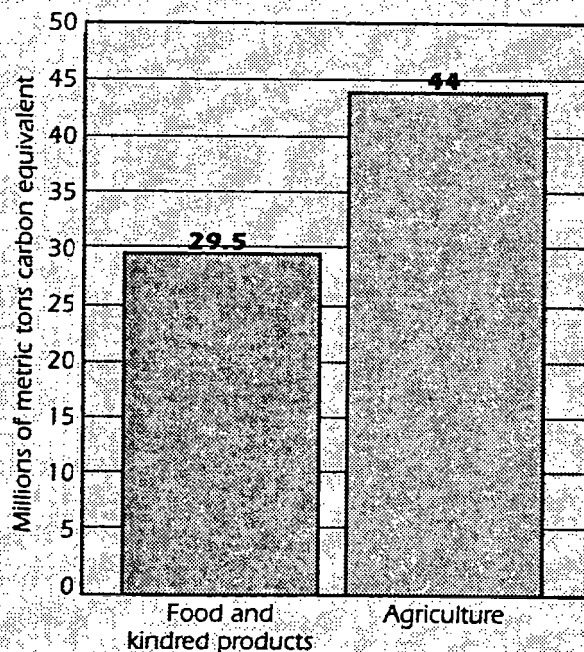


Figure 9. Comparison of carbon dioxide emissions in millions of tons of carbon equivalent emitted into the atmosphere. The food and kindred products data was from Table 10 using the 1994 data. The agriculture data was from Table 2 for all U.S. agricultural sources for 1996.

Because the baseline data for Table 10 were developed in 1990, years shown in parentheses were projections made at that time. Actual 1994 data are shown for comparison purposes.

A graphical representation of the carbon emissions data in Table 10 is presented in Figure 11 for the years 1985 and 2010.

We obtained data on future carbon emission reductions for the 13 main food-processing sub-industries by converting the energy use estimates in Energetics (1990) to carbon emission estimates. Only the technology scenario represented as "100% advanced" was used to estimate carbon emission reductions in the year 2010, because that scenario represents the maximum reduction found possible by Energetics (1990). Table 11 gives the numerical carbon emission reductions, and Figure 12 is a graphical representation of the carbon emission reduction. The total carbon emission reduction (6.688 MMTC) is shown in a percentage representation in Summary Graphic C in the Executive Summary of this white paper.

The three technology scenarios described in Energetics (1990) are:

1. Current practices: Continuation of the technology used today.

2. Business as usual: Uses 30% current technology, 45% state-of-the-art technology, and 25% advanced technology. This is supposedly the "most likely" mix of current, state-of-the-art, and advanced technology and forecasted production level and mix in 2010.

3. Advanced: Use of 100% advanced technologies. These technologies are conceptual or under development and have not yet reached pilot-plant scale, but have potential for industry acceptance.

The projections given for future reduction of carbon emissions in food manufacturing should be viewed as the best that can be done, not necessarily what will be done, because they are based on the use of "100% advanced technology" in the year 2010. In some sectors of food manufacturing (especially canning, freezing, baking, and drying), new technologies tend to be implemented slowly due to capital cost requirements. Even the 30%/45%/25% "Business as Usual" technology mix identified above and quantified in Table 11 may not be accurate for these segments. Adaptation of new technology is especially slow in the seasonal, commodity-based

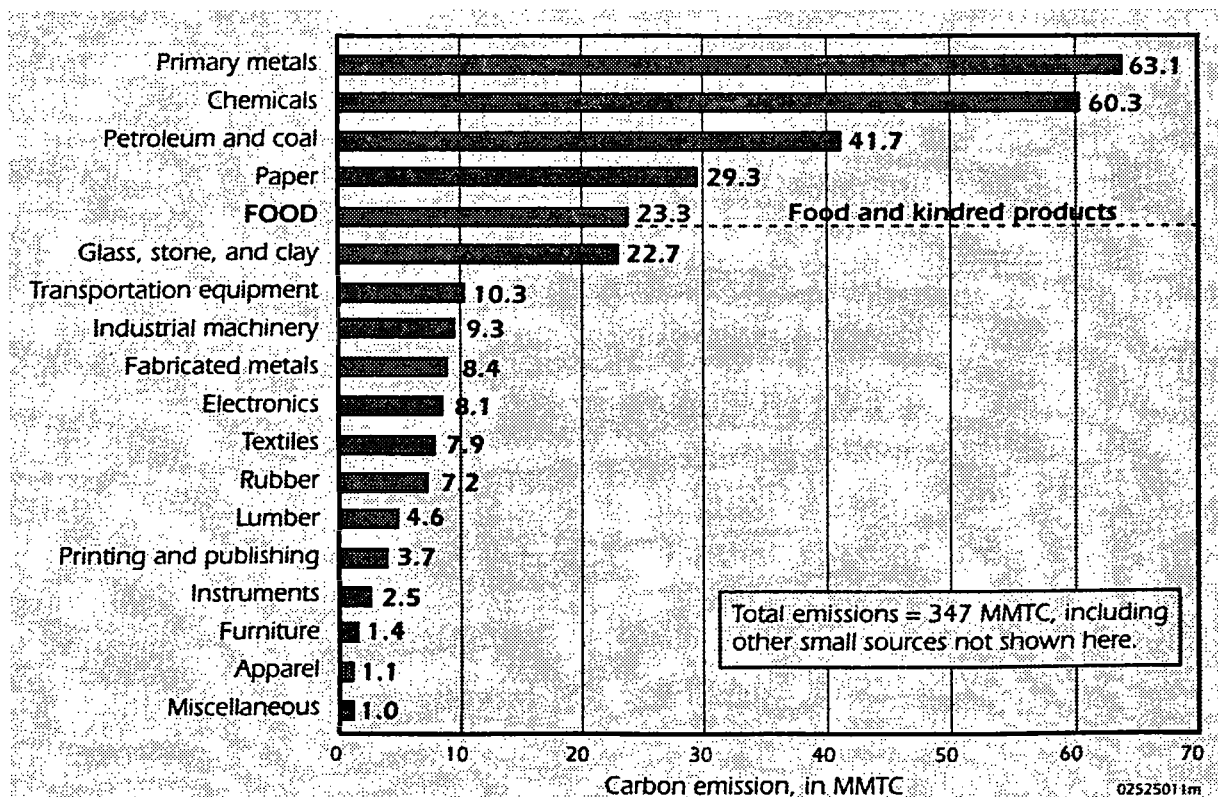


Figure 10. Carbon dioxide emissions from the U.S. manufacturing sector in 1987, given in MMTC
Source: Marland and Pippin 1990.

Table 10. Historical and projected carbon emissions for the U.S. food industry, in MMTC

Year	Electricity ¹	Natural gas	Oil	Coal	LPG	Other	Total
1975	6.4	10.0	3.5	1.9	0.1	0.0	21.9
1980	6.9	10.5	2.4	2.5	0.1	0.7	23.1
1985	7.6	9.6	1.4	2.4	0.2	2.3	23.5
(1990) ²	8.2	9.7	0.3	2.8	0.2	3.3	24.5
1994 Actual ³	9.8 ^A	12.6	1.0 ^B	3.3	N/A	2.8 ^C	29.5
(1995)	8.8	9.5	0.0	3.1	0.2	3.7	25.3
(2000)	9.4	9.2	0.0	3.4	0.2	3.8	26.0
(2005)	10.0	9.0	0.0	3.6	0.3	3.9	26.8
(2010)	10.6	8.8	0.0	3.9	0.3	4.0	27.6

Source: Carbon emissions were calculated using the carbon coefficient method applied to energy use (first use). Energetics (1990) was used for the Historical and Projected Energy Use for the U.S. Food Industry (Table 10 in that reference) and Marland and Pippin (1990) for the derived average carbon coefficient of 20 MMTC/quad at 99% combustion efficiency for hydrocarbon fuels. (This carbon coefficient differs slightly from the value of 21 at full combustion derived from EIA 1996.) A different average carbon coefficient was used for those processes that use predominantly electrical energy: 16 MMTC/quad, derived from Marland and Pippin (1990).

¹ Gross electricity use, which includes all the energy that was used to produce the electricity less transmission losses. Gross electricity is associated with the conversion factor (10,500 Btu/kWh) and net electricity is associated with the conversion factor (3412 Btu/kWh). Net electricity use is obtained by summing purchases, transfers in, and generation from noncombustible renewable resources, minus quantities sold and transferred out. It does not include electricity inputs from outside cogeneration or generation from combustible fuels because that energy has already been included as generating fuel (for example, coal) (Pellegrino 1998).

² Data for years in parentheses are projections from Energetics (1990) report.

1 quad = 1 quadrillion Btus = 10¹⁵ Btus

³ MECS 1994.

^A The MECS 1994 net electricity value was converted to gross electricity by applying the scaling (net electricity) x (10,500/3412) = Gross electricity.

^B "Distillate Fuel Oil" includes Nos. 1, 2, and 4 fuel oils and Nos. 1, 2, and 4 diesel fuels.

^C "Other" includes net steam (the sum of purchases, generation from renewables, and net transfers), and other energy that respondents indicated was used to produce heat and power or as feedstock/raw material inputs.

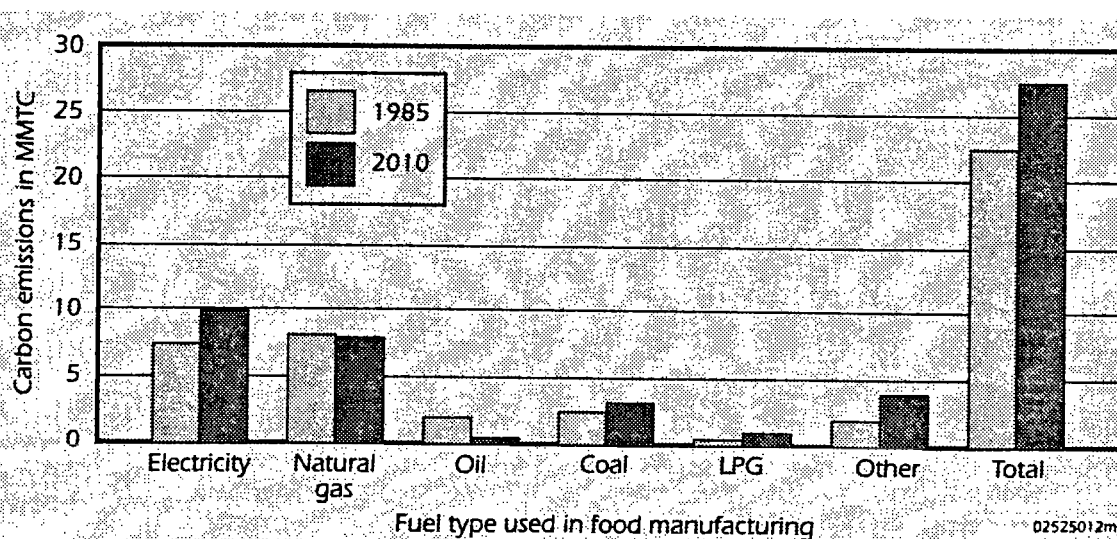


Figure 11 Carbon emissions to the atmosphere by fuel type in the manufacturing of food and kindred products, in millions of metric tons. 2010 estimates are based on a linear regression projection of historical data and a total energy use of 1.5 quads for SIC-20 (Standard Industrial Classification) in that year. Source: Adapted from Energetics 1990 and Table 10.

Table 11. Summary of energy use and potential savings in the year 2010 for three technology-use scenarios; and carbon emission reduction for 100% advanced technology use in the year 2010

Process	Energy use (10^{12} Btu) in 2010					Carbon emissions reduction in 2010	
	Current practices	Business as usual		100% advanced		Carbon coefficient (MMTC/quad)	Carbon emission ₁ reduction (MMTC)
	Use	Use	Savings	Use	Savings		
Evisceration	21.3	13.8	7.5	4.2	17.1	20	0.342
Rendering	17.7	11.3	6.4	1.8	15.9	20	0.318
Cooking	37.4	26.6	10.8	5.0	32.4	20	0.648
Baking	16.7	13.2	3.5	7.1	9.6	20	0.192
Exhausting	6.6	3.6	3.0	0.2	6.4	20	0.128
Heat treatment/ pasteurization	40.7	24.7	16.0	3.7	37.0	20	0.740
Evaporation/ concentration	103.7	73.8	29.9	29.1	74.6	20	1.492
Conditioning	11.7	8.4	3.3	1.0	10.7	20	0.214
Drying	90.5	60.3	30.2	4.7	85.8	20	1.716
Chilling/cooling/ refrigerating	44.6	28.7	15.9	3.0	41.6	16	0.666
Freezing	16.2	10.9	5.3	1.7	14.5	16	0.232
TOTAL	407.1	275.3	131.8	61.5	345.6		6.688

Carbon Emissions Reduction in % of 1996 Total U.S. CO₂ Emissions (1496 MMTC) = 0.45%

Carbon Emissions Reduction in % of 1996 Total Global CO₂ Emissions (7100 MMTC) = 0.09%

Source: Adapted from Energetics (1990) and Marland and Pippin (1990).

1. Uses an average carbon coefficient of 20 MMTC/quad at 99% combustion efficiency for hydrocarbon fuels derived from Marland and Pippin (1990). This carbon coefficient differs slightly from the value of 21 at full combustion derived from EIA 1996. In producing Table 11, a different average carbon coefficient was used for those processes that use predominantly electrical energy. The carbon coefficient used for electrical energy (gross electricity) is 16 MMTC/quad, derived from Marland and Pippin (1990).

1 quad = 1 quadrillion Btus = 10^{15} Btus

portion of the food industry because it is difficult to justify significant expenditures for costly new technology when equipment may be utilized only a few months a year.

The principal factor driving reductions in carbon and other greenhouse gas emissions in the food industry is cost savings through more efficient use of energy, as is probably the case in most other industries. It is also difficult to determine the impact that advances in biotechnology will have on the industry, or on agriculture in general. By 2010, new crops and cropping systems may be available. Also, a greater variety of nontraditional foods (e.g.,

nutraceuticals) may constitute a significant portion of the diet. The impact of these new materials on energy requirements is difficult to predict.

RESEARCH NEEDS

We obtained information in this section from the Food Manufacturing Coalition (FMC), an ongoing, industry-driven technology transfer program sponsored by the EPA and the USDA. It is hosted by the University of Nebraska's Lincoln Food Processing Center (Taylor 1998).

Through extensive surveys and focused prioritization of generic technology needs, industry experts

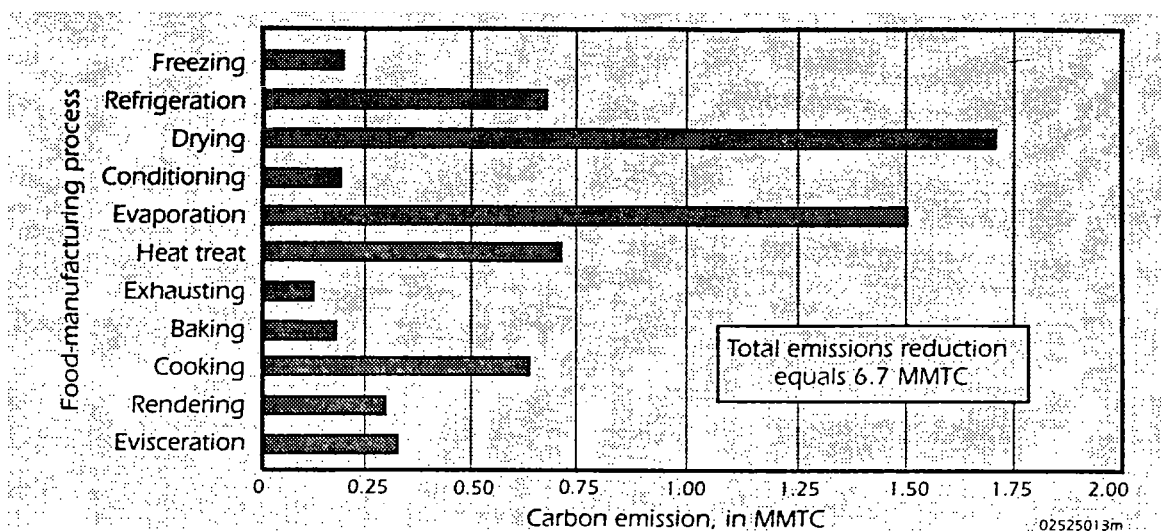
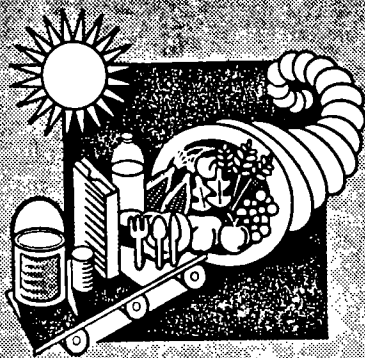


Figure 12. Potential reduction in carbon emissions to the atmosphere by process type used in food manufacturing using 100% advanced technologies in the year 2010. These projected reductions should be viewed as an upper limit that will likely be reduced by economic factors related to decisions necessary for profitable business operation.

Source: Adapted from Energetics (1990) and Marland and Pippin (1990).

developed a number of needs statements. To address these needs, FMC searched for technology from a wide variety of researchers, technology developers, and laboratories, including, for example, aerospace, medical, military, environmental, and process-engineering sources. A total of 20 potential projects directed toward maximizing air and water quality, minimizing solid waste, and increasing control and processing efficiencies were designated for further analysis and effort. These are listed below.

- Recycling processes for plastic food containers
- Detection, monitoring, and management of allergenic foods in manufacturing operations
- Real-time microbiological analysis of foodborne pathogens
- Alternative methods for the use of solvent-based coatings, ink, and glues
- Eggshells (by-products/disposal)
- Reduction of food-processing waste stream volume through membrane filtration
- Biochemical oxygen demand and nutrient removal from food-processing wastewater
- Odor control of food-processing operations by applications of air-cleaning technologies
- Management and removal of fats, oils, and greases
- Volatile organic compound reduction control in the food-processing industry
- Management training for integration of process systems
- Efficient peeling technology
- Efficient use of steam (reduction and alternatives)
- Management of chlorine compounds in production processes
- Blanching and dehydration technology
- Life-cycle cost analysis
- Extraction, separation, and/or reuse of solid wastes from food processing
- Raw material inspections and sorting technologies
- Sensors (humidity, temperature, and critical parameters) for process monitoring
- Thawing (bulk products).



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APPENDIX A: ABBREVIATIONS, ACRONYMS, AND DEFINITIONS

C	Carbon
CAST	Council for Agricultural Science and Technology
CCTS	Climate Change Technology Strategy
CE	Carbon equivalent
CH ₄	Methane
CO ₂	Carbon dioxide
DOE/EIA	U.S. Department of Energy/Energy Information Administration
EPA	U.S. Environmental Protection Agency
Gg	Gigagram, 10 ⁹ grams (one thousand metric tons)
GTC	Gigatons of carbon, 10 ⁹ metric tons (10 ¹⁵ grams)
GTCE	Gigatons of carbon equivalent
GW/P	Global warming potential
ha	Hectare (2.47 acres)
IPCC	Intergovernmental Panel on Climate Change (United Nations Environment Program)
kg	Kilogram, 10 ³ grams
M	Million (metric)
MECS	Manufacturing Energy Consumption Survey
MMTC	Million metric tons of carbon (10 ⁶ metric tons), 10 ¹² grams
MMTCE	Million metric tons of carbon equivalent ("carbon" from gases other than carbon dioxide)
MT	Metric ton, 10 ⁶ grams
MTC	Metric tons of carbon (carbon from carbon dioxide)
N	Nitrogen
N ₂ O	Nitrous oxide
OH	Hydroxyl radical
ppbv	part per billion by volume
ppmv	part per million by volume
SIC	Standard Industrial Classification (Manual)
Tg	Teragram, 10 ¹² grams (one million metric tons)
TMTC	Thousand metric tons of carbon, 10 ⁹ grams
USDA	U.S. Department of Agriculture

Advanced agricultural systems:

Information-based agricultural systems comprised of three components: (1) capture of data at an appropriate scale and frequency; (2) interpretation and analysis of that data; and (3) implementation of an agricultural-management response at an appropriate scale and time.

Aerosols: A suspension of ultramicroscopic solid or liquid particles in the troposphere that are derived naturally from biogenic sources such as the oceans or terrestrial vegetation, followed by oxidation in the troposphere;

distinguished from the propellant used in spray cans.

Afforestation: The process of converting to forest land that has not previously been forested.

Anaerobic: A microbiological process that occurs in an oxygen-free environment.

Anthropogenic: Caused or produced by humans.

Biofuels: Fuels obtained as a product of biomass conversion (e.g., ethanol).

Biogas: A gas composed principally of a mixture of methane and carbon dioxide produced by anaerobic digestion of biomass.

Biomass: The total quantity of living matter in a particular habitat; plant and organic waste materials used as fuel and feedstock in place of fossil fuels.

Bioproducts: As distinguished from biofuels, these are chemicals and products produced from plant/crop-based materials, such as paints, adhesives, lubricants, textile fibers, surfactants, plasticizers, carbon black, detergents, and plastics.

Biota: The total flora and fauna.

British Thermal Unit (Btu): The quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit.

Carbon cycle: All carbon reservoirs and exchanges of carbon from reservoir to reservoir by various chemical, physical, geological, and biological processes. Usually thought of as a series of the four main reservoirs of carbon interconnected by pathways of exchange. The four reservoirs (regions of the Earth) in which carbon behaves in a systematic manner are the (1) atmosphere, (2) terrestrial biosphere (usually includes freshwater systems), (3) oceans, and (4) sediments (includes fossil fuels). Each of these global reservoirs may be subdivided into smaller pools, ranging in size from individual communities or ecosystems to the total of all living organisms (biota).

Carbon dioxide equivalent: The concentration of carbon dioxide that would cause the same amount of radiative forcing as a given mixture of carbon dioxide and other greenhouse gases. Carbon dioxide equivalents are generally computed by multiplying the amount of the gas of interest by its estimated global warming potential. From the carbon dioxide equivalent it is possible to define a carbon equivalent, which is the carbon dioxide equivalent multiplied by the molecular weight ratio of carbon to carbon dioxide (i.e., 12/44).

Carbon sequestration: The biochemical process through which carbon in the atmosphere is absorbed by biomass such as trees, soils, and crops.

Cellulose: A linear polysaccharide made up of glucose residues joined by β , 1, 4 linkages: the most

abundant organic compound in the biosphere, comprising the bulk of plant and algal cell walls, where it occurs as cellulose microfibrils.

Conservation tillage: Any tillage system that reduces loss of soil and water from cropland relative to conventional tillage, such as plow-based methods.

D-linked; L-linked: Prefixes denoting particular molecular configurations, defined according to convention, of certain optically active compounds, especially monosaccharides and amino acids. The L configuration is a mirror image of the D configuration. In living cells such molecules usually occur in one or the other of these configurations, but not in both (e.g., glucose as D-glucose, amino acids always in the L form in proteins).

Enteric fermentation: A digestive process by which carbohydrates are broken down by microorganisms into simple molecules for absorption into the bloodstream of an animal.

Evisceration: The process of removing the entrails of an animal.

Flatus: Gas generated in the intestines or the stomach of an animal.

Global warming potential (GWP): A numerical index created and used to provide a means of estimating the relative radiative effects of the various greenhouse gases. GWP is the time-integrated radiative forcing from the instantaneous release of 1 kg of a trace gas expressed relative to that of 1 kg of a reference gas.

Greenhouse gas: Any gas that absorbs infrared radiation in the atmosphere.

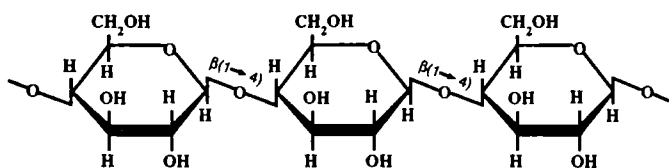
Hydroxyl radical (OH): An important chemical scavenger of greenhouse gases.

Liquefied petroleum gas (LPG): Ethane, ethylene, propane, propylene, normal butane, butylene, and isobutane produced at refineries or natural gas processing plants, including plants that fractionate new natural gas plant liquids.

Nitrification: The oxidation of ammonium to nitrites and the further oxidation to nitrates.

Nutraceutical: Any substance that can be considered to be a food or part of a food, and which provides medical or health benefits, including the prevention and treatment of disease.

Photosynthesis: Light-driven oxidation of water resulting in the production of O_2 . This oxidation is coupled to the reduction of CO_2 or other physiological electron acceptors (e.g., NO_2^- , SO_4^{2-} , and O_2).



Primary energy: The energy that is embodied in resources as they exist in nature (e.g., coal, crude oil, natural gas, uranium, or sunlight).

Quad: One quadrillion British Thermal Units (10^{15} Btus).

Radiative forcing: A simple measure of the importance of a potential climate change mechanism. Radiative forcing is the perturbation to the energy balance of the Earth-atmosphere system (in watts per square meter) following, for example, a change in the concentration of carbon dioxide or a change in the output of the sun; the climate system responds to the radiative forcing so as to reestablish the energy balance. A positive radiative forcing tends to warm the surface and a negative radiative forcing tends to cool the surface. The radiative forcing is normally quoted as a global and annual mean value. (A more precise definition of radiative forcing, as used in Intergovernmental Panel on Climate Change reports, is the perturbation of the energy balance of the surface-troposphere system, after allowing for the stratosphere to readjust to a state of global-mean radiative equilibrium.)

Reforestation: The process of renewing forest cover on land previously forested.

Rendering: The conversion of wastes from meat-packing operations into industrial fats and oils.

Respiration: The metabolic process by which organisms meet their internal energy needs and release CO_2 . In plants it is the oxidation of reduced carbon compounds with the production of CO_2 and the transfer of electrons to O_2 , resulting in its chemical reduction to H_2O .

Rumen: The large first compartment of the stomach of certain animals in which cellulose is broken down by the action of bacteria.

Soil organic carbon pool: The aggregate of carbon present in crop residues, plant roots, and other organic material returned to the soil by various agricultural practices. Organic materials of high importance to enhancing organic soil carbon content and carbon sequestration are the below-ground or root biomass and the total biomass produced by weeds.

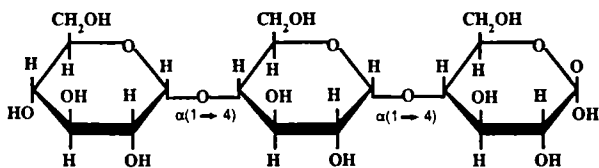
Starch: Polysaccharide made up of a long chain of glucose units joined by $\alpha, 1,4$ linkages, either

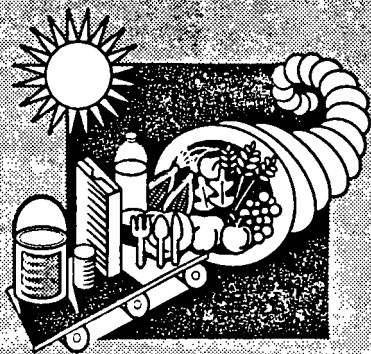
unbranched or branched at an $\alpha, 1,6$ linkage, and which is the storage carbohydrate in plants.

Sustainable: A term used to characterize human action that can be undertaken in such a manner as to not adversely affect environmental conditions (e.g., soil, water quality, or climate) that are necessary to support those same activities in the future.

Troposphere: The inner layer of the atmosphere below about 15 kilometers, within which there is normally a steady decrease of temperature with increasing altitude. Nearly all clouds are formed, and weather conditions manifest themselves, within this region. Its thermal structure is caused primarily by the heating of the Earth's surface by solar radiation, followed by heat transfer through turbulent mixing and convection.

Understory: A foliage layer lying beneath and shaded by the main canopy of a forest. The plants that form the foliage understory of a forest sometimes distinguished from ground cover.





APPENDIX B: ENERGY USE IN FOOD MANUFACTURING

The largest energy consumers in the U.S. manufacturing sector are shown in Figure B1. Energy use by fuel type for the main thermal and chemical processes used to manufacture food is given in Table B1 for 1987 and in Table B2 for estimates in the year 2010.

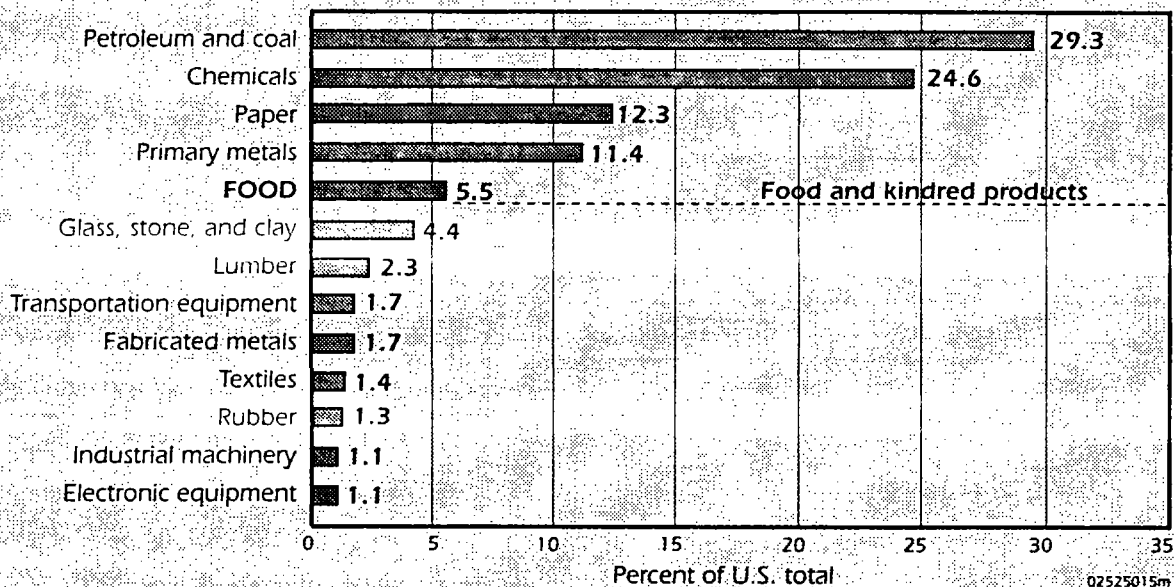


Figure B1. Largest energy consumers in U.S. manufacturing sector, 1994. Source: MECS 1994.

Table B1. Energy use by fuel type for major processes used in food manufacturing, 1987

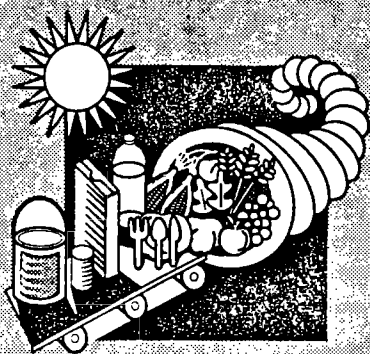
Process	Energy use (10 ¹² Btu) in 1987						Total
	Electricity	Gas	Oil	Coal	Propane	Other	
Evisceration	0.3	8.7	1.2	1.9	0.1	1.3	13.5
Rendering	1.9	5.7	1.0	1.5	0.1	1.0	11.2
Cooking	-	14.6	2.4	3.8	0.3	2.6	23.7
Baking	0.7	7.8	0.5	0.9	0.1	0.6	10.6
Exhausting	-	2.6	0.4	0.7	0.1	0.4	4.2
Heat treatment/ pasteurization	-	15.9	2.6	4.2	0.3	2.8	25.8
Evaporation/ concentration	-	40.6	6.6	10.7	0.8	7.1	65.8
Conditioning	-	4.6	0.7	1.2	0.1	0.8	7.4
Drying	4.0	42.2	2.9	4.7	0.4	3.2	57.4
Chilling/cooling /refrigerating	26.9	1.4	-	-	-	-	28.3
Freezing	10.3	-	-	-	-	-	10.3
TOTAL	44.1	144.1	18.3	29.6	2.3	19.8	258.2

Source: Energetics (1990).

Table B2. Estimated energy use by fuel type for major processes used in food manufacturing, 2010

	Energy use (10 ¹² Btu) Business-As-Usual case, 2010					
Process	Electricity	Gas	Oil	Coal	Other	Total
Evisceration	0.3	9.0	1.2	1.9	1.4	13.8
Rendering	1.9	5.8	1.0	1.5	1.1	11.3
Cooking	-	16.4	2.7	4.3	3.2	26.6
Baking	0.9	9.7	0.7	1.1	0.8	13.2
Exhausting	-	2.2	0.4	0.6	0.4	3.6
Heat Treatment/ Pasteurization	-	15.2	2.5	4.0	3.0	24.7
Evaporation/ Concentration	-	45.5	7.5	12.0	8.8	73.8
Conditioning	-	5.2	0.8	1.4	1.0	8.4
Drying	4.2	44.3	3.1	5.0	3.7	60.3
Chilling/cooling/ refrigerating	27.3	1.4	-	-	-	28.7
Freezing	10.9	-	-	-	-	10.9
TOTAL	45.5	154.7	19.9	31.8	23.4	275.3

Source: Energetics (1990).



APPENDIX C: THEORETICAL POTENTIAL FOR REDUCTION OF GREENHOUSE GAS EMISSIONS*

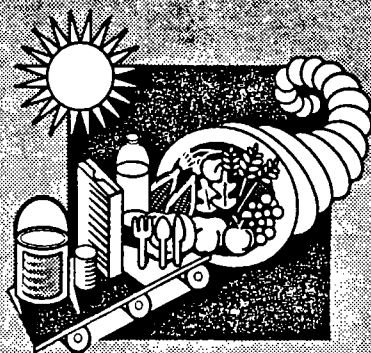
Table C1. Source data and calculations of the theoretical potential for reducing carbon and carbon equivalent emissions of carbon dioxide, methane, and nitrous oxide by U.S. agriculture and food manufacturing

Category	Theoretical potential for reduction in U.S. emissions (MMTCE/yr)	U.S. carbon-equivalent emissions reduction due to a reduction in carbon equivalent emission from the indicated category (%)	Global carbon-equivalent emissions reduction due to a U.S. reduction in carbon equivalent emission from the indicated category (%)
Advanced food manufacturing	6.7 ^A	0.38	0.069
Advanced nitrous oxide management	7.2 ^B	0.41	0.074
Advanced agricultural systems	1.5 ^C	0.085	0.015
Advanced livestock management	17 ^D	0.94	0.17
Improved cropping systems	35 ^E	2.0	0.36
Improved Irrigation and water management	8 ^F	0.46	0.082
Conservation tillage	71 ^G	4.0	0.73
Bioproducts	3.5 ^H	0.20	0.036
Biofuels/biopower	94 ^I	5.3	0.96
Afforestation	112 ^J	6.4	1.1

* Shown in graphical form in Summary Graphic C in the Executive Summary of this document.

Sources:

- A From Table 11 of this document. The annual rate is a projection for the year 2010.
- B Estimated from the global mitigation potential for reducing N₂O shown in Figure 8 of this document, and from Table 2. $(0.71) \times (310) \times (12/44) = 60.03$ MMTCE global reduction potential = $(60.03) \times (0.06)/(0.507) = 7.1$ MMTCE U.S. agriculture reduction potential = $(7.1)/9755 \times 100 = 0.073\%$ reduction in global C equivalent emission due to a U.S. emission reduction in this category = $(7.1)/1759 \times 100 = 0.404\%$ reduction in U.S. C equivalent emissions due to an emission reduction in this category.
- C From CCTS 1997, Appendix B4.2, p. B-35, for the year 2010.
- D Obtained by adding 1.9 MMTCH₄ from Table 7 (year 2010) to 1.0 MMTCH₄ from Table 8 (year 2010) = $(2.9) \times (21) \times (12/44) = 16.609$ MMTCE U.S. agriculture reduction potential = $(16.609)/9755 \times 100 = 0.1703\%$ reduction in global C equivalent emission due to a U.S. emissions reduction in this category = $(16.609)/1759 \times 100 = 0.944\%$ reduction in U.S. C equivalent emission due to a reduction in this category.
- E From Table 5 of this document, following Lal, et al. (1996), based on their mid-range values.
- F From Page 12 of this document, following Lal, et al. (1998), based on their mid-range values.
- G From Page 11 of this document, following Lal, et al. (1998), based on their mid-range values. Most of the options dealing with land use and soil C sequestration are limited in duration in that vegetation and soils, under a given set of environmental and management conditions, have a finite capacity to sequester carbon. An exception is carbon accumulation in wetlands, where carbon increases can be sustained for much longer periods.
- H From CCTS 1997, Appendix B4.1, p. B-33, for the year 2010.
- I From page 10 of this document. An energy substitution factor of 0.7 was used to obtain the 94 MMTC/yr number. The above estimate of 94 MMTC/yr is made without specifying how the biofuels will be used (i.e., they can be used to generate electricity by substituting for coal in existing power plants, or used alone in plants that displace new fossil fuel-fired plants, or they can be used in gasified form to produce power in advanced gas turbines or to produce transportation fuels for automobiles and trucks). Thus, the estimate of 94 MMTC/yr given here should be viewed as an upper limit that will likely be reduced further by thermodynamic constraints and by real-world constraints such as market forces (that are influenced greatly by the prevailing price of a barrel of oil) and public policy decisions. In the appendices of CCTS (1997), carbon reduction estimates were made only on ethanol, using switchgrass as a feedstock at 10% and 95% blends, compared with reformulated gasoline, and with market penetration for these blends of 4 billion gallons in 2010 and other projections for future years. Using these parameters, CCTS (1997) concluded that neat ethanol was not cost effective enough to use as a transportation fuel during the next 30-year period. Carbon reductions were estimated at 10 MMTC/yr in 2010 for ethanol, which included biomass-generated electricity returned to the grid from ethanol plants, and 15 MMTC/yr for biopower applications in the year 2010. The sum of these estimates of carbon offset (25 MMTC/yr) is about one-quarter of the estimate based on technical potential alone as reported in IPCC (1996), and adjusted to the United States in this white paper (94 MMTC/yr). Lal, et al. (1998) estimated the carbon offset to be 35 MMTC/yr by assuming energy and short-rotation woody crops would be grown on approximately one-half of the available U.S. idle cropland (10 Mha by their estimate) and further assuming an energy substitution factor of 0.7 for the biofuels. In Table C above, the Biofuels/ biopower entry was obtained using the full 22.6 Mha of idle U.S. cropland discussed earlier in this white paper, along with a 0.7 energy substitution factor, to obtain 94 MMTC/yr. We acknowledge that it may not be economical to utilize all of the available idle U.S. cropland using fixed processing facilities because of geographic separation of some of the parcels that comprise that cropland.
- J From page 10 of this document. The average net weight of 2.0 tons of carbon per acre per year was obtained from three independent sources: Birdsey 1998; Follett 1998; and Sampson 1998.



APPENDIX D: GLOBAL WARMING POTENTIALS FOR CH₄ AND N₂O

Global warming potential (GWP) is a numerical index created and used to provide a means of estimating the relative radiative effects of the various greenhouse gases. The index is defined as the cumulative radiative forcing between the present and some later time "horizon" caused by a unit mass of gas emitted in the present, expressed relative to some reference gas. (CO₂ is used in this white paper.)

In general, such indices are used to estimate the relative impact of emission of a fixed amount of one greenhouse gas compared to another for globally averaged radiative forcing of the climate system over the chosen time horizon. These gases can exert a radiative forcing of the climate system both directly and indirectly. Direct forcing occurs when the emitted gas is itself a greenhouse gas. Indirect forcing occurs when a chemical transformation of the original gas produces or destroys a gas or gases that themselves are greenhouse gases. The future global warming impact of a greenhouse gas over the reference time horizon is the appropriate GWP multiplied by the amount of gas emitted. Although GWPs are quoted as single values, the typical uncertainty is $\pm 35\%$. GWPs have a number of important limitations and underlying assumptions. For example, the GWP concept is currently inapplicable to gases and aerosols that are very unevenly distributed, as is the case for tropospheric ozone and aerosols and their chemical precursors. Further, the indices and the estimated uncertainties are intended to reflect global averages only, and do not account for regional effects.

There are three main technical factors that affect the index (IPCC 1994). These are

1. The strength with which a given chemical species absorbs long-wavelength radiation and the spectral location of its absorbing wavelength. Although the absorption of infrared radiation by many greenhouse gases varies linearly with their concentrations, a few important ones display nonlinear behavior (e.g., CO₂, CH₄, and N₂O). For these gases, the relative radiative forcing will depend on concentration, and hence on the scenario adopted for the future trace-gas atmospheric concentrations. A key factor in the greenhouse role of a given chemical species is the location of its own absorption spectrum relative to the holes in the absorption spectrum of water vapor, through which most outgoing planetary thermal radiation escapes to space.

2. The lifetime or response time of the given chemical species in the atmosphere. Greenhouse gases differ greatly in how long they reside in the atmosphere once emitted. Generally speaking, greenhouse gases that persist in the atmosphere for a long time are more important in radiative forcing than those that are shorter lived. An initial dominance of molecular absorption strength for one gas (e.g., most hydrochlorofluorocarbons) in determining the instantaneous radiative forcing at early times can be overwhelmed by the longer lifetime of another gas (e.g., nitrous oxide) having a lower molecular absorption of infrared radiation.

3. The time period over which the radiative effects of the species are to be considered. It is the cumulative forcing of a greenhouse gas, rather than its instantaneous value, that is of primary importance to the construct of a relevant radiative forcing index. As a consequence, such indices involve an integral over time. Figure D-1 shows the integrals for nitrous oxide and methane, relative to carbon dioxide, over a period ranging from 1 to 500 years. The integral of carbon dioxide relative to itself is unity for all integration time periods.

An illustration of how these indices are reflected in emissions of greenhouse gases from agriculture is shown in Figure D2. The relative carbon equivalent emissions for nitrous oxide and methane are revealed to be slightly greater than carbon dioxide alone.

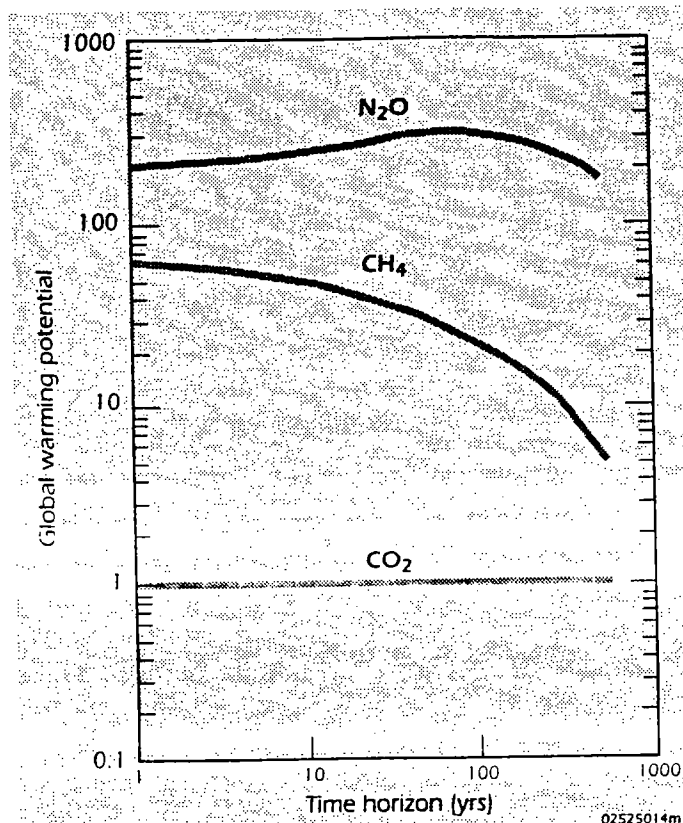


Figure D1. Global warming potential (GWP) for nitrous oxide, methane, and carbon dioxide, for differing lifetimes of as many as 500 years, using CO₂ as the reference gas. GWP is the time-integrated radiative forcing from the instantaneous release of 1 kg of a trace gas expressed relative to that of 1 kg of a reference gas. The global warming potential of gas *i* is defined mathematically as

$$GWP_i = \frac{\int_0^{TH} a_i[c_i(t)]dt}{\int_0^{TH} a_r[c_r(t)]dt},$$

where *TH* is the time horizon over which the integration is performed; *a_i* is the instantaneous radiative forcing due to a unit increase in the concentration of gas *i*; and [*c_i(t)*] is the time-decaying concentration of gas *i* at time *t* after its release. The corresponding quantities for the reference gas *r* are in the denominator. Source: IPCC 1994.

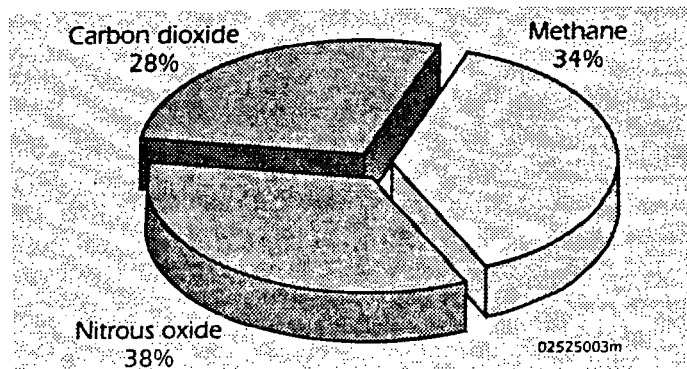


Figure D2. Relative carbon equivalent emissions of the three greenhouse gases attributable to U.S. agriculture. Total annual emission by U.S. agriculture of the carbon equivalent of these three gases is about 158 million metric tons, or about 9% of all U.S. emissions of these three greenhouse gases. Source: Table 2 by taking horizontal ratios.

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