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DEPUTY ASSISTANT TO THE PRESIDENT

(prepared by Angie Mizeur)

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Comparison of Executive Order 13134 and the Biomass Research & Development Act of 2000

On June 20th, the President signed the Agricultural Risk Protection Act of 2000 (P.L. 106-244), Title III is the Biomass Research and Development Act of 2000.

The scope of the E.O. and Act are similar though the E.O. is broader. The Act defines Biobased industrial products as including "fuels, chemicals, building materials, electric power or heat from biomass". The Act does not specifically remove old growth timber from the biomass definition.

The E.O. spans R&D to include commercialization and market development while the Act includes pre-commercialization activities, demos (test beds) and field work. The Act does not address market pull or federal purchases.

The Act authorizes $49 million in funding within the Department of Agriculture to carry out research under the Biomass R&D Initiative through competitively awarded grants, contracts and financial assistance. The technical areas, players, selection considerations, and peer review by independent technical and scientific boards are spelled out.

The Act designates that the Points of Contact from DOE and USDA will cooperate in the coordination of the R&D programs, arrange for site specific and interlaboratory agreements, and jointly administer the Initiative.

The Act established a Biomass Research and Development Board which supersedes the Interagency Council established under the E.O. The Board will be co-chaired by the Department of Energy and Agriculture Points of Contact. Membership is to include DOI, EPA, NSF, and OSTP representatives of similar rank, appointed by heads of each agency. If needed, the co-chairs may add more agency members. The current action on this item has included a redraft the Charter of the Interagency Council, and re-designation of the co-chairs and members of the Interagency Council to the new Biomass R&D Board. The Biomass R&D Board is to meet quarterly; the next meeting is tentatively scheduled for the week of September 11th and will be hosted by EPA.

The Act establishes a Biomass Research and Development Technical Advisory Committee which supersedes the Advisory Committee on Biobased Products and Bioenergy established under the E.O. The Committee is to advise the Board on the technical focus and direction of requests for proposals issued, and evaluate and perform strategic planning on program activities related to the initiative. Members are to be jointly designated by the DOE and USDA, the requirements and responsibilities were slightly altered from the E.O., and members will be appointed for 3 years except that initially 1/3 will be one -year terms, and 1/3 2 -year terms. Currently the DOE and USDA have agreed on a list of 25 names and the list is awaiting final approval; 20 of those names were the original list approved for the E.O. Advisory Group. The Biomass

R&D Technical Advisory Committee is to meet quarterly.

Reporting requirements under the E.O. include the preparation of an Annual Strategic Plan by the Council, the first Strategic Plan is in the final stages of preparation. The Act requires a Report to Congress 180 days after enactment, followed by annual reports to Congress; reports should describe the status of R&D in Federal and private sector, and establish criteria for evaluating economic, energy and environmental impacts.

The Act does not mention the Biobased Products and Bioenergy Coordination Office, which was established under the E.O.; nor are the DOE and USDA working groups mentioned. However, the Act does authorize that 4% of the authorized funds may be used for administration.

Krista
Joe Jobe

10/4/00

Bio Diesel

- Europe - using biodiesel widely, from B5 to B100
  - tax incentives and subsidies much higher.
- Plenty of excess capacity in domestic "oleo" chemical industry.
- "yellowgrease" is recycled soybean oil that is already traded. Bio diesel from this is different than virgin biodiesel.
- Should help deal w/ 15/million EPA low sulpher diesel rule.

An Overview of Biodiesel and Petroleum Diesel Life Cycles

A Joint Study Sponsored by:

U.S. Department of Agriculture and
U.S. Department of Energy

May 1998

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NREL/TP-580-24772

An Overview of Biodiesel and Petroleum Diesel Life Cycles

John Sheehan
Vince Camobreco
James Duffield
Michael Graboski
Housein Shapouri

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Life cycle studies require thoughtfulness, hard work, and patience. We have been fortunate to have all these. The core team of workers comes from a variety of organizations, and their ability to collaborate on such a project is a tribute to their professionalism and to the dedication of these organizations.

From the U.S. Department of Energy's National Renewable Energy Laboratory...

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- K. Shaine Tyson, NREL project manager for DOE's Biodiesel Program, provided overview and management for the work and shared her insights based on her experience conducting a life cycle study for ethanol.

From the U.S. Department of Agriculture's Office of Energy...

- Jim Duffield coordinated this study for USDA, and was the lead contributor to the soybean agriculture portion of the model.
- Housein Shapouri, a coauthor of the soybean agriculture section, provided invaluable support in collecting and analyzing USDA's data on soybean farm practices.

From Ecobalance, Inc., and the Colorado Institute for Fuels and High Altitude Engine Research (CIFER) at the Colorado School of Mines...

Ecobalance, Inc.

- Vince Camobreco coordinated this study for Ecobalance with support from DOE, and tirelessly led the effort to construct the life cycle models for petroleum diesel and biodiesel using Ecobalance's invaluable software tools designed for this type of work. Remi Coulon and Jacques Besnainou provided technical oversight of the model development, and provided invaluable insight on life cycle modeling.

CIFER

- Mike Graboski, with the support of USDA's Office of Energy, took the lead in collecting and analyzing all the available data on biodiesel and petroleum diesel performance in bus engines.

We would be remiss if we did not recognize the hours of volunteer time put in by our stakeholders and peer reviewers. Their efforts lend credibility to this work. Finally, we want to thank the leaders at DOE and USDA for their support and patience during this long and trying effort. In particular, we would like to thank...

- Roger Conway, USDA Office of Energy
- John Ferrell and Mike Voorhies, DOE Office of Fuels Development

This overview is extracted from a detailed, comprehensive report entitled *Life Cycle Inventories of Biodiesel and Petroleum Diesel for Use in an Urban Bus.*, NREL/SR-580-24089 UC Category 1503, National Renewable Energy Laboratory, Golden, CO. That report contains the detail engineering analysis, assumptions, and other technical material that supports this overview. For a copy of that report, contact the same addresses provided on the previous page.

1 Executive Summary

What is biodiesel?

Biodiesel is a renewable diesel fuel substitute that can be made by chemically combining any natural oil or fat with an alcohol such as methanol or ethanol. Methanol has been the most commonly used alcohol in the commercial production of biodiesel. In Europe, biodiesel is widely available in both its neat form (100% biodiesel, also known as B100) and in blends with petroleum diesel. Most European biodiesel is made from rapeseed oil (a cousin of canola oil). In the United States, initial interest in producing and using biodiesel has focused on the use of soybean oil as the primary feedstock, mainly because this country is the world's largest producer of soybean oil.

Why biodiesel?

Proponents of biodiesel as a substitute for diesel fuel (neat or in blends) point to its advantages:

- ✓ ***It can reduce our dependence on foreign petroleum...***
  Petroleum imports are at record levels in the United States, and will continue to rise as domestic oil supplies shrink. Our transportation sector, with its great demand for gasoline and diesel fuel, relies almost exclusively on petroleum for energy. Biodiesel can be produced domestically from agricultural oils and from waste fats and oils. Because it can be used directly in diesel engines, biodiesel offers the immediate potential to reduce our demand for petroleum.

- ✓ ***It can leverage limited supplies of fossil fuels...***
  Regardless of whose perspective we choose to believe on the future of coal, oil, and natural gas, their supply is, ultimately, limited. Biodiesel can help us leverage our use of these fuels.

- ✓ ***It can help reduce greenhouse gas emissions...***
  The burning of fossil fuels during the past century has dramatically increased the levels of carbon dioxide (CO_2) and other "greenhouse gases" that trap heat in our atmosphere. Their implications are hotly debated, but the levels of these gases have unquestionably risen at unprecedented rates in the context of geological time[1]. To the extent that biodiesel is truly renewable, it could help reduce greenhouse gas emissions from the transportation sector.

- ✓ ***It can help reduce air pollution and related public health risks...***
  One of the U.S. Environmental Protection Agency's (EPA) primary charges is to reduce public health risks associated with environmental pollution. Biodiesel can play a role in reducing emissions of many air pollutants, especially those targeted by EPA in urban areas. These include particulate matter (PM), carbon monoxide (CO), hydrocarbons (HC), sulfur oxides (SO_x), nitrogen oxides (NO_x), and air toxics.

---

[1]Revelle published the groundbreaking work on atmospheric CO_2 buildup during the International Geophysical Year of 1957, in which he clearly stated the problem of greenhouse gases. He wrote: "Human beings are carrying out a large-scale geophysical experiment of a kind that could not have happened in the past nor be produced in the future. Within a few centuries, we are returning to the atmosphere and the oceans the concentrated organic carbon stored in sedimentary rocks over hundreds of millions of years." Revelle, R.; Suess, H. *Tellus* 9(11):18-21, 1957.

✓ ***It can benefit our domestic economy...***

Spending on foreign imports of petroleum takes dollars away from our economy. Biodiesel can help us shift this spending to domestically produced energy, and offers new energy-related markets to farmers.

✓ ***One gallon of biodiesel provides the same benefits used neat (100%) or used in blends, such as B20 (20% biodiesel with 80% diesel fuel)***

Because the tailpipe emissions of biodiesel vary linearly with the blend level, the benefit of any blend level of biodiesel can be estimated by using the following formula: percent biodiesel multiplied by biodiesel life cycle inventory plus percent diesel fuel multiplied by diesel fuel life cycle inventory.

Why a life cycle analysis?

Life cycle analyses look at the whole picture of how a fuel is made, from "cradle to grave." The life cycles begin with the extraction of all raw materials to make petroleum diesel and biodiesel, and end with using the fuels in an urban bus. Examining global issues, such as CO_2 emissions, requires a comprehensive life cycle analysis. Understanding the benefits of biodiesel requires us to compare its life cycle emissions to those of petroleum diesel. This study examines biodiesel energy's balance, its effect on greenhouse gas emissions, and its effects on the generation of air, water, and solid waste pollutants for every operation needed to made biodiesel and diesel fuel. We made no attempt to quantify its domestic economic benefits.

This study provides a life cycle inventory of environmental and energy flows to and from the environment for both petroleum diesel and biodiesel, as well as for blends of biodiesel with petroleum diesel.

Scope

Life cycle analysis is a complex science. One characteristic of the process is that you have to choose very specific technologies and assumptions to represent very complex and diverse industries and systems. So life cycles can oversimplify "reality." Also, you cannot model a system or process without data. So the availability of published data often determines which technologies and assumptions are modeled in a life cycle analysis. For example, a great deal of information is available from bus engine tests and bus demonstrations of soybean-derived biodiesel, so we chose to model soybean oil production and conversion to biodiesel, and based the end use on bus applications.

Findings

Life cycle analyses all have similar limitations. Incomplete data are the rule rather than the exception. We have varying degrees of confidence in the results, but the most reliable conclusions are for overall energy balance and CO_2 emissions. For these two measures, our data are the most complete. More importantly, our sensitivity studies show that the estimates of CO_2 emissions and energy requirements are very robust: they show little change in response to changes in key assumptions.

Reductions in petroleum and fossil energy consumption

Biodiesel offers tremendous potential as one component of a strategy for reducing petroleum oil dependence and minimizing fossil fuel consumption.

> ***The benefit of using biodiesel is proportionate to the blend level of biodiesel used. Substituting B100 for petroleum diesel in buses reduces the life cycle consumption of petroleum by 95%. A 20% blend of biodiesel and petroleum diesel (B20) causes the life cycle consumption of petroleum to drop 19%.***

Biodiesel and petroleum diesel production processes are almost equally efficient at converting raw energy resources (in this case, petroleum or soybean oil) into fuels. Biodiesel's advantage is that its largest raw resource (soy oil) is renewable. So biodiesel requires less fossil energy (only 0.31 units) to make a 1 unit of fuel.

> ***Biodiesel yields 3.2 units of fuel product energy for every unit of fossil energy consumed in its life cycle. The production of B20 yields 0.98 units of fuel product energy for every unit of fossil energy consumed.***

By contrast, society uses 1.2 units of fossil resources to produce 1 unit of petroleum diesel. Such measures confirm the "renewable" nature of biodiesel.

Reductions in CO_2 emissions

Because biodiesel production requires such small amounts of fossil fuel, its CO_2 life cycle emissions are, not surprisingly, much lower than those of petroleum diesel. Displacing petroleum diesel with biodiesel in urban buses is an extremely effective strategy for reducing CO_2 emissions.

> ***Biodiesel reduces net CO_2 emissions by 78.45% compared to petroleum diesel. For B20, CO_2 emissions from urban buses drop 15.66%.***

Changes in air pollutant emissions

The effect of biodiesel on air quality is complex and requires an understanding of the chemical interactions of air pollutants. To begin such an analysis, you need to know the amounts and type of air pollutants each fuel releases into the environment. Biodiesel, as it is available today, substantially reduces some air pollutants; it leads to increases in others.

Using B100 in urban buses substantially reduces life cycle emissions of total particulate matter (32%), CO (35%), and SO_x (8%), relative to petroleum diesel's life cycle.

Biodiesel reduces particulate, carbon monoxide, and sulfur dioxide emissions compared to diesel fuel. The EPA targets these three emissions because they pose public health risks, especially in urban areas where they can affect more people. Because transportation emissions contribute significantly to urban concentrations of these pollutants, reducing tailpipe emissions is a powerful tool for improving air quality. Using biodiesel in buses operating in urban areas significantly reduces these pollutants.

Tailpipe emissions of particulates smaller than 10 microns are 68% lower for buses that run on biodiesel (compared to petroleum diesel). Tailpipe CO emissions are 46% lower. Biodiesel completely eliminates tailpipe SO_x emissions.

The reductions in air emissions reported here are proportional to the amount of biodiesel in the fuel. Thus, for B20, users can expect to see 20% of the reductions reported for B100.

NO_x is one of three pollutants implicated in the formation of ground-level ozone and smog in urban areas (NO_x, CO, and HCs). Biodiesel increases tailpipe NO_x emissions, and these emission sources dominate its life cycle NO_x emission levels.

The use of B100 in urban buses increases NO_x life cycle emissions by 13.35%. Blending biodiesel with petroleum proportionately lowers NO_x emissions. B20 exhibits a 2.67% increase in life NO_x cycle emissions. Most of this increase is directly attributable to increases in NO_x tailpipe emissions. B100, for example, increases NO_x tailpipe levels by 8.89%.

Our results are based on the performance of current fuel and engine technologies. Our study points out the need for research on improving engine design and biodiesel fuel formulation to address this problem.

The biodiesel life cycle also produces more hydrocarbon (HC) emissions compared to the diesel fuel life cycle. Most of the biodiesel life cycle emissions are produced during farming and soybean processing operations. Tailpipe HC emissions are actually lower for biodiesel than for diesel fuel.

Total life cycle emissions of HCs are 35% higher for B100 than for petroleum diesel. However, HC emissions at the bus's tailpipe are 37% lower.

These results point out opportunities for improving the life cycle of biodiesel. Future agricultural research should focus on ways of reducing HC releases from today's agricultural systems.

Next Steps

We designed this study to identify and quantify the advantages of biodiesel as a substitute for petroleum diesel. These advantages are substantial, especially in the areas of energy security and control of greenhouse gases. We have also identified weaknesses or areas of concern for biodiesel—such as its emissions of NO_x and HCs. We see these as opportunities for further research to resolve these concerns. We hope our findings will be used to focus research on these critical issues.

Much can be done to build on and improve the work we have done here. Next steps for this work include:

- ***Use the life cycle inventory to assess the relative effects of petroleum diesel and biodiesel on our environment and on public health risks to gain an understanding of the benefits associated with biodiesel.***
- ***Quantify the costs and benefits of biodiesel.***
- ***Assess the economic impact of biodiesel as an alternative fuel (e.g., its effects on jobs and the trade deficit).***
- ***Evaluate other feedstock sources.***
- ***Incorporate new health effects data on HC emissions from biodiesel and petroleum diesel.***
- ***Develop regional life cycle models for biodiesel use.***
- ***Evaluate performance of newer diesel engines and new fuel production technologies.***

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1 Introduction

This report presents the findings from a study of the life cycle inventories (LCIs) for petroleum diesel and biodiesel. An LCI comprehensively quantifies all the energy and environmental flows associated with a product from "cradle to grave." It provides information on:

- Raw materials extracted from the environment
- Energy resources consumed
- Air, water, and solid waste emissions generated.

By "cradle to grave," we mean all the steps from the first extraction of raw materials to the end use of the fuel. Comparing the LCIs of two or more fuels provides insights to their relative strengths and weaknesses. LCIs are also used to examine greenhouse gas emissions because these emissions can be produced anywhere in a fuel's life cycle. LCIs include other environmental emissions as well, particularly regulated air emissions such as carbon monoxide (CO), hydrocarbons (HCs), nitrogen oxides (NO_x), sulfur oxides (SO_x), and particulate matter (PM). These LCI data will be used by industry and government decision makers considering biodiesel as an alternative fuel. This study is the product of a highly effective partnership between the U.S. Department of Agriculture (USDA) and the U.S. Department of Energy (DOE). This partnership has brought together the agricultural and energy expertise needed to adequately address an LCI of biodiesel.

1.1 Stakeholder Involvement

A good life cycle study uses every opportunity to obtain input from everyone who has a stake in the final outcome. This is especially true for life cycle studies being conducted to support important government policy decisions. Many early decisions made in setting the scope of the study (see section 2) can have a profound effect on its outcome. All stakeholders must therefore have an opportunity to:

- Discuss the key assumptions and options.
- Provide input throughout the project to ensure that the best available data are used and interpreted properly.
- Provide their perspective on the results as they become available to help the researchers avoid "tunnel vision."

The most important reason for stakeholder involvement is *credibility*. When studies are done in a vacuum, they stand little chance of getting acceptance from the industries involved. In the end, LCI results are only as good as the "buy-in" or level of credibility they engender.

We made stakeholder involvement a top priority. The following groups provided input:

- Petroleum Industry
- Oilseed Processing Industry
- Animal Renderers and Recyclers
- Chemical Process Industry
- Biodiesel Producers
- Engine Manufacturers

- U.S. Department of Agriculture
- U.S. Department of Energy
- U.S. Environmental Protection Agency
- State and Local Governments
- Environmental Public Interest Groups.

Stakeholders were given many opportunities to communicate with us in writing, by phone, and by e-mail, as well as in our face-to-face meetings.

1. Before pen was put to paper, USDA and DOE brought together a consortium of stakeholders at a meeting hosted by USDA in Washington, DC, to discuss the needs and goals of our study.
2. Based on input from this group, a preliminary scoping document was put together and distributed for review.
3. A second face-to-face meeting with stakeholders was held to work out the details of the project scope.
4. Once the basic data were collected on all aspects of the petroleum diesel and biodiesel life cycles, the stakeholders reconvened to review the data. Feedback from this meeting resulted in our updating data sources and filling in gaps.
5. Finally, once results from the LCI model were available, we sought detailed comments from a representative group of stakeholders (those willing to put in the time to study our results). They were given a first draft of this report. Their comments have been carefully compiled. Wherever possible, we made changes to the model and the report to reflect their concerns and criticisms. This document is a product of that final review.

The quality of our results is much better for the input of these groups. We are indebted to those who participated.

2 Scope

2.1.1 Purposes

The purposes of this study were to (1) conduct an LCI to quantify and compare the comprehensive sets of environmental flows (to and from the environment) associated with biodiesel and petroleum-based diesel, over their life cycles; and (2) provide the information to answer the questions posed by policy makers:

2.1.2 What Is "Biodiesel?"

In its most general sense, "biodiesel" refers to any diesel fuel substitute derived from renewable biomass. More specifically, biodiesel refers to a family of products made from vegetable oils or animal fats and alcohol, such as methanol or ethanol, called alkyl esters of fatty acids. For these to be considered as viable transportation fuels, they must meet stringent quality standards. One popular process for producing biodiesel, modeled in this report, is "transesterification."

Biodiesel is made from a variety of natural oils, especially rapeseed oil (a close cousin of canola oil) and soybean oil. Rapeseed oil dominates the growing biodiesel industry in Europe. In the United States, biodiesel is made from soybean oil because more soybean oil is produced here than all other sources of fats and oil combined. There are many other feedstock candidates, including recycled cooking oils, animal fats, and other oilseed crops. We selected soybean oil because of the vast number of data about this oil as a biodiesel feedstock.

We chose methanol for our model because it is the most widely used alcohol for biodiesel production, it is easy to process, and is relatively low cost. Thus, our working definition of biodiesel is a diesel fuel substitute made by transesterifying soybean oil with methanol. In industry parlance, it is called soy methyl ester or methyl soyate.

2.1.3 What Is "Petroleum Diesel?"

We defined petroleum diesel as "on-highway" low-sulfur diesel made from crude oil. Recent regulations promulgated by the U.S. Environmental Protection Agency (EPA), as part of its enforcement of the 1990 Clean Air Act Amendments, set tougher restrictions for on-road versus off-road diesel. The "on-highway" diesel must now meet limits for sulfur content that are an order of magnitude lower than previously allowed (0.05 wt% versus 0.5% sulfur). We restrict our evaluation of petroleum diesel to this diesel[2].

2.1.4 Defining the Product Application

The fuels' end uses can greatly affect the life cycle flows. Potential markets for biodiesel cover a wide range of applications, including most truck operations, stationary generation, mining equipment, marine diesel engines, and bus fleets. We compare petroleum diesel and biodiesel in urban buses because many

[2] In our analysis, low-sulfur diesel fuel is used in urban buses. This is not true for agricultural use of diesel fuel in soybean production. Data for "off-highway" diesel-powered tractors characterize performance and emissions of these engines. This diesel is not held to the same strict standard for sulfur content.

end-use data are available. The U.S. biodiesel industry early on identified the urban bus market as a near-term opportunity, and many data are available on the performance of diesel bus engines.

2.1.5 What Is Included in the Life Cycle Systems?

Major operations within the boundary of the petroleum diesel system include:

- Extract crude oil from the ground
- Transport crude oil to an oil refinery
- Refine crude oil to diesel fuel
- Transport diesel fuel to its point of use
- Use the fuel in a diesel bus engine.

For the biodiesel system, major operations include:

- Produce soybeans
- Transport soybeans to a soy crushing facility
- Recover soybean oil at the crusher
- Transport soybean oil to a biodiesel manufacturing facility
- Convert soybean oil to biodiesel
- Transport biodiesel fuel to the point of use
- Use the fuel in a diesel bus engine.

This is not a comprehensive list of what we modeled. These operations include detailed processes described in detail in the comprehensive report, *Life Cycle Inventories of Biodiesel and Petroleum Diesel for Use in an Urban Bus*. For example, crude oil extraction includes flows from operations such as onshore and offshore drilling and natural gas separation. Onshore drilling is further characterized as either conventional or advanced technology.

In addition to the energy and environmental flows in each step, we include energy and environmental inputs from raw materials production. Generally, life cycle flows are characterized for all raw materials from the point of extraction. For example, methanol use in the biodiesel manufacturing facility contributes life cycle flows that go back to the extraction of natural gas. Likewise, we include life cycle flows from intermediate energy sources such as electricity—back to the extraction of coal, oil, natural gas, limestone, and other primary resources.

2.1.6 What Are the Geographic Boundaries?

The LCA is limited to the use of petroleum diesel and biodiesel in the United States; however, it includes some steps that go beyond domestic boundaries. Petroleum diesel's life cycle, in particular, includes foreign crude oil production because half the crude oil used in the United States is imported. Other aspects of the geographic limits involve the choice of national versus regional or even site-specific assessment. For domestic operations, we rely on national average data. For foreign operations, we rely on industry average data. Electricity generation is modeled on a national basis. Table 1 and Table 2 present specific information on the geographic scope of the analysis for each stage of the petroleum diesel and biodiesel life cycles.

Table 1: Geographic Scope of the Petroleum Diesel Life Cycle

Life Cycle Stage	Geographic Scope
Crude Oil Extraction	International average based on the consumption of crude oil in the United States
Crude Oil Transportation	International average transportation distances to the United States
Crude Oil Refining	U.S. national average
Diesel Fuel Transportation	U.S. national average
Diesel Fuel Use	U.S. national average based on urban bus use

Table 2: Geographic Scope of the Biodiesel Life Cycle

Life Cycle Stage	Geographic Scope
Soybean Agriculture	Average based on data from the 14 key soybean-producing states
Soybean Transportation	U.S. national average
Soybean Crushing	U.S. national average based on modeling of a generic U.S. crushing facility
Soybean Oil Transport	U.S. national average
Soybean Oil Conversion	U.S. average based on modeling of a generic biodiesel facility
Biodiesel Transportation	U.S. national average
Biodiesel Fuel Use	U.S. national average based on urban bus use

2.1.7 What Is the Time Frame?

We were faced with two basic options: (1) model technology and markets as they are today; or (2) model a futuristic scenario based on projected technology and markets. We chose to focus on the present, so we consider production and end-use technologies now available for petroleum diesel and biodiesel. In doing so, we ignore future advances in production efficiency, emission reduction, new technology, and other changes that reasonable people anticipate. The benefit of basing the analysis on current technology and markets it that the analysis is far more "grounded" and objective because it relies on documented data rather than on projections. The results provide a baseline for considering future scenarios.

2.1.8 Basis for Comparing the Life Cycles

Common sense dictates that two fuels should be compared on the same basis. So the "service" that the fuels provide, in our case the work that the bus engine provide, is the unit of comparison. For example, for light-duty vehicles, like automobiles, the service provided by the fuel is that it propels the vehicle for 1 mile. For heavy-duty diesel engines, the common unit of "work" is a brake-horsepower hour (bhp-h). Once this shared function is defined, a comparison of fuel life cycles for diesel engines characterizes all life cycle flows per bhp-h of diesel bus service.

3 Key Assumptions

Details of the assumptions and modeling steps of the life cycle are presented in the comprehensive report, *Life Cycle Inventories of Biodiesel and Petroleum Diesel Used in an Urban Bus*. However, there are two assumptions worth noting here for a better appreciation of the LCIs shown in this report. One, national average distances were used to describe the transportation distances for all feedstocks, intermediate products, and fuels. We also tested the effect of this assumption in a sensitivity analysis to see what impact this assumption has on the LCI results. Two, both fuels were assumed to be used in engines calibrated to meet 1994 EPA regulations for diesel exhaust when operated on low-sulfur petroleum diesel. Other assumptions that will help the reader understand the fuel cycles we modeled include:

- Sources of crude oil, domestic and foreign, are split almost evenly.
- Publicly available refinery data were used to model a "generic" refinery.
- Engine emissions from petroleum diesel are taken from published 1994 engine certification data.

Biodiesel assumptions include:

- Agriculture practices and yields are based on weighted averages for 14 soybean-producing states.
- Emissions are based on actual engine data for biodiesel emissions that are then modeled as changes in the oxygen content[3] in the fuel.
- Energy efficiencies of biodiesel-fueled engines are identical to those of petroleum diesel-fueled engines[4].
- Biomass-derived carbon dioxide (CO_2) in the fuel emissions is recycled in soybean production.
- Soybean crushing and soy oil esterification data were based on published data and engineering models.

[3] Diesel fuel contains no oxygen. The amount of oxygen is a measure of biodiesel content in the fuel. Also, percent oxygen proves to be a good basis for predicting emissions.

[4] This is substantiated with an analysis of engine performance data.

4 Findings

LCI results are presented for 100% biodiesel (B100), a 20% blend of biodiesel with petroleum diesel (B20), and petroleum diesel. These results include estimates of:

- Overall energy requirements
- CO_2 emissions
- Other regulated and non-regulated air emissions. Regulated pollutants include carbon monoxide (CO), particulate matter smaller than 10 microns (PM10), non-methane hydrocarbons (NMHC), and nitrogen oxides (NO_x). Non-regulated air emissions include methane (CH_4), formaldehyde, benzene, total hydrocarbons (THC), and total particulate matter (TPM).
- Water emissions
- Solid wastes.

These life cycle flows are presented for the base-case scenarios and for two sensitivity studies. The base case describes petroleum diesel and biodiesel life cycle flows for "national average" scenarios.

We conducted sensitivity studies on the biodiesel life cycle to establish sensitivities associated with key assumptions.

1. We felt it was important to understand the impact of location on biodiesel production. This allows us to consider the benefits of the best agricultural productivity available in the United States and the shortest distances for transporting fuel and materials. It also sets an upper bound on biodiesel benefits from the perspective of current agricultural practices and transportation logistics.
2. We identified the conversion of soybean oil to biodiesel as an aspect of the life cycle that has significant impact on energy use and emissions and that has a broad range of efficiencies, depending on the commercial technology used.

Our base-case estimate of the energy requirements for soy oil conversion is based on a preliminary engineering design that was loosely based on data from a transesterification plant in Kansas City, Missouri. Our energy budget proved to be much lower than that reported for this facility. A literature review of recent technology revealed that our design estimate is at the high end of the range of recently published literature values. To deal with this disparity, we decided to look at the range of reported energy budgets as a sensitivity study.

Changes in engine and processing technologies may also create avenues for improving biodiesel on a life cycle basis. We opted to forego this area in our sensitivity analysis because of limited data. Thus, we present the results of two sensitivity studies:

- We compared the base case for B100 with the LCI for an optimal biodiesel location (Chicago), based on an evaluation of regions with the most efficient soybean production, local concentration of soybean producers, and large end-use markets for urban buses.
- We compared results for a range of high and low energy demands for soybean conversion to biodiesel to determine the impact of this biodiesel life cycle stage on overall emissions and energy flows. We

based low and high values for energy consumption on a literature survey of the most recent, commercially available, technologies.

4.1 Results of the Base-Case Study

The LCI results allow a side-by-side comparison of biodiesel and petroleum diesel fuels. Both LCIs reflect generic "national average" models. The only exception is soybean agriculture data, which are provided for each of the 14 key soybean-producing states. These were used because they provided a level of detail that was not available at a national level.

In most cases, biodiesel is interchangeable with petroleum diesel without engine modifications. However, one key issue for biodiesel is the effect of regional climate on its performance. Its cold flow properties may limit its use in certain parts of the country during the winter. Researchers are evaluating ways to mitigate biodiesel's cold flow properties, but no clear solution is at hand. Low-sulfur #2 diesel fuel has similar limitations that are being addressed with the use of additives and by blending with #1 diesel fuel.

The LCI results that are covered in the following sections include (1) life cycle energy balances, (2) CO_2 cycles for each life cycle, (3) major air pollutants for each life cycle, and (4) the results of both sensitivity analyses.

4.1.1 Life Cycle Energy Balance

LCIs provide an opportunity to quantify the total energy demands and the overall energy efficiencies of processes and products. We need to understand the overall energy requirements of biodiesel to be able to understand the extent to which biodiesel made from soybean oil is renewable. The more fossil energy required to make a fuel, the less this fuel is renewable. Thus, the renewable nature of a fuel can vary across the spectrum of "completely renewable" (no fossil energy input) to nonrenewable (fossil energy inputs as much or more than the energy output of the fuel)[5]. Energy efficiency estimates help us determine how much additional energy must be expended to convert the energy available in raw materials used in the fuel's life cycle to a useful transportation fuel. The following sections describe these basic concepts in more detail, as well as the results of our analysis of the life cycle energy balances for biodiesel and petroleum diesel.

4.1.1.1 Types of Life Cycle Energy Inputs

We tracked several types of energy flows through each fuel life cycle. Each energy flow is defined below.

- *Total Primary Energy.* All raw materials extracted from the environment can contain[6] energy. In estimating the total primary energy inputs to each fuel's life cycle, we consider the cumulative energy content of all resources extracted from the environment.

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[5] This statement is an oversimplification. We consider the energy trapped in soybean oil to be renewable because it is solar energy stored in liquid form through biological processes that are much more rapid than the geologic time frame associated with fossil energy formation. Also, other forms of nonrenewable energy besides fossil fuel exist.

[6] The energy "contained" in a raw material is the amount of energy that would be released by the complete combustion of that raw material. This "heat of combustion" can be measured as either a higher or a lower heating value. Combustion causes CO_2 and water to form. Higher heating values consider the amount of energy released when the final combustion products are gaseous CO_2 and liquid water. Lower heating values take into account the loss of energy associated with the vaporization of the liquid water combustion product. Our energy content is based on the lower heating values for each material.

- *Feedstock Energy*. Energy contained in raw materials that end up directly in the final fuel product is termed "feedstock energy." For biodiesel production, feedstock energy includes the energy contained in the soybean oil and methanol feedstocks that are converted to biodiesel. Likewise, the petroleum directly converted to diesel in a refinery contains primary energy that is considered a feedstock energy input for petroleum diesel. Feedstock energy is a subset of the primary energy inputs.
- *Process Energy*. The second major subset of primary energy is "process energy." This is limited to energy inputs in the life cycle exclusive of the energy contained in the feedstock (as defined in the previous bullet). It is the energy contained in raw materials extracted from the environment that does not contribute to the energy of the fuel product itself, but is needed in the processing of feedstock energy into its final fuel product form. Process energy consists primarily of coal, natural gas, uranium, and hydroelectric power sources consumed directly or indirectly in the fuel's life cycle.
- *Fossil Energy*. Because we are concerned about the renewable nature of biodiesel, we also track the primary energy that comes from fossil sources specifically (coal, oil, and natural gas). All three of the previously defined energy flows can be categorized as fossil or nonfossil energy.
- *Fuel Product Energy*. The energy contained in the final fuel product, which is available to do work in an engine, is what we refer to as the "fuel product energy." All other things being equal, fuel product energy is a function of the energy density of each fuel.

4.1.1.2 Defining Energy Efficiency

We report two types of energy efficiency. The first is the overall "life cycle energy efficiency." The second is the "fossil energy ratio." Each illuminates a different aspect of the life cycle energy balance for the fuels studied.

The calculation of the life cycle energy efficiency is the ratio of fuel product energy to total primary energy:

Life Cycle Energy Efficiency = Fuel Product Energy/Total Primary Energy

This ratio estimates the total amount of energy that goes into a fuel cycle compared to the energy contained in the fuel product. This efficiency accounts for losses of feedstock energy and additional process energy needed to make the fuel.

The fossil energy ratio tells us something about the degree to which a fuel is or is not renewable. It is defined as the ratio of the final fuel product energy to the amount of fossil energy required to make the fuel:

Fossil Energy Ratio = Fuel Energy/Fossil Energy Inputs

If the fossil energy ratio has a value of zero, a fuel is completely nonrenewable and provides no usable fuel product energy because of the fossil energy consumed to make the fuel. If the fossil energy ratio is 1, it is still nonrenewable because no energy is lost in the process of converting the fossil energy to a usable fuel. For fossil energy ratios greater than 1, the fuel begins to leverage the fossil energy required to make it available for transportation. As a fuel approaches "complete" renewability, its fossil energy ratio approaches "infinity." That is, a completely renewable fuel has no fossil energy requirements.

From a policy perspective, these are important considerations. Policy makers want to understand how much a fuel increases the renewability of our energy supply. Another implication of the fossil energy ratio is the question of climate change. Higher fossil energy ratios imply lower net CO_2 emissions. This is a secondary aspect of the ratio, as we are explicitly estimating total CO_2 emissions from each fuel's life cycle. Nevertheless, the fossil energy ratio checks on our calculation of CO_2 life cycle flows (the two should be correlated).

4.1.1.3 Petroleum Diesel Life Cycle Energy Consumption

Table 3 and Figure 1 show the total primary energy requirements for the key steps in producing and using petroleum diesel. The LCI model shows that 1.2007 MJ of primary energy is used to make 1 MJ of petroleum diesel fuel. This corresponds to a life cycle energy efficiency of 83.28%[7].

The distribution of the primary energy requirements for each stage of the petroleum diesel life cycle is shown in Table 3. In Figure 1, the stages of petroleum diesel production are ranked from highest to lowest in terms of primary energy demand. Ninety-three percent of the primary energy demand is for extracting crude oil from the ground. About 88% of the energy shown for crude oil extraction is associated with the energy value of the crude oil. The crude oil refinery step for making diesel fuel dominates the remaining 7% of the primary energy use.

Removing the feedstock energy of the crude from the primary energy total allows us to analyze the relative contributions of the process energy used in each life cycle. Process energy used in each stage of the petroleum life cycle is shown in Figure 2. Process energy demand represents 20% of the energy ultimately available in the petroleum diesel fuel product. About 90% of the total process energy is in refining (60%) and extraction (29%). The next largest contribution to total process energy is for transporting foreign crude oil to domestic petroleum refiners.

Table 3: Primary Energy Requirements for the Petroleum Diesel Life Cycle

Stage	Primary Energy (MJ per MJ of Fuel)	Percent
Domestic Crude Production	0.5731	47.73%
Foreign Crude Oil Production	0.5400	44.97%
Domestic Crude Transport	0.0033	0.28%
Foreign Crude Transport	0.0131	1.09%
Crude Oil Refining	0.0650	5.41%
Diesel Fuel Transport	0.0063	0.52%
Total	1.2007	100.00%

There are some significant implications in the process energy results shown in Figure 2 regarding trends for foreign and domestic crude oil production and use. Transportation of foreign crude oil by tanker carries a fourfold penalty for energy consumption compared to domestic petroleum transport because it increases the travel distance for foreign oil by roughly a factor of four.

At the same time, domestic crude oil extraction is more energy intensive than foreign crude oil production. Advanced oil recovery practices in the United States represent 11% of the total production volume, compared to 3% for foreign oil extraction. Advanced oil recovery uses twice as much primary energy per kilogram of oil than conventional extraction. Advanced crude oil extraction requires almost 20 times more process energy than onshore domestic crude oil extraction because the processes are energy intensive and the amount of oil recovered is lower than with other practices. Domestic crude oil supply is essentially equal to foreign oil supply (50.26% versus 49.74%) in our model, but its process energy requirement is 62% higher than that of foreign crude oil production (see Figure 2).

[7] Using the total primary energy reported in Table 3, Life Cycle Energy Efficiency = 1 MJ of Fuel Product Energy/1.2007 MJ of Primary Energy Input = 0.8328.

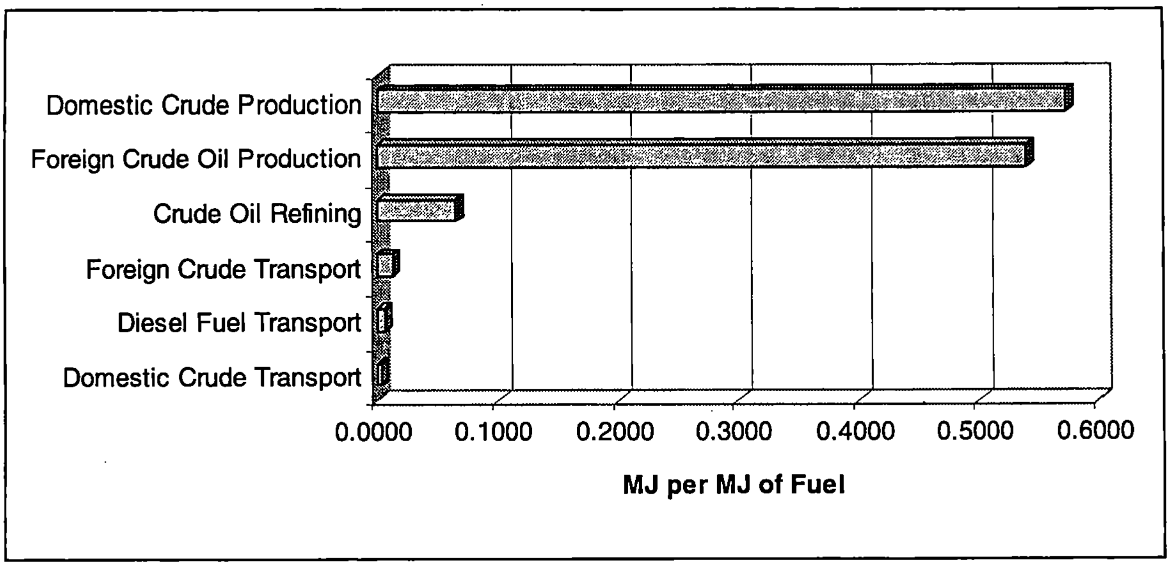
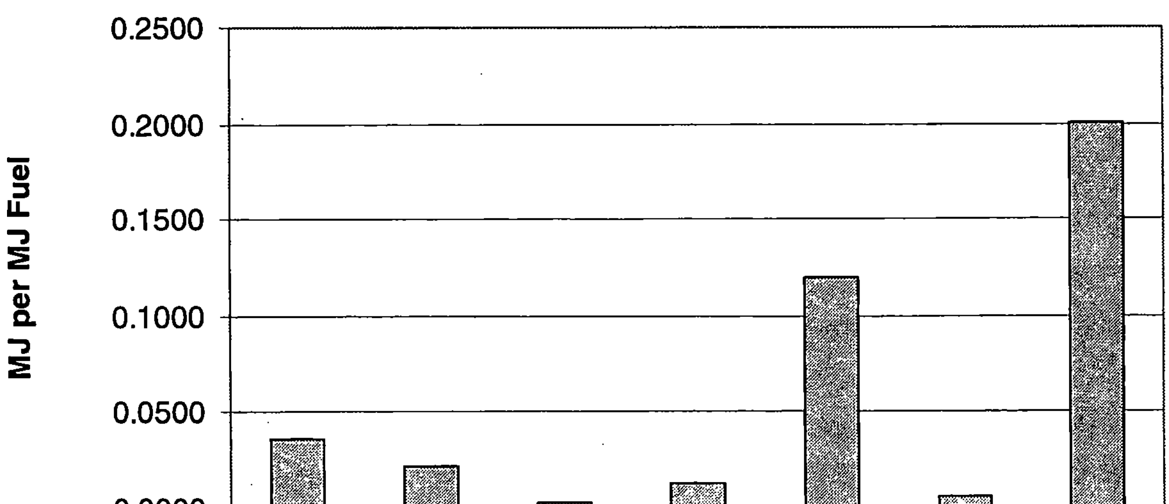


Figure 1: Ranking of Primary Energy Demand for the Stages of Petroleum Diesel



	Domestic Crude Production	Foreign Crude Oil Production	Domestic Crude Transport	Foreign Crude Transport	Crude Oil Refining	Diesel Fuel Transport	Total
Process Energy	0.0361	0.0223	0.0033	0.0131	0.1198	0.0063	0.2009

Figure 2: Process Energy Demand for Petroleum Diesel Life Cycle

If our present trend of increased dependence on foreign oil continues, we can expect the life cycle energy efficiency of petroleum diesel to worsen because of the higher energy costs of transporting foreign crude to the United States. Also, with declining domestic oil supplies, we may see increased energy penalties for domestic crude oil extraction, as advanced oil recovery becomes more common.

Table 4 and Figure 3 summarize the fossil energy inputs with respect to petroleum diesel's energy output. Petroleum diesel uses 1.1995 MJ of fossil energy to produce 1 MJ of fuel product energy. This corresponds to a fossil energy ratio of 0.8337[8]. Because the main feedstock for diesel production is a fossil fuel, this ratio is, not surprisingly, almost identical to the life cycle energy efficiency of 83.28%. In fact, fossil energy associated with the crude oil feedstock accounts for 93% of the total fossil energy consumed in the life cycle. The fossil energy ratio is slightly less than the life cycle energy ratio because there is a very small contribution to the total primary energy demand, which is met through hydroelectric and nuclear power supplies related to electricity generation.

Table 4: Fossil Energy Requirements for the Petroleum Diesel Life Cycle

Stage	Fossil Energy (MJ per MJ of Fuel)	Percent
Domestic Crude Production	0.572809	47.75%
Foreign Crude Oil Production	0.539784	45.00%
Domestic Crude Transport	0.003235	0.27%
Foreign Crude Transport	0.013021	1.09%
Crude Oil Refining	0.064499	5.38%
Diesel Fuel Transport	0.006174	0.51%
Total	1.199522	100.00%

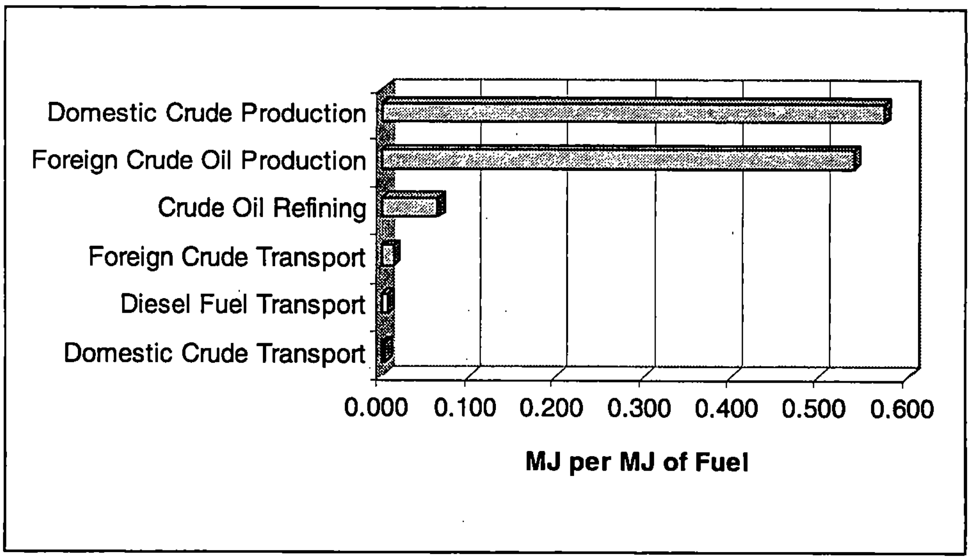


Figure 3: Ranking of Fossil Energy Demand for Stages of the Petroleum Diesel Life Cycle

[8] Fossil Energy Ratio = 1 MJ Fuel Energy/1.1995 MJ of Fossil Energy Input = 0.8337.

4.1.1.4 Biodiesel Life Cycle Energy Demand

Table 5 and Figure 4 present the total primary energy demand used in each stage of the biodiesel life cycle. One MJ of biodiesel requires an input of 1.2414 MJ of primary energy, resulting in a life cycle energy efficiency of 80.55%. Biodiesel is comparable to petroleum diesel in the conversion of primary energy to fuel product energy (80.55% versus 83.28%). The largest contribution to primary energy (87%) is the soybean oil conversion step because this is where the feedstock energy associated with the soybean oil is included[9]. As with the petroleum life cycle, the stages of the life cycle that are burdened with the feedstock energy overwhelm all other stages. Had the soybean oil energy been included with the farming operation, soybean agriculture would have been the dominant consumer of primary energy. This is analogous to placing the crude oil feedstock energy in the extraction stage for petroleum diesel fuel. The next two largest primary energy demands are for soybean crushing and soybean oil conversion. They account for most of the remaining 13% of the total demand. When we look at process energy separately from primary energy, we see that energy demands in the biodiesel life cycle are not dominated by soybean oil conversion (Figure 5). The soybean crushing demands 34.25% of the total process energy; soy oil conversion demands 34.55%. Agriculture accounts for almost 25% of the total demand. Each transportation step is only 2%-3% of the process energy used in the life cycle.

Table 6 and Figure 6 summarize the fossil energy requirements for the biodiesel life cycle. Because 90% of its feedstock requirements (soybean oil) are renewable, biodiesel's fossil energy ratio is favorable. Biodiesel uses 0.3110 MJ of fossil energy to produce 1 MJ of fuel product; this equates to a fossil energy ratio of 3.215. In other words, the biodiesel life cycle produces more than three times as much energy in its final fuel product as it uses in fossil energy. Fossil energy demand for the conversion step is almost twice that of its process energy demand, making this stage of the life cycle the largest contributor to fossil energy demand. The use of methanol as a feedstock in the production of biodiesel accounts for this high fossil energy demand. We have counted the feedstock energy of methanol coming into the life cycle at this point, assuming that the methanol is produced from natural gas. This points out an opportunity for further improvement of the fossil energy ratio by substituting natural gas-derived methanol with renewable sources of methanol, ethanol, or other alcohols.

4.1.1.5 Effect of Biodiesel on Life Cycle Energy Demands

Compared on the basis of primary energy inputs, biodiesel and petroleum diesel are essentially equivalent. Biodiesel has a life cycle energy efficiency of 80.55%, compared to 83.28% for petroleum diesel. The slightly lower efficiency reflects a slightly higher demand for process energy across the life of cycle for biodiesel. On the basis of fossil energy inputs, biodiesel enhances the effective use of this finite energy resource because it leverages fossil energy inputs by more than three to one.

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[9] Energy contained in the soybean oil represents, in effect, the one place in the biodiesel life cycle where input of solar energy is accounted for. Total radiant energy available to soybean crops is essentially viewed as "free" in the life cycle calculations. It becomes an accountable element of the life cycle only after it has been incorporated in the soybean oil. This is analogous to counting the feedstock energy of crude petroleum as the point in its life cycle where solar energy input occurs. Petroleum is essentially stored solar energy. The difference between petroleum and soybean oil as sinks for solar energy is their time scale. Soybean oil traps solar energy on a rapid ("real time") basis; petroleum storage occurs in geologic time. This difference in the dynamic nature of solar energy use is the key to our definitions of renewable and nonrenewable energy.

Table 5: Primary Energy Requirements for Biodiesel Life Cycle

Stage	Primary Energy (MJ per MJ of Fuel)	Percent
Soybean Agriculture	0.0660	5.32%
Soybean Transport	0.0034	0.27%
Soybean Crushing	0.0803	6.47%
Soy Oil Transport	0.0072	0.58%
Soy Oil Conversion	1.0801	87.01%
Biodiesel Transport	0.0044	0.35%
Total	1.2414	100.00%

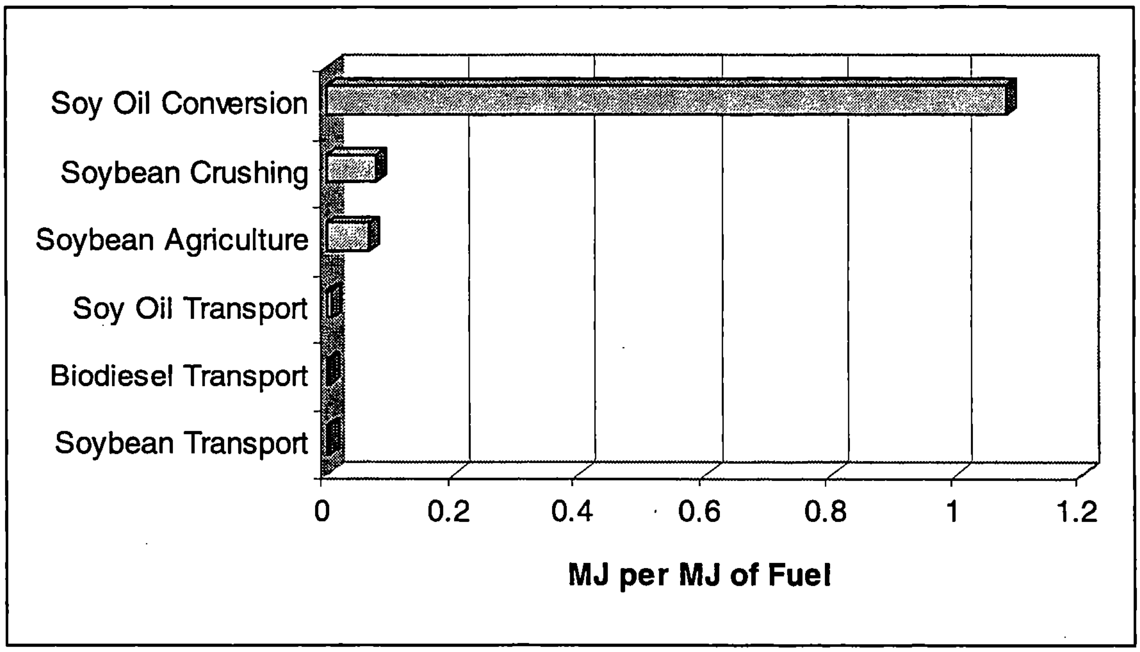

Figure 4: Ranking of Primary Energy Demand for Stages of the Biodiesel Life Cycle

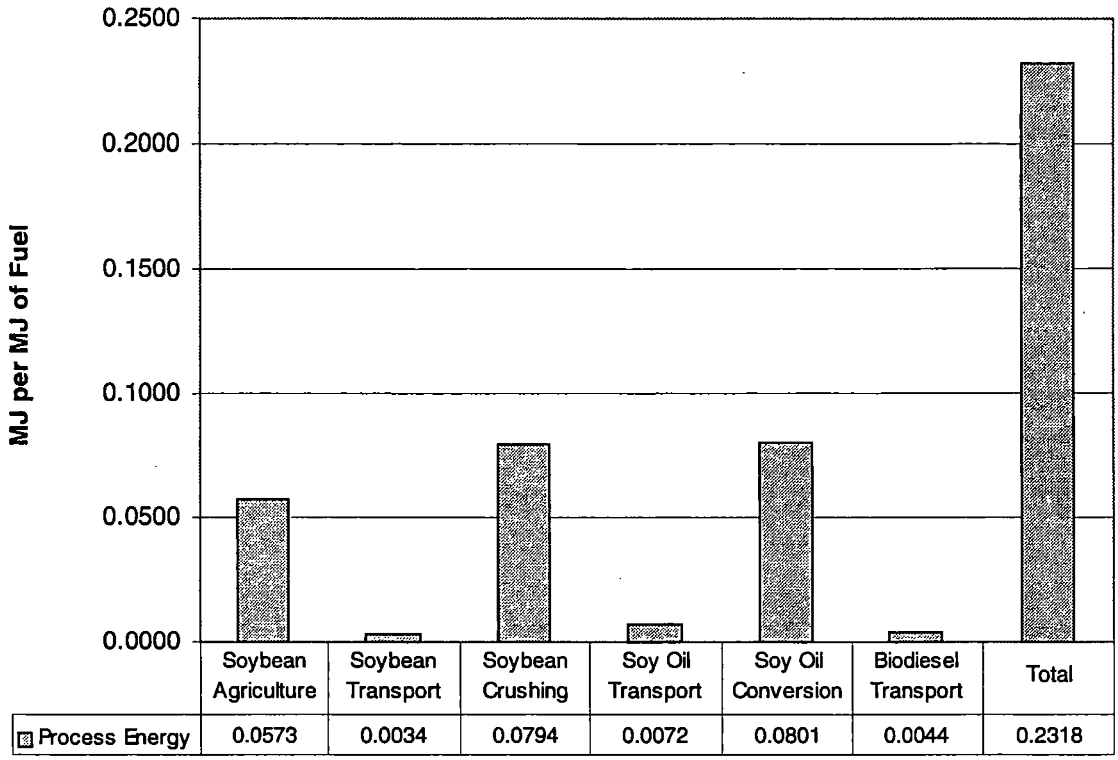

Figure 5: Process Energy Requirements for Biodiesel Life Cycle

Table 6: Fossil Energy Requirements for the Biodiesel Life Cycle

Stage	Fossil Energy (MJ per MJ of Fuel)	Percent
Soybean Agriculture	0.0656	21.08%
Soybean Transport	0.0034	1.09%
Soybean Crushing	0.0796	25.61%
Soy Oil Transport	0.0072	2.31%
Soy Oil Conversion	0.1508	48.49%
Biodiesel Transport	0.0044	1.41%
Total	0.3110	100.00%

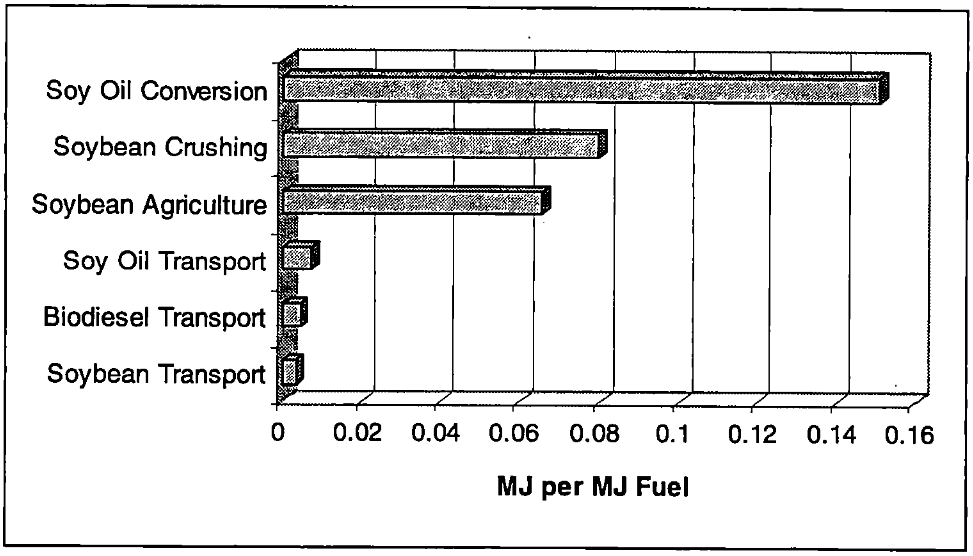

Figure 6: Fossil Energy Requirements versus Fuel Product Energy for the Biodiesel Life Cycle

4.1.2 CO_2 Emissions

4.1.2.1 Accounting for Biomass-Derived Carbon

Biomass plays a unique role in the dynamics of carbon flow in our biosphere. Carbon is biologically cycled when plants such as soybean crops convert atmospheric CO_2 to carbon-based compounds through photosynthesis. This carbon is eventually returned to the atmosphere as organisms consume the biological carbon compounds and respire. Biomass-derived fuels reduce the net atmospheric carbon in two ways. First, they participate in the relatively rapid biological cycling of carbon to the atmosphere (via engine tailpipe emissions) and from the atmosphere (via photosynthesis). Second, they displace fossil fuels. Fossil fuel combustion releases carbon that took millions of years to be removed from the atmosphere; combustion of biomass fuels participates in a process that allows CO_2 to be rapidly recycled to fuel. The net effect of shifting from fossil fuels to biomass-derived fuels is thus to reduce the amount of CO_2 in the atmosphere.

Because of the differences in the dynamics of fossil carbon flow and biomass carbon flow to and from the atmosphere, biomass carbon must be accounted for separately from fossil-derived carbon. The LCI model tracks carbon from the point at which it is taken up as biomass via photosynthesis to its final combustion as biodiesel used in an urban bus. The biomass-derived carbon that becomes CO_2 leaving the tailpipe is subtracted from the total CO_2 emitted by the bus because it is ultimately reused to produce new soybean oil. To ensure that we accurately credit the biodiesel LCI for the amount of recycled CO_2, we provide a material balance on biomass carbon.

The material balance shows all the biomass carbon flows associated with the delivery of 1 bhp-h of engine work (Figure 7). For illustration, only the case of 100% biodiesel is shown. Lower blend rates proportionately lower the amount of biomass carbon credited as part of the recycled CO_2. Carbon incorporated in the meal fraction of the soybeans is not included in the carbon balance. Only carbon in the fatty acids and triglycerides used to produce biodiesel are tracked. Not all the carbon incorporated in fatty acids and triglycerides becomes CO_2 after biodiesel is combusted. Some oil is lost in the meal by-product. Glycerol is removed from the triglycerides as a by-product. Fatty acids are removed as soaps and waste. Finally, carbon released in combustion ends up as CO_2, CO, THC, and TPM. Of the 169.34 grams of carbon absorbed in the soybean agriculture stage, only 148.39 grams (87%) end up in biodiesel. After

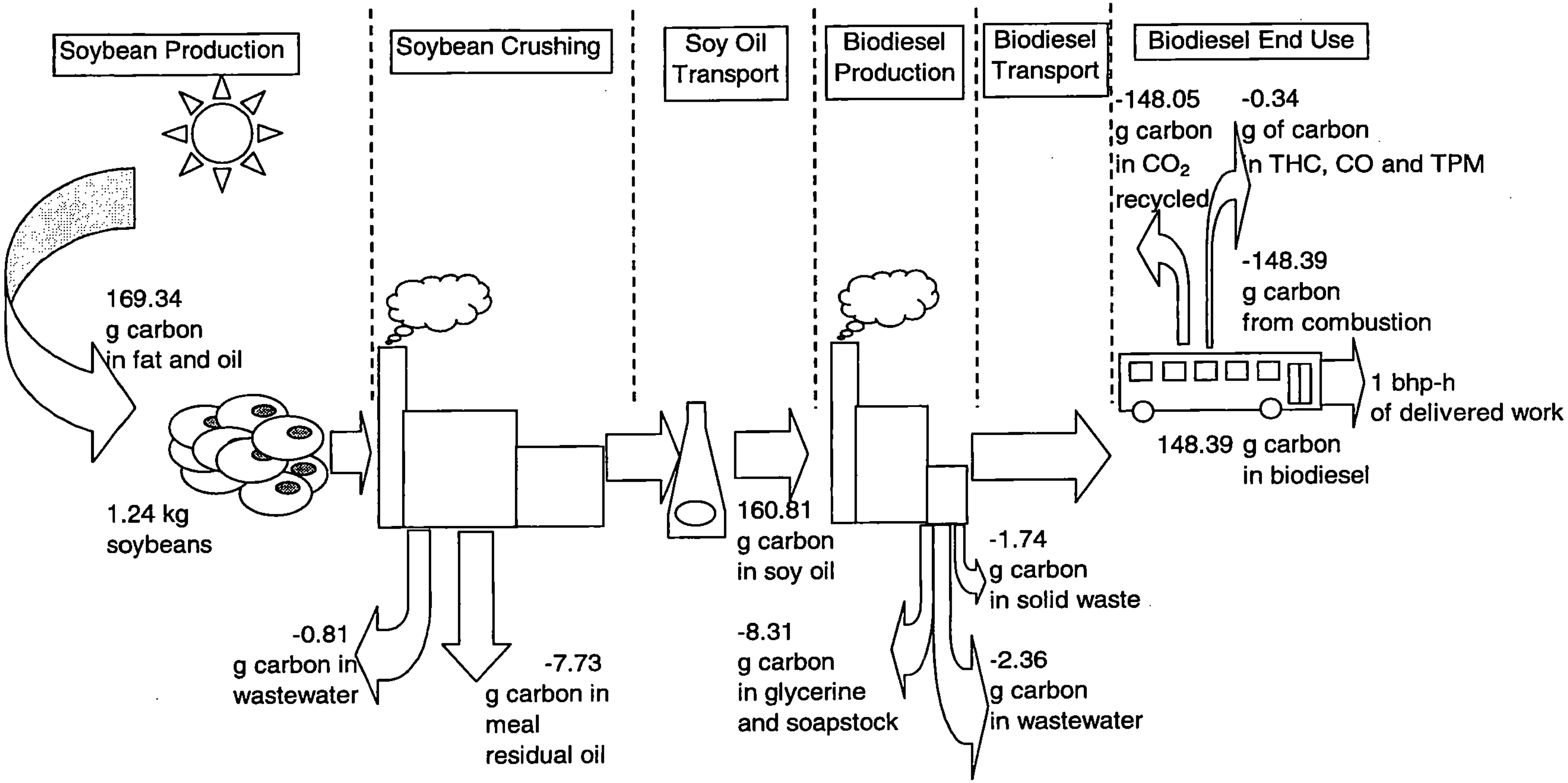

Figure 7: Biomass Carbon Balance for Biodiesel Life Cycle (g carbon/bhp-h)[10]

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[10] All numbers presented as carbon equivalent. To calculate actual CO_2 emissions, multiply carbon equivalent numbers by 3.67 (the ratio of the molecular weight of CO_2 divided by the molecular weight of carbon).

accounting for carbon that ends up in other combustion products, 148.05 grams of carbon end up as 543.34 grams of tailpipe CO_2. This CO_2 is subtracted from the diesel engine emissions as part of the biological recycle of carbon. No credit is taken for the 13% of the carbon that ends up in various by-products and waste streams.

4.1.2.2 Comparison of CO_2 Emissions for Biodiesel and Petroleum Diesel

Table 7 and Figure 8 summarize CO_2 flows from the total life cycles of biodiesel and petroleum diesel and the total CO_2 released at the tailpipe for each fuel. The dominant source of CO_2 for both the petroleum diesel and the biodiesel life cycles is the combustion of fuel in the bus. For petroleum diesel, CO_2 emitted from the tailpipe represents 86.54% of the total CO_2 emitted across the entire life cycle of the fuel. Most remaining CO_2 comes from emissions at the oil refinery, which contribute 9.6% of the total CO_2 emissions. For biodiesel, 84.43% of the CO_2 emissions occur at the tailpipe. The remaining CO_2 comes almost equally from soybean agriculture, soybean crushing, and soy oil conversion to biodiesel. Figure 9 shows the effect of biodiesel blend levels on CO_2 emissions.

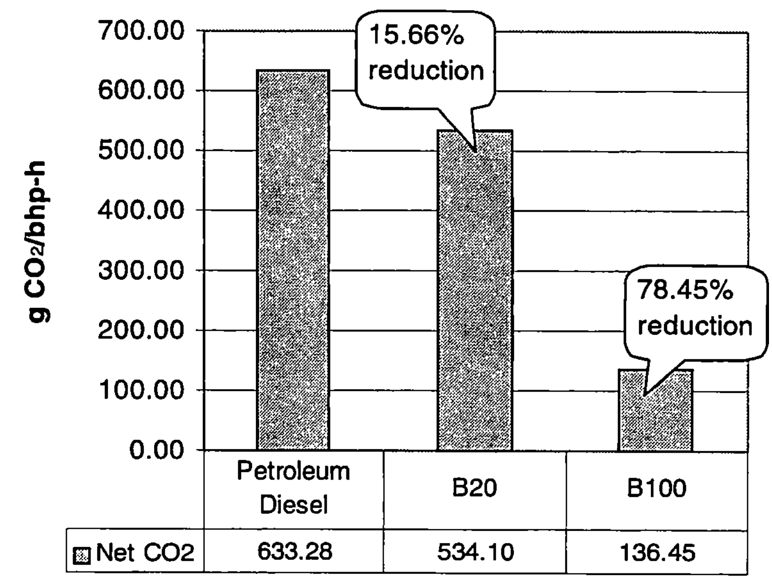


Figure 8: Comparison of Net CO_2 Life Cycle Emissions for Petroleum Diesel and Biodiesel Blends[11]

Table 7: Tailpipe Contribution to Total Life Cycle CO_2 for Petroleum Diesel and Biodiesel (g CO_2/bhp-h)

Fuel	Total Life Cycle Fossil CO_2	Total Life Cycle Biomass CO_2	Total Life Cycle CO_2	Tailpipe Fossil CO_2	Tailpipe Biomass CO_2	Total Tailpipe CO_2	% of Total CO_2 from Tailpipe
Petroleum Diesel	633.28	0.00	633.28	548.02	0.00	548.02	86.54%
B100	136.45	543.34	679.78	30.62	543.34	573.96	84.43%

[11] Net CO_2 calculated by setting biomass CO_2 emissions from the tailpipe to zero.

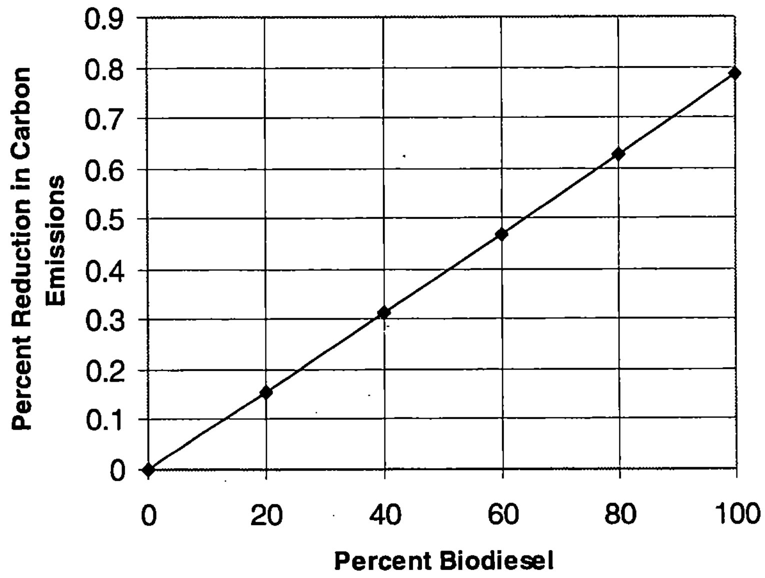


Figure 9: Effect of Biodiesel Blend Level on CO_2 Emissions

At the tailpipe, biodiesel (most of which is renewable) emits 4.7% more CO_2 than petroleum diesel. The nonrenewable portion comes from the methanol. Biodiesel generates 573.96 g/bhp-h compared to 548.02 g/bhp-h for petroleum diesel. The higher CO_2 levels result from more complete combustion and the concomitant reductions in other carbon-containing tailpipe emissions. As Figure 8 shows, the overall life cycle emissions of CO_2 from B100 are 78.45% lower than those of petroleum diesel. The reduction is a direct result of carbon recycling in soybean plants. B20 reduces net CO_2 emissions by 15.66%.

4.1.3 Primary Resource Consumption for Biodiesel and Petroleum Diesel

B100 effects a 95% reduction in life cycle consumption of petroleum. Figure 10 compares petroleum oil consumption for petroleum diesel, B20, and B100. TB20 provides a proportionate reduction of 19%.

Coal and natural gas consumption is a different story (Figure 11). B100 increases life cycle consumption of coal by 19%. This reflects the higher overall demand for electricity in the biodiesel life cycle, relative to petroleum diesel. Electricity demand for soybean crushing is the dominant factor in electricity consumption for biodiesel because of the mechanical processing and solids handling equipment involved. Life cycle consumption of natural gas increases by 77% for biodiesel versus petroleum diesel. Two factors contribute to this increase: (1) the assumed use of natural gas for the supply of steam and process heat in soybean crushing and soy oil conversion, and (2) the use of natural gas to produce methanol used in the conversion step.

The biodiesel life cycle uses much more water than does the petroleum diesel life cycle. Water use for petroleum diesel is not even visible on a plot scaled to show biodiesel use (Figure 12): the biodiesel life cycle's water use is three orders of magnitude higher. The impact of this water use is not addressed in this report. We offer no simple way to compare water use between the two life cycles because there is no simple equivalency in its use and final disposition.

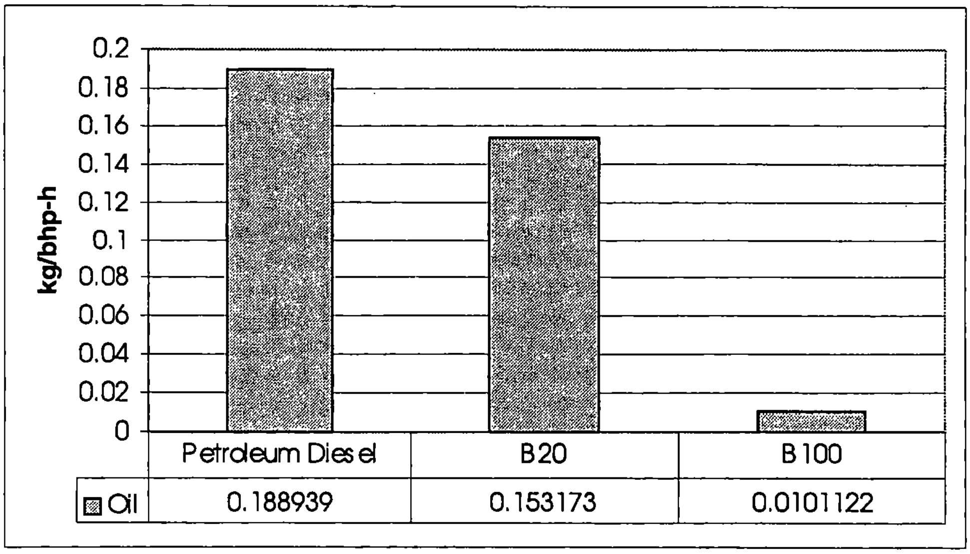


Figure 10: Petroleum Consumption for Petroleum Diesel, B20, and B100

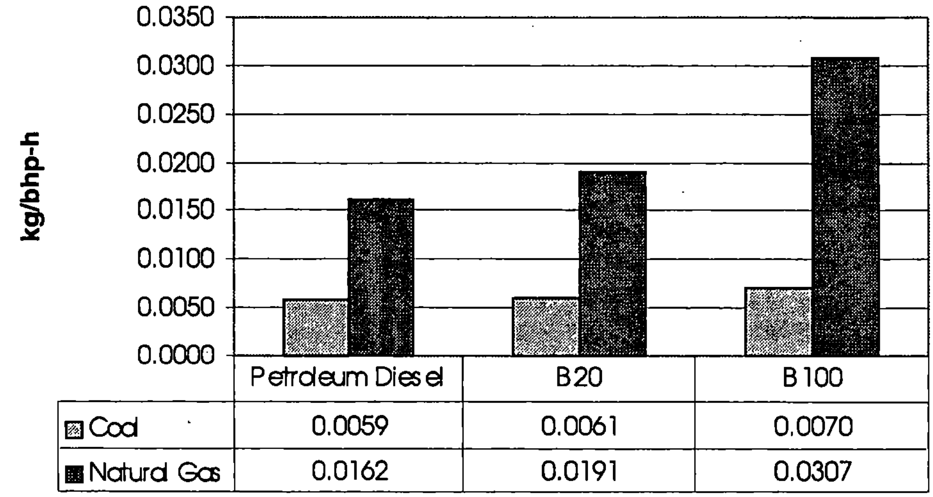
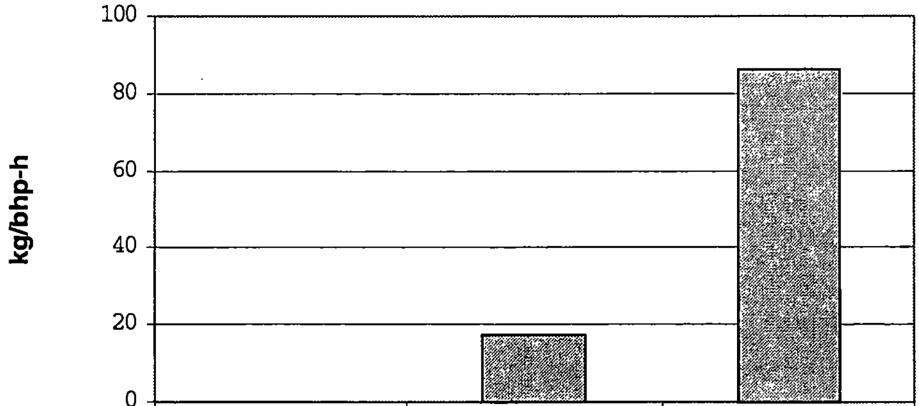


Figure 11: Coal and Natural Gas Consumption for Petroleum Diesel, B20, and B100

4.1.4 Life Cycle Emissions of Regulated and Nonregulated Air Pollutants

Regulated air pollutants include the following:

- Carbon Monoxide (CO)
- Nitrogen Oxides (NO_x)
- Particulate Matter Smaller Than 10 Microns (PM10)
- Sulfur Oxides (SO_x)
- Non-Methane Hydrocarbons (NMHC)



	Petroleum Diesel	B20	B100
Water	0.0262924	17.2938	86.3636

Figure 12: Water Use for Petroleum Diesel, B20, and B100

The emissions of these air pollutants are regulated at the tailpipe for diesel engines. SO_x has no specific tailpipe limits, but it is controlled through the sulfur content of the fuel. Other air emissions included in this study are CH_4, benzene, formaldehyde, nitrous oxide (N_2O), hydrochloric acid (HCl), hydrofluoric acid (HF), and ammonia. N_2O is associated with agricultural field emissions. HCl and HF are associated with coal combustion in electric power stations. Ammonia is released primarily during fertilizer production.

In this section, we discuss overall differences in the emissions of the biodiesel and petroleum life cycles. More detail on the sources of the differences is presented in the comprehensive report, *Life Cycle Inventories of Biodiesel and Petroleum Diesel for Use in an Urban Bus.* Because of variations in how various data sources for the life cycle stages report PM and HC emissions, we report them differently from the EPA definitions. Benzene and formaldehyde emissions are not consistently reported. Some sources explicitly define emissions for NMHC; others do not specify this distinction. HC data are reported as THC, defined as:

$$THC = (CH_4 + Benzene + formaldehyde + HC_{unspecified} + HC_{noCH4})$$

where:

THC = total hydrocarbons

CH_4 = methane

$HC_{unspecified}$ = unspecified hydrocarbons

HC_{noCH4} = hydrocarbons excluding methane

Likewise, particulates are combined as a single category according to the following formula:

$$TPM = (PM10 + PM_{unspecified})$$

where:

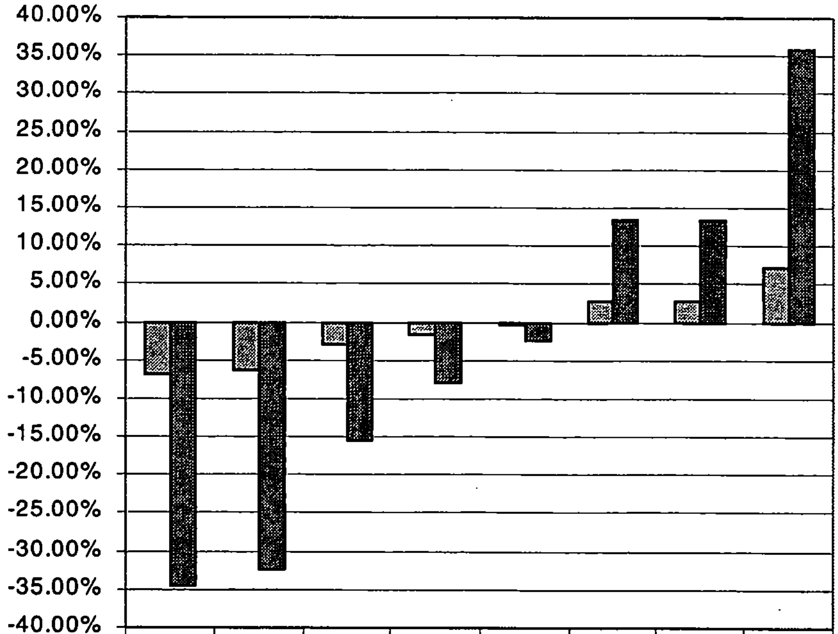
TPM = total particulate matter

PM10 = particulate matter smaller than 10 microns

$PM_{unspecified}$ = unspecified particulate matter

4.1.4.1 Comparison of Life Cycle Air Emissions for Biodiesel and Petroleum Diesel

Figure 13 summarizes the differences in life cycle air emissions for B100 and B20 versus petroleum diesel fuel. Replacing petroleum diesel with biodiesel in an urban bus reduces life cycle air emissions for all but three of the pollutants we tracked. The largest reduction (34.5%) in air emissions that occurs when B100 or B20 is used as a substitute for petroleum diesel is for CO. The effectiveness of B20 in reducing life cycle emissions of CO drops proportionately with the blend level. Biodiesel could, therefore, effectively reduce CO emissions in CO non-attainment areas[12].



	CO	TPM	HF	SOx	CH4	NOx	HCl	THC
B20	-6.90%	-6.48%	-3.10%	-1.61%	-0.51%	2.67%	2.71%	7.19%
B100	-34.50	-32.41	-15.51	-8.03%	-2.57%	13.35%	13.54%	35.96%

Figure 13: Life Cycle Air Emissions for B100 and B20 Compared to Petroleum Diesel Life Cycle Air Emissions

B100 exhibits life cycle TPM emissions that are 32.41% lower than those of the petroleum diesel life cycle. As with CO, the effectiveness of biodiesel in reducing TPM drops proportionately with blend level. This is a direct result of reductions in PM10 at the tailpipe, which are 68% lower for urban buses operating on B100 versus petroleum diesel. PM10 emitted from mobile sources is a major EPA target because of its role in respiratory disease. Urban areas represent the greatest risk in terms of numbers of people exposed and levels of PM10. Using biodiesel in urban buses may be an option for controlling life cycle emissions of TPM and tailpipe emissions of PM10[13].

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[12] Urban areas in the United States that do not currently meet National Ambient Air Quality Standards for CO levels.

[13] Among the options EPA is considering, are regulations that would control levels of PM2.5 (particles of 2.5 microns or smaller), as opposed to PM10. That is, EPA is focusing its attention on the very smallest particles in

Biodiesel's life cycle produces 35% more THC than petroleum diesel's life cycle, even though tailpipe THC emissions for B100 are 37% lower. Most of the biodiesel life cycle THC emissions are produced during agricultural operations and soybean crushing. To understand the implications of the higher life cycle emissions, it is important to remember that HC emissions, as with all the air pollutants discussed, have localized effects. *Where* these emissions occur is important. The fact that biodiesel's tailpipe HC emissions are lower than diesel fuel's may indicate that the biodiesel life cycle has beneficial effects on urban air quality (although diesel engines have very low HC emission levels and diesel HC emissions have not been a concern in the past).

Methane (CH_4) is a special subset of THC emissions and a greenhouse gas. CH_4 emissions are 25% of the life cycle emissions of THC for B100 and 32% for B20. All occur in the fuel production and use steps and are associated with producing the methanol used to transesterify soy oil. CH_4 life cycle emissions are 2.57% lower for B100 and 0.51% for B20, compared to petroleum diesel. Though the reductions achieved with biodiesel are small, they could be significant when estimated on the basis of its "CO_2 equivalent"-warming potential[14].

Perhaps the next most critical pollutant from the perspectives of human health and environmental quality is NO_x. The triumvirate of CO, THC, and NO_x is the key to controlling ground-level ozone and smog in urban areas. Their relative importance is not at all clear because they interact in a complex set of chemical reactions catalyzed by sunlight[15]. Biodiesel effectively reduces tailpipe emissions of CO and THC. However, both B100 and B20 have life cycle *and* tailpipe emissions of NO_x that are higher than those of petroleum diesel. B100 and B20 exhibit 13.35% and 2.67% higher life cycle emissions, respectively, compared to petroleum diesel. TPM and NO_x emissions are inversely related in diesel engine exhaust; reducing one often leads to increasing the other. Reducing NO_x emissions involves a combination of fuel research and engine technology research. Within these two arenas, there may be solutions for meeting the tougher future standards for NO_x without sacrificing the other benefits of this fuel.

B100 and B20 life cycle SO_x emissions are lower than those of petroleum diesel (8.03% and 1.61%, respectively). This is a relatively low reduction given that biodiesel completely eliminates SO_x at the tailpipe. The amount of SO_x in the emissions from a diesel engine is a function of sulfur content in the fuel. With this in mind, EPA regulates diesel fuel's sulfur content, rather than tailpipe SO_x emissions. The latest requirements for diesel fuel include 0.05 wt% sulfur for on-highway fuel. Biodiesel can eliminate tailpipe SO_x emissions because it is sulfur-free. On a life cycle basis, the SO_x emissions eliminated at the tailpipe are offset by creating SO_x emissions when we produce the electricity used in the biodiesel life cycle.

HCl and HF emissions are emitted in very low levels as a part of the life cycles of both petroleum diesel and biodiesel. We tracked them because they may contribute to acidification in the environment. Both pollutants occur as a result of coal combustion in electric power generation. HF levels drop with biodiesel in proportion to the amount of electricity consumed over the life cycle of the fuel. This amounts to 15.51% reductions for B100. HCl emissions, on the other hand, increase with biodiesel blend. Biodiesel has additional sources of HCl associated with the production and use of inorganic acids and bases used in the conversion step. B100 increases emissions of HCl by 13.54%.

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ambient air. Data collected in this study focus on PM10. Our results bode well for lowering levels of PM10, but no information on the effect of biodiesel on this new class of smaller particles is available.

[14] CH_4 is a more potent greenhouse gas, but its half-life in the atmosphere is less than that of CO_2. These complications illustrate why we have avoided making quantitative judgments about the life cycle impacts of biodiesel. We leave it to others to evaluate the comparative inventories of biodiesel and diesel in terms of their positive and negative impacts.

[15] For an excellent discussion of the complexities of urban air pollution, see Seinfeld, John H., "Urban Air Pollution: State of the Science" in *Science* 243:745-752.

The results shown so far describe *life cycle* emission levels. Many people are also interested in only a subset of life cycle emissions, those being tailpipe emissions. For the reader's convenience, Table 8 provides the data used to model tailpipe emissions for biodiesel, diesel, and B20.

Table 8: Effect of Biodiesel on Tailpipe Emissions (g/bhp-h)

Emission	Diesel Fuel Baseline	20% Biodiesel Blend	100% Neat Biodiesel
Carbon Dioxide (fossil)	633.28	534.10	136.45
Carbon Dioxide (biomass)	0	108.7	543.34
Carbon Monoxide	1.2	1.089	0.6452
Hydrocarbons	0.1	0.09265	0.06327
Particulate Matter (PM10)	0.08	0.0691	0.02554
Sulfur Oxides (as SO_2)	0.17	0.14	0
Nitrogen Oxides (as NO_2)	4.8	4.885	5.227

4.1.5 Life Cycle Emissions of Water Effluents

We tracked a number of waterborne effluents through the life cycles for petroleum diesel and biodiesel such as biological oxygen demand and chemical oxygen demand. However, relatively few data were consistently available. Therefore, comparisons of the two life cycles are limited to total wastewater flow. Foreign and domestic crude oil extraction account for 78% of the total wastewater flow in the petroleum diesel life cycle. Only about 12% is associated with the refinery. Two-thirds of the total wastewater flows in the biodiesel life cycle come from the soy oil conversion process. This step generates relatively dilute wastewater that contains oil and soap from soybean oil processing. A comparison of total wastewater flows from the life cycles for petroleum diesel and biodiesel is shown in Figure 14. Petroleum diesel generates roughly five times as much wastewater flow as biodiesel.

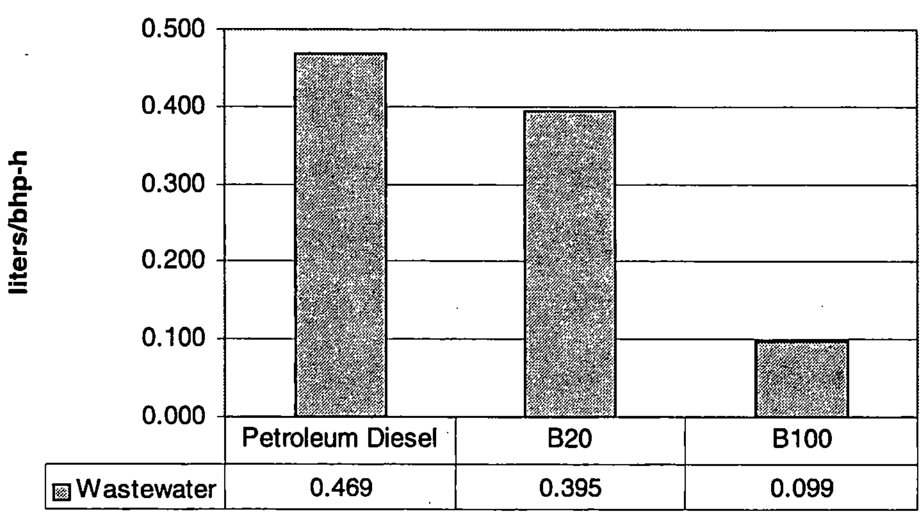


Figure 14: Comparison of Total Wastewater Flows for Petroleum Diesel and Biodiesel Life Cycles

4.1.6 Comparison of Solid Waste Life Cycle Flows

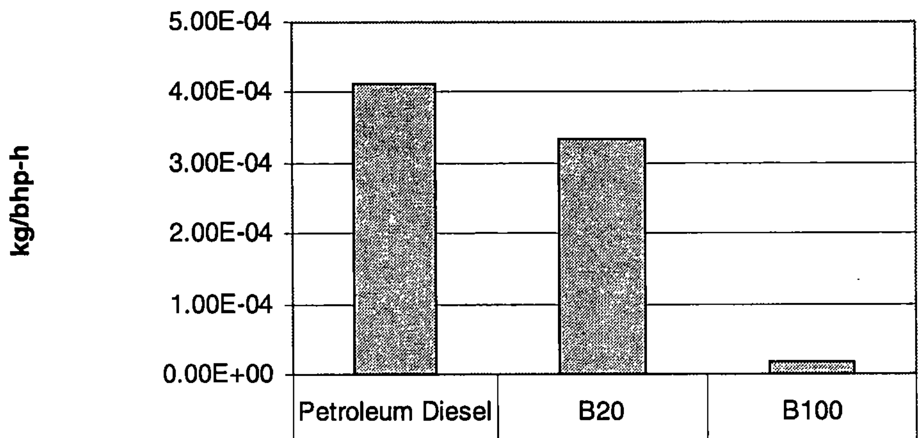
Solid waste from the two life cycles is classified as hazardous or nonhazardous. In the petroleum diesel life cycle, hazardous waste is derived almost entirely from the crude oil refining process. The minor levels of solid waste that show up in foreign crude transport and diesel fuel transport are indirect flows of solid waste attributable to production of diesel fuel and gasoline used in the transportation process. Total hazardous waste generation amounts to 0.41 g/bhp-h of engine work. About half of the nonhazardous waste generated by petroleum diesel is in the crude oil refining step. Another third is generated in the foreign and domestic crude oil extraction steps. Total nonhazardous waste generation in the petroleum diesel life cycle is 2.8 g/bhp-h.

Hazardous waste from the biodiesel life cycle amounts to only 0.018 g/bhp-h of engine work. Soybean agriculture contributes 70% of the hazardous waste from the life cycle, but these flows are indirect charges against agriculture for hazardous waste flows associated with the production of diesel fuel and gasoline used on the farm. Nonhazardous solid waste generated in the biodiesel life cycle is 12.7 g/bhp-h of engine work. This waste is primarily trash and tramp metals removed from soybeans brought into the soybean crushing stage. Figure 15 and Figure 16 show hazardous and nonhazardous solid waste generation for petroleum diesel and biodiesel. The B100 life cycle produces 96% less hazardous waste compared to petroleum diesel life cycle. Nonhazardous waste, on the other hand, is twice as high for B100.

4.2 Sensitivity Studies

4.2.1 The Effect of Enhanced Location for Biodiesel Production and Use

We studied the effect of placing biodiesel production and use in a more optimal location, which mimics how similar renewable fuels industries, such as ethanol, have developed. We therefore modeled biodiesel production and use in the Chicago area, which provides a good outlet for biodiesel sales for the urban bus end use. More importantly, it allows us to consider near-term access to some of the best soybean farmland in the United States. This scenario reduces the distances required to move beans, oil, and biodiesel, and allows us to take advantage of high-yield soybean agriculture.



	Petroleum Diesel	B20	B100
Hazardous Waste	4.13E-04	3.34E-04	1.82E-05

Figure 15: Hazardous Waste Generation for Petroleum Diesel, B20, and B100

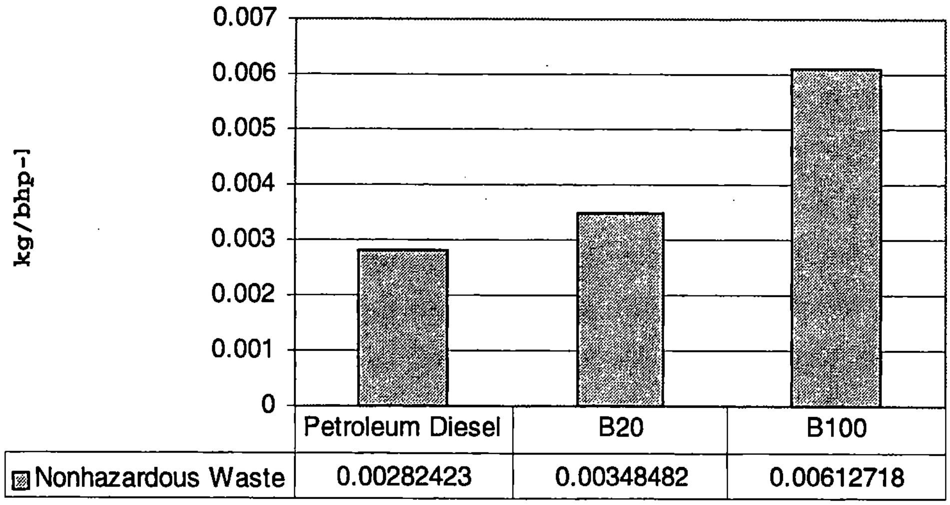


Figure 16: Nonhazardous Waste Generation for Petroleum Diesel, B20, and B100

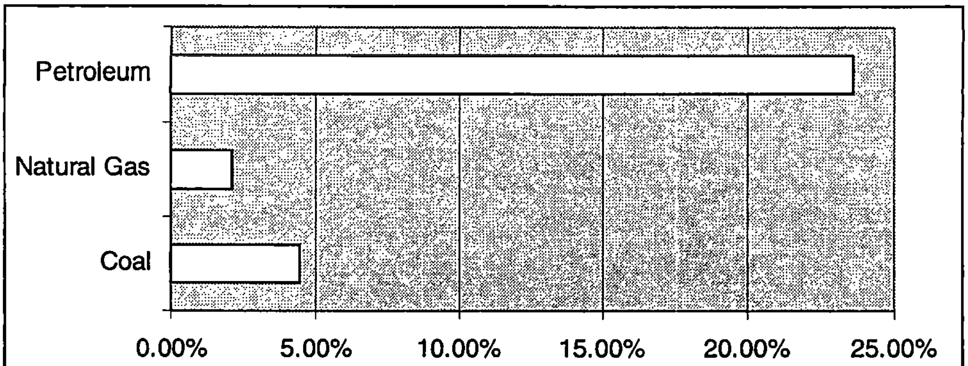
Basic changes to the model are shown inTable 9. The reduced distance for shipping soybean oil is based on an evaluation of the location of crushing facilities to potential market locations. The results of the model with these assumptions is presented for B100 (the improvements or worsening in life cycle emissions relative to petroleum diesel are proportional to the blend level).

Placing biodiesel production and use in the Chicago area has benefits for energy consumption (see Figure 17). Impacts on natural gas and coal consumption are minor (2% and 5% savings, respectively). Petroleum consumption, on the other hand, drops by 23.53% from the national average base case. This leads to a slight increase in life cycle energy efficiency from the base case value of 80.55% to 81.84%. Biodiesel's fossil energy ratio increases from 3.22 to 3.43. The energy savings occur primarily on the farm. Process energy requirements for farming drop by 22%. Energy savings of 56% are also realized in the soy oil transport step, but this impact is smaller because of the relatively small contribution to energy demand made by this step. Water use drops dramatically (31%) in the Chicago area scenario.

Table 9: Model Parameters for the Chicago Area Biodiesel Scenario

Model Parameter	Baseline Scenario	Chicago Area Scenario
Soybean Agriculture	Yields and inputs based on national average (14 key soybean-producing states)	Yields and inputs based on production of soybeans from Illinois and Iowa. 50% of soybean supply is taken from each state.
Transport Distances	National average distance for soy oil of 571 miles	Reduced travel distance of 248 miles.

The percent reductions of key air pollutants are tabulated in Figure 18. The change to a more favorable location has modest benefits for air emissions. The exception is for ammonia emissions, which drop by 45%. Ammonia emissions occur as a result of nitrogen fertilizer use. The large drop in life cycle ammonia emissions is due to improved yields and lower nitrogen fertilizer use rates per kg of soybeans produced. The next largest saving is for PM10 emissions, which drop 10% from the base case. This is consistent



	Coal	Natural Gas	Petroleum
□%	4.45%	2.13%	23.53%

Percent Reduction

Figure 17: The Effect of an Enhanced Location for Biodiesel on Life Cycle Consumption of Primary Energy Resources

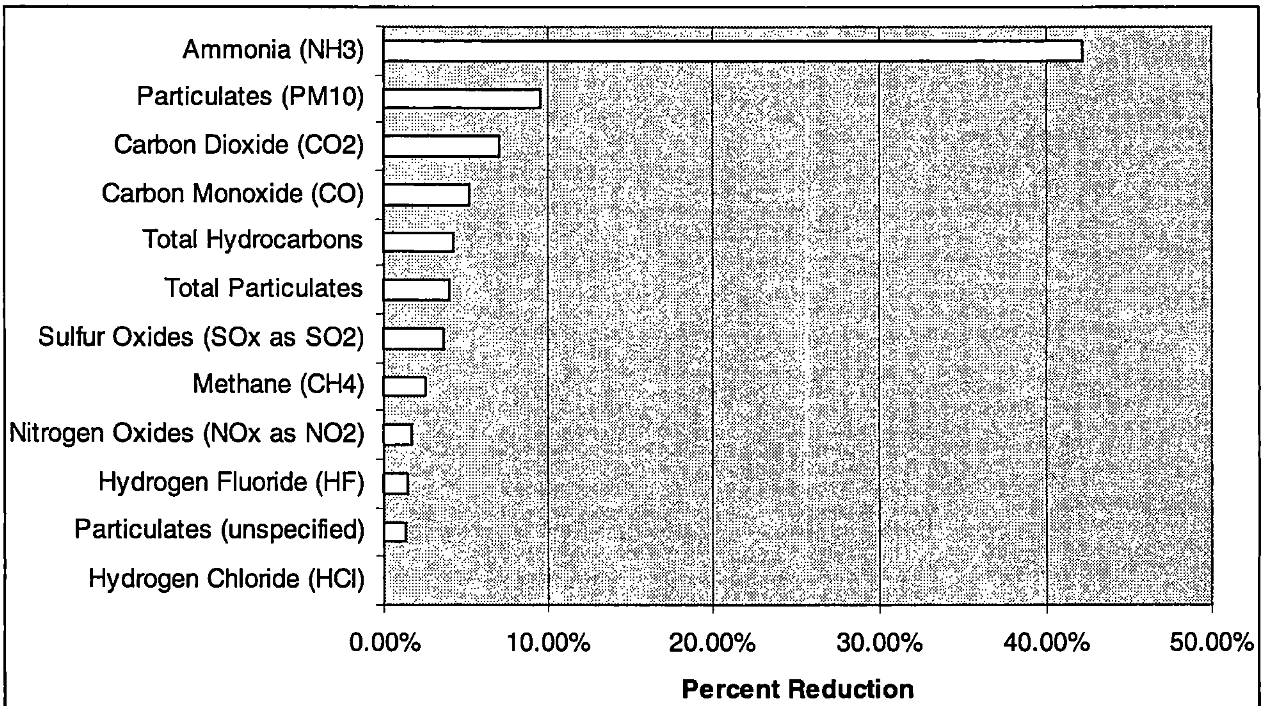


Figure 18 : Reductions in Life Cycle Air Emissions for the Chicago Area Biodiesel Scenario

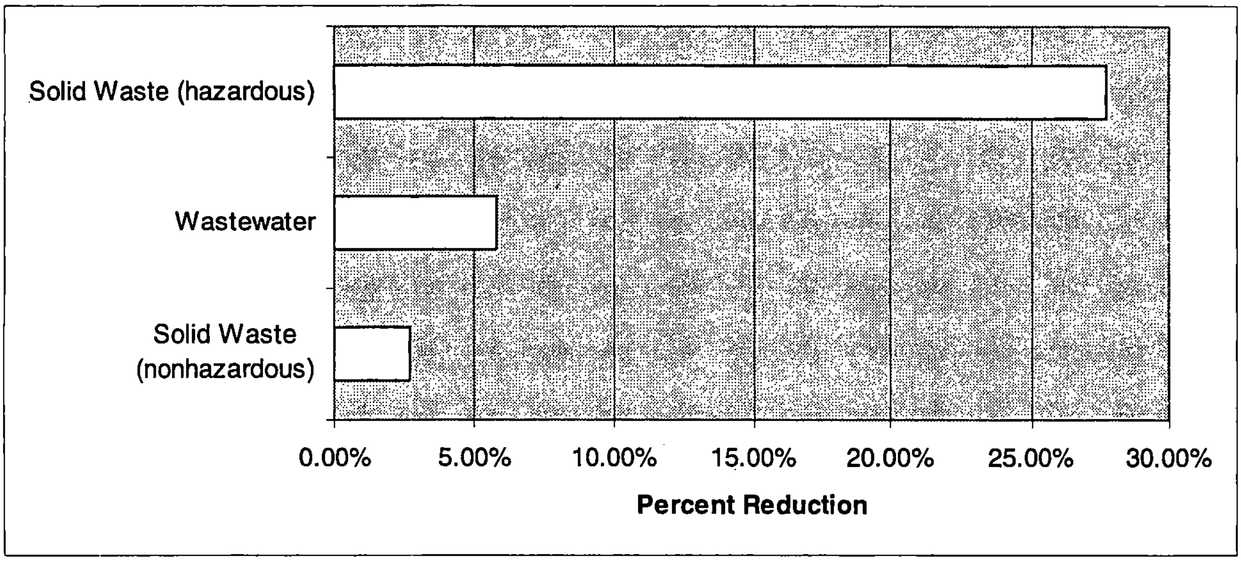


Figure 19: Water and Solid Waste Emissions Reductions for the Chicago Area Biodiesel Scenario

with the reductions in petroleum consumption associated with diesel fuel use on the farm. The Chicago scenario provides an additional savings of 7% in CO_2 emissions. All other emissions savings are less than 5%, compared to the base case.

Reductions in life cycle waste emissions are shown in Figure 19. Hazardous waste emissions are reduced dramatically. The 28% reduction corresponds to lower levels of diesel fuel use in soybean farming. Wastewater is reduced by 5.79%; nonhazardous solid wastes by 2.72%.

4.2.2 The Effect of Energy Requirements for Conversion of Soybean Oil to Biodiesel

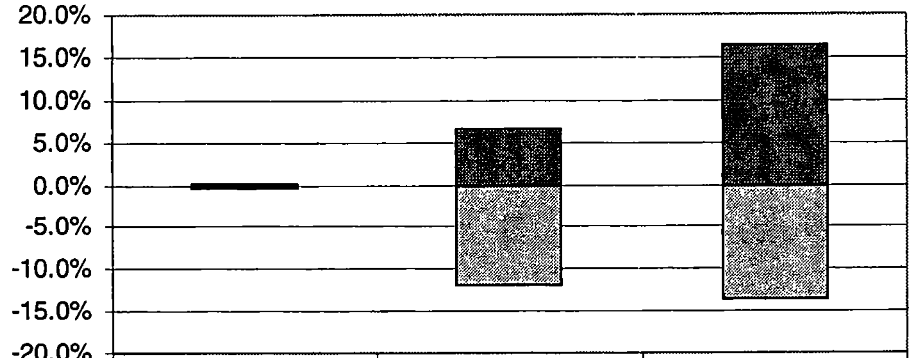
A range of energy inputs for converting soybean oil to biodiesel was used in the LCI model to test the effect of these modeling assumptions on the overall LCI of biodiesel. A survey of current commercial technology for biodiesel reveals a high degree of variation on reported steam and electricity requirements for the transesterification process. High and low estimates for both steam and electricity used in the model are indicated in Table 10.

Table 10: Range of Energy Inputs for Soybean Oil Conversion Tested in LCI Model

Energy Use	Low Value	Baseline Scenario	High Value
Steam (kcal/metric ton of biodiesel produced)	95,022.7	329,793.5	617,922.2
Electricity (kWh/metric ton of biodiesel produced)	9.0	28.9	40.0

Steam requirements vary 3.5-fold from the lowest to the highest value. Electricity varies 4.4-fold. This high degree of variability warrants testing the range of our assumptions to assess the uncertainty of our pertinent results. Also, energy inputs for soybean oil conversion comprise a substantial part of the life cycle, and make this variability even more important.

The effect of conversion energy variability on the demand for primary energy resources is shown in Figure 20. Overall effects on primary energy are considerably smaller than the range of variation in energy inputs. Oil consumption is unaffected. Because natural gas is the sole source of process energy in the conversion model, it is the most affected by the energy requirements assumed for this stage. Natural gas consumption increases 16.41% for the high energy inputs and decreases by 13.5% for the low energy inputs. Coal consumption ranges from +6.55% to –11.7% of the base case.

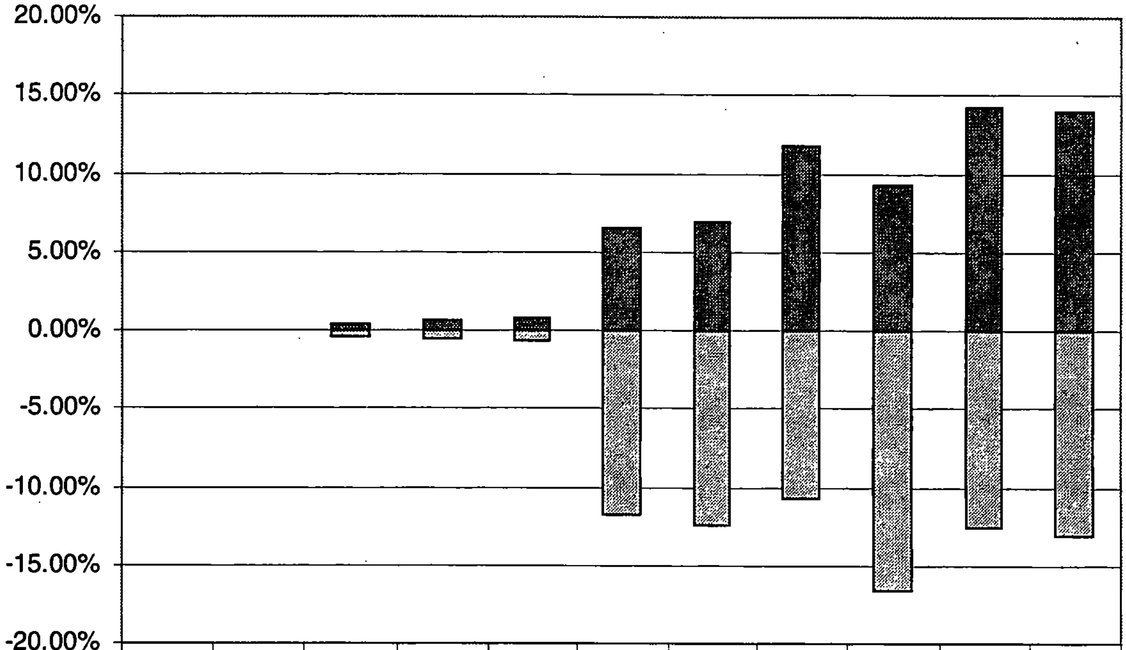


	Oil	Coal	Natural Gas
% High	0.16%	6.55%	16.41%
% Low	-0.3%	-11.7%	-13.5%

Figure 20: The Effect of Conversion Energy Requirements on Primary Energy Resource Demands for Biodiesel

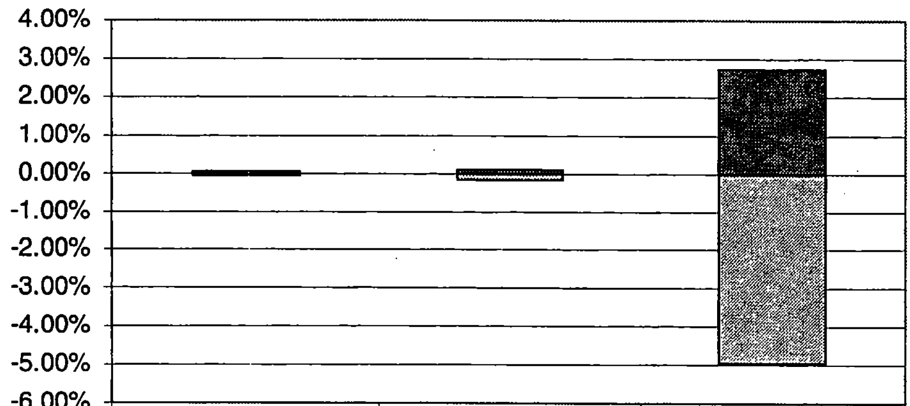
Figure 21 presents changes in biodiesel's life cycle air emissions across the range of assumed energy requirements for soybean oil conversion. Life cycle emissions are listed in order of increasing sensitivity to energy requirement assumptions. Changes in steam requirements (and hence natural gas consumption) strongly affect CH_4 emissions, which can vary by 14% in both directions. From a greenhouse gas perspective, this is probably the most significant change observed in this sensitivity study. CO_2 shows similar responses. Unspecified PM and SO_x emissions are also affected significantly, reflecting emissions from combustion for electricity generation. The other emissions show little response to the energy inputs for soy oil conversion.

The relative changes in solid waste and wastewater emissions are presented in Figure 22. Wastewater and hazardous solid waste emissions change little across the range of assumed energy requirements. Nonhazardous solid waste shows a moderate response.



	HC unspec	HC less CH4	NOx	CO	PM10	PM unspec	HCl	CO2	HF	SOx	CH4
% High	0.03%	0.04%	0.43%	0.63%	0.76%	6.60%	6.91%	11.83%	9.29%	14.25%	14.03%
% Low	-0.04%	-0.04%	-0.43%	-0.55%	-0.62%	-11.82%	-12.39%	-10.66%	-16.65%	-12.54%	-13.13%

Figure 21: The Effect of Soybean Oil Conversion Energy Demands on Air Emissions for Biodiesel



	Wastewater	Solid Waste (Hazardous)	Solid Waste (Non-hazardous)
% High	0.04%	0.11%	2.75%
% Low	-0.06%	-0.19%	-4.93%

Figure 22: The Effect of Soybean Oil Conversion Energy Demands on Water and Solid Waste Emissions for Biodiesel

5 Conclusions

Conducting LCIs is fraught with difficulties. Incomplete data are the rule rather than the exception, so we have varying degrees of confidence in our results. The most complete data, and hence the most reliable conclusions, are for overall energy balance and CO_2 emissions. More importantly, our sensitivity studies show that the estimates of CO_2 emissions and energy requirements are very robust; that is, they show little change in response to changes in key assumptions.

5.1 Life Cycle Energy and Environmental Flows

Major analytical results are presented below in order of decreasing confidence:

- ***Energy Balance.*** Biodiesel and petroleum diesel have very similar energy efficiencies. The base-case model estimates life cycle energy efficiencies of 80.55% for biodiesel versus 83.28% for petroleum diesel. The lower efficiency for biodiesel reflects slightly higher process energy requirements for converting the energy contained in soybean oil to fuel. In terms of effective use of fossil energy resources, biodiesel yields around 3.2 units of fuel product energy for every unit of fossil energy consumed in the life cycle. By contrast, petroleum diesel's life cycle yields only 0.83 units of fuel product energy per unit of fossil energy consumed. Such measures confirm the "renewable" nature of biodiesel. The life cycle for B20 has a proportionately lower fossil energy ratio (0.98 units of fuel product energy for every unit of fossil energy consumed). B20's fossil energy ratio reflects the impact of adding petroleum diesel into the blend.
- ***Carbon Dioxide Emissions.*** The demand for fossil energy associated with biodiesel is low, so its life cycle emissions of CO_2 are, not surprisingly, much lower. Per unit of work delivered by a bus engine, B100 reduces net CO_2 emissions by 78.45% compared to petroleum diesel. B20's life cycle CO_2 emissions are 15.66% lower. Thus, replacing petroleum diesel with biodiesel in urban buses is an extremely effective strategy for reducing CO_2 emissions.
- ***Total Particulate Matter and Carbon Monoxide Emissions.*** The B100 life cycle produces 32% less TPM and 35% less CO than the petroleum diesel life cycle. Most occur because of lower emissions at the tailpipe. PM10 emissions from an urban bus operating on biodiesel are 68% lower than those from an urban bus operating on petroleum diesel. Biodiesel reduces tailpipe CO emissions by 46%.
- ***Nitrogen Oxide Emissions.*** At the same time, NO_x emissions are 13% higher for the B100 life cycle compared to the petroleum diesel life cycle. B20 has 2.67% higher life cycle emissions of NO_x. Again, this increase is attributed to higher NO_x emissions at the tailpipe. An urban bus run on B100 has NO_x emissions that are 8.89% higher than a bus operated on petroleum diesel.
- ***Total Hydrocarbons.*** We also report 35% higher life cycle emissions of THC compared to petroleum diesel, but tailpipe THC emissions are 37% lower for B100 than for petroleum diesel. The increase results from hexane being released during soybean processing and to volatilization of agrochemicals applied on the farm. We have less

confidence in the HC air emissions results from this study. Air emissions data are often not reported on the same basis. For example, data run the gamut from specific HC compounds such as CH_4 or benzene to broad measures of THCs, which are not measured consistently. Our data set includes numbers reported as unspecified HCs and as NMHCs. We therefore view these data with caution.

- ***Water and Solid Waste***. We report total wastewater and solid waste flows. Our results show that biodiesel life cycle wastewater flows are almost 80% lower than those of petroleum diesel. Biodiesel is also responsible for only about 5% of the hazardous waste generated by petroleum diesel. However, we do not have a consistent basis for comparing these flows because their final disposition and composition are so different.
- ***Water Consumption.*** On a life cycle basis, B100 uses water at a level that is three orders of magnitude higher than petroleum diesel.

5.2 Next Steps

We designed this study to identify and quantify the advantages of biodiesel as a substitute for petroleum diesel. These advantages are substantial, especially in the area of energy security and greenhouse gas control. We have also identified weaknesses or areas of concern for biodiesel—such as its NO_x and THC emissions. We see these as opportunities for further research. We hope our findings will be used to focus future biodiesel research on these critical issues.

Next steps for this work include:

- ✓ Use the LCI to assess the relative environmental and public health effects of petroleum diesel and biodiesel to better understand the benefits associated with biodiesel.
- ✓ Quantify the costs and benefits of biodiesel.
- ✓ Assess the economic impact of biodiesel as an alternative fuel (e.g., its effects on jobs and the trade deficit).
- ✓ Evaluate other feedstock sources.
- ✓ Incorporate new health effects data on emissions from biodiesel and petroleum diesel.
- ✓ Develop regional life cycle models for biodiesel use.
- ✓ Evaluate performance of newer diesel engines and new fuel production technologies.

This study provides the building blocks for assessing the relative merits of this fuel under a wide variety of circumstances. It also provides information that local regulators seek when developing approaches to solving our air, water, and solid waste problems. We leave it to these individuals to use this information to customize their evaluations of their particular questions. We ask only that it be used wisely.

6 Life Cycle Data Tables

The life cycle analysis produced data describing each major step in the production and use of biodiesel and diesel fuel. These tables are provided here to aid the reader in understanding where various emissions and inputs occurred during the life cycles. In order to understand these tables the following issues need to be considered. First, all the inputs and outflows associated with each step in the life cycles are shown as units per brake horsepower hour of diesel engine service. Second, these data have already been "allocated;" in other words, if a process creates two products, the inputs (energy, chemicals, feedstocks) and the emissions (air, water, solid wastes) have been divided up between the two products based on a mass allocation. Only the fraction of the inputs and emissions that have been allocated to diesel fuel and biodiesel are shown. Third, some inputs, such as electricity, are not shown directly. Instead, the raw materials consumed to make the electricity are shown. So instead of electricity, you will see estimates of coal, natural gas, or uranium inputs. Lastly, the degree of accuracy shown, e.g., number of spaces right of a decimal point, are not indicative of the confidence we place in the number itself. The degree of accuracy shown provides an opportunity for another researcher to reproduce our numbers. Our confidence in how accurately the number reflects actual industry averages may be quite different, and has been described in earlier sections. For more information, please see the detailed, comprehensive report, *Life Cycle Inventories of Biodiesel and Petroleum Diesel for Use in an Urban Bus.*

The life cycle tables are provided in the following order: energy efficiency, carbon balance, inputs, and air emissions.

Table 11: Primary Energy Demand for the Petroleum Diesel Life Cycle Inventory

Stage	Primary Energy (MJ per MJ of Fuel)	Percent
Domestic Crude Production	0.5731	47.73%
Foreign Crude Oil Production	0.5400	44.97%
Domestic Crude Transport	0.0033	0.28%
Foreign Crude Transport	0.0131	1.09%
Crude Oil Refining	0.0650	5.41%
Diesel Fuel Transport	0.0063	0.52%
Total	1.2007	100.00%

Table 12: Fossil Energy Requirements for the Petroleum Diesel Life Cycle

Stage	Fossil Energy (MJ per MJ of Fuel)	Percent
Domestic Crude Production	0.572809	47.75%
Foreign Crude Oil Production	0.539784	45.00%
Domestic Crude Transport	0.003235	0.27%
Foreign Crude Transport	0.013021	1.09%
Crude Oil Refining	0.064499	5.38%
Diesel Fuel Transport	0.006174	0.51%
Total	1.199522	100.00%

Table 13: Primary Energy Requirements for Biodiesel Life Cycle

Stage	Primary Energy (MJ per MJ of Fuel)	Percent
Soybean Agriculture	0.0660	5.32%
Soybean Transport	0.0034	0.27%
Soybean Crushing	0.0803	6.47%
Soy Oil Transport	0.0072	0.58%
Soy Oil Conversion	1.0801	87.01%
Biodiesel Transport	0.0044	0.35%
Total	1.2414	100.00%

Table 14: Fossil Energy Requirements for the Biodiesel Life Cycle

Stage	Fossil Energy (MJ per MJ of Fuel)	Percent
Soybean Agriculture	0.0656	21.08%
Soybean Transport	0.0034	1.09%
Soybean Crushing	0.0796	25.61%
Soy Oil Transport	0.0072	2.31%
Soy Oil Conversion	0.1508	48.49%
Biodiesel Transport	0.0044	1.41%
Total	0.3110	100.00%

Table 15: Biomass Carbon Balance for Biodiesel Life Cycle (g/bhp-h)[16]

Life Cycle Stage	g carbon per bhp-h	g CO_2/bhp-h
Soybean Production	**169.34**	**621.48**
Uptake of carbon in triglycerides and fatty acids	169.34	621.48
Soybean Crushing	**160.81**	**590.16**
Release of carbon via residual oil in meal	(7.73)	(28.36)
Release of carbon via waste	(0.81)	(2.97)
Biodiesel Production	**148.39**	**544.60**
Release of carbon via glycerine	(8.26)	(30.32)
Release of carbon via wastewater	(2.36)	(8.67)
Release of carbon via solid waste	(1.74)	(6.40)
Release of carbon in soapstock	(0.05)	(0.17)
Combustion in bus		-
Release of carbon in biodiesel (total)	(148.39)	(544.60)
Release of carbon in CO_2	(148.05)	(543.34)
Release of carbon in HC	(0.04)	(0.16)
Release of carbon in CO	(0.28)	(1.01)
Release of carbon in PM	(0.02)	(0.08)
Release of carbon in HC, CO, and PM	(0.34)	(1.26)

[16] Highlighted life cycle stages show cumulative carbon moving through the life cycle. Soybean production shows a net inflow of 169 grams of carbon for 1 bhp-h of engine work. Each subsequent stage consumes carbon, so that, at the point of end-use combustion, the carbon which remains is zero. Inflows of carbon are shown as positive numbers and outflows are shown as negative numbers (in parentheses).

Table 16: LCI Inventory of Raw Material Consumption for Petroleum Diesel (kg/bhp-h)

Raw Material	Domestic Crude Oil Production	Foreign Crude Oil Production	Domestic Crude Oil Transport	Foreign Crude Oil Transport	Crude Oil Refining	Diesel Fuel Transport	Total
Coal	0.00119	0.00104	0.000334	0.000372	0.002544	0.000405	0.00589
Limestone	0.00023	0.00020	6.36E-05	7.09E-05	0.00048	7.73E-05	0.00112
Natural Gas	0.00596	0.00311	5.19E-05	0.000188	0.00679	9.27E-05	0.01620
Oil	0.09331	0.09231	0.000196	0.001793	0.000734	0.000598	0.18894
Perlite	0	0	4.21E-08	4.05E-07	4.24E-05	1.33E-07	0.00004
Phosphate Rock	0	0	0	0	0	0	0
Potash	0	0	0	0	0	0	0
Sodium Chloride	0	0	0	0	0	0	0
Uranium	2.86E-08	2.50E-08	8.00E-09	8.91E-09	6.03E-08	9.71E-09	1.41E-07
Water Used	0.02025	0.00549	3.58E-05	0.000258	0.000167	9.33E-05	0.02629

Table 17: Life Cycle Consumption of Primary Resources for Biodiesel

Raw Material	Soybean Agriculture	Soybean Transport	Soybean Crushing	Soybean Oil Transport	Soybean Oil Conversion	Biodiesel Transport	Total
Coal	0.001328	0.000017	0.003221	0.000035	0.002405	0.000022	0.00703
Limestone	0.000172	0.000003	0.000614	0.000007	0.000340	0.000004	0.00114
Natural Gas	0.002599	0.000046	0.008729	0.000097	0.019219	0.000059	0.03075
Oil	0.006826	0.000533	0.000519	0.001133	0.000413	0.000689	0.01011
Perlite	1.330E-06	1.211E-07	0.000E+00	2.575E-07	0.000E+00	1.566E-07	1.87E-06
Phosphate Rock	0.009397	0	0	0	0	0	0.00940
Potash	0.004417	0	0	0	0	0	0.00442
Sodium Chloride	0	0	0	0	0.00350	0	0.00350
Uranium	7.293E-08	3.97E-10	7.721E-08	8.44E-10	3.542E-08	5.15E-10	1.87E-07
Water Used	86.2493	7.41E-05	0.0007109	0.000158	0.113338	9.58E-05	86.364

Table 18: LCI of Air Emissions for Petroleum Diesel (g/bhp-h)[17]

Air Pollutant	Domestic Crude Oil Production	Foreign Crude Oil Production	Domestic Crude Transport	Foreign Crude Transport	Crude Oil Refining	Diesel Fuel Transport	Diesel Use	Total
NH_3	4.39E-09	3.84E-09	1.85E-09	6.69E-09	1.08E-08	3.92E-09	0.00E+00	3.15E-08
Benzene	2.14E-05	2.03E-05	4.15E-08	4.00E-07	1.45E-07	1.31E-07	0.00E+00	4.24E-05
CO	0.006091	0.011088	0.001064	0.001546	0.043144	0.006875	1.200000	1.269810
Formaldehyde	0.000277	0.000281	0.000001	0.000005	0.000002	0.000002	0.000000	0.000568
NMHC	0.013648	0.015506	0.000103	0.000306	0.000470	0.001433	0.100000	0.131467
Hydrocarbons (unspecified)[18]	9.76E-05	8.54E-05	1.02E-02	5.53E-02	1.82E-01	1.19E-03	0.00E+00	2.49E-01
Hydrogen Chloride	0.000644	0.000564	0.000180	0.000201	0.001357	0.000219	0.000000	0.003164
Hydrogen Fluoride (HF)	8.05E-05	7.05E-05	2.25E-05	2.51E-05	1.70E-04	2.73E-05	0.00E+00	3.96E-04
CH_4	0.045281	0.093621	0.002656	0.004278	0.053414	0.003589	0.000000	0.202839
NO_x	0.024000	0.015720	0.006651	0.010242	0.129891	0.022055	4.800000	5.008558
N_2O	0.004049	0.001149	0.000034	0.000082	0.001255	0.000216	0.000000	0.006784
PM10	0.000194	0.000066	0.000159	0.000006	0.001459	0.002210	0.080000	0.084094
Particulates (unspecified)	0.016796	0.014704	0.004956	0.008848	0.079114	0.005864	0.000000	0.130281
SO_x	0.128553	0.083197	0.011121	0.080880	0.440475	0.009708	0.172402	0.926335

[17] Note that THC (not listed in the table) is the sum of benzene, formaldehyde, hydrocarbons (unspecified), NMHC (non-methane hydrocarbons), and CH_4. Similarly, data we report in other parts of this study for TPM (total particulate matter) represent the sum of PM10 and particulates (unspecified). This latter category represents data in which the type of particulates measured was not specified.

[18] Unspecified hydrocarbons are *not* the sum of NMHC and CH_4. This is because the unspecified category of emissions is ambiguous. We do not know if original data sources were referring to THC or NMHC. This ambiguity is a common problem in life cycle analysis because of the need to use data collected across a wide range of sources.

Table 19: LCI Air Emissions for Biodiesel (g/bhp-h)[19]

Air Pollutant	Soybean Agriculture	Soybean Transport	Soybean Crushing	Soybean Oil Transport	Soybean Oil Conversion	Biodiesel Transport	Biodiesel Use	Total
NH_3	0.0734632	2.2735E-09	8.02E-06	4.83E-09	5.4472E-09	2.94E-09	0	0.073471
Benzene	1.313E-06	1.195E-07	0	2.54E-07	0	1.54E-07	0	1.84E-06
CO	0.136856	0.00602014	0.01054	0.012727	0.0125584	0.007782	0.64524	0.831723
Formaldehyde	1.78E-05	1.60E-06	5.20E-13	3.40E-06	2.38E-13	2.07E-06	0	2.48E-05
NMHC)	0.0539448	0.00129623	0.323816	0.00019	0.00031698	0.001676	0.06327	0.44451
Hydrocarbons (unspecified)[20]	0.11591	0.00070209	0.000263	0.00442	0.0296103	0.000908	0	0.151813
HCl	0.000282	8.9382E-06	0.001738	1.9E-05	0.00153278	1.16E-05	0	0.003593
HF	1.23E-05	1.12E-06	2.17E-04	2.38E-06	9.97E-05	1.45E-06	0	0.000334
CH_4	0.0283374	0.00063603	0.064765	0.001371	0.101683	0.000823	0	0.197616
NO_x	0.201205	0.0166995	0.065193	0.062899	0.0829794	0.021588	5.22672	5.677283
N_2O	0.0013084	0.00017635	0.000315	4.07E-05	0.00022874	0.000228	0	0.002297
PM10	0.0137127	0.00201252	0.000592	0.001541	0.00056848	0.002602	0.025544	0.046572
Particulates (unspecified)	0.0154781	0.00037925	0.045433	0.000806	0.0357402	0.000491	0	0.098329
SO_x	0.0939614	0.00261499	0.248258	0.005551	0.498182	0.003382	0	0.851949

[19] Note that THC (not listed in the table) is the sum of benzene, formaldehyde, hydrocarbons (unspecified), NMHC (non-methane hydrocarbons), and CH_4. Similarly, data we report in other parts of this study for TPM (total particulate matter) represent the sum of PM10 and particulates (unspecified). This latter category represents data in which the type of particulates measured was not specified.

[20] Unspecified hydrocarbons are *not* the sum of NMHC and CH_4. This is because the unspecified category of emissions is ambiguous. We do not know if original data sources were referring to THC or NMHC. This ambiguity is a common problem in life cycle analysis because of the need to use data collected across a wide range of sources.

Table 20: Air Emissions for Petroleum Diesel, B20, and B100 (g/bhp-h)[21]

Pollutant	Petroleum Diesel	B20	B100
CH_4	0.202839	0.201795	0.197616
NO_x	0.006784	0.005887	0.002297
CO	1.26981	1.18219	0.831723
NMHC	0.131467	0.194075	0.44451
Hydrocarbons (unspecified)[22]	0.249053	0.229605	0.151814
Benzene	4.24E-05	3.43E-05	1.84E-06
Formaldehyde	0.000568	0.000459	2.48E-05
PM10	0.084094	0.076589	0.046572
Particulates (Unspecified)	0.130281	0.123891	0.098329
SO_x	0.926335	0.911458	0.851949
NO_x	5.00856	5.1423	5.67728
HCl	0.003164	0.00325	0.003593
HF	0.000396	0.000383	0.000334
NH_3	3.15E-08	0.014694	0.073471

[21] Note that THC (not listed in the table) is the sum of benzene, formaldehyde, hydrocarbons (unspecified), NMHC (Non Methane Hydrocarbons), and CH_4. Similarly, data we report in other parts of this study for TPM (total particulate matter) represent the sum of PM10 and Particulates (unspecified). This latter category represents data in which the type of particulates measured was not specified.

[22] Unspecified hydrocarbons are *not* the sum of NMHC and CH_4. This is because the unspecified category of emissions is ambiguous. We do not know if original data sources were referring to total hydrocarbons or NMHC. This ambiguity is a common problem in life cycle analysis because of the need to use data collected across a wide range of sources.

Table 21: Relative Change in Life Cycle Air Emissions for Fuels Containing 20% and 100% Biodiesel

Pollutant	B20	B100
CO	-6.90%	-34.50%
PM	-6.48%	-32.41%
HF	-3.10%	-15.51%
SOx	-1.61%	-8.03%
CH_4	-0.51%	-2.57%
NOx	2.67%	13.35%
HCl	2.71%	13.54%
HC	7.19%	35.96%

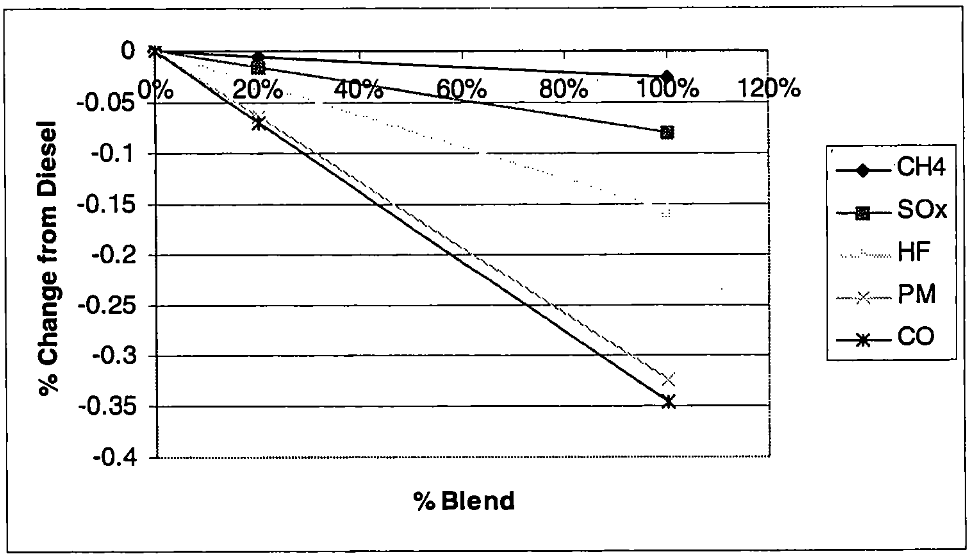


Figure 23: Effect of Biodiesel Blend on Life Cycle Air Emissions of CH_4, SO_x, HF, PM10, and CO

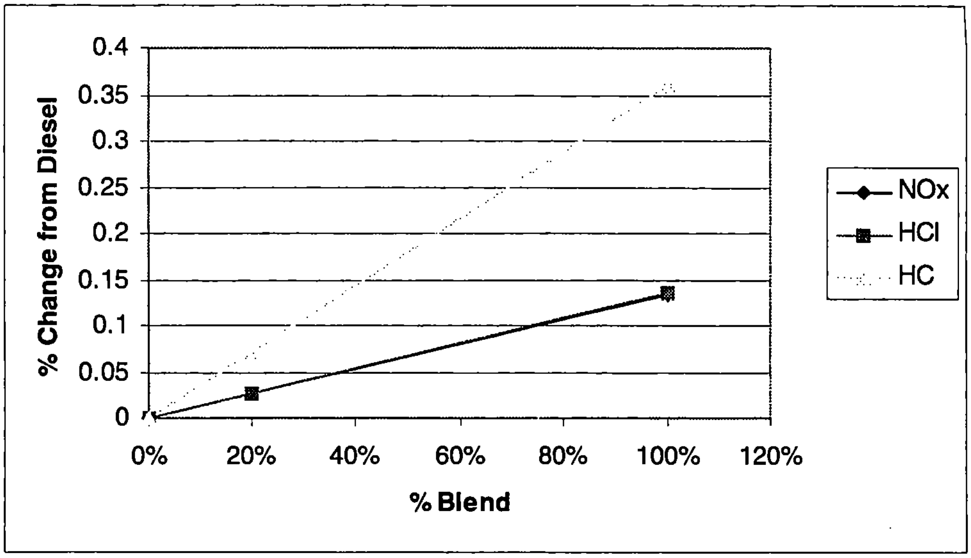


Figure 24: Effect of Biodiesel Blend Level on Air Emissions of NO_x, NMHC and HCl

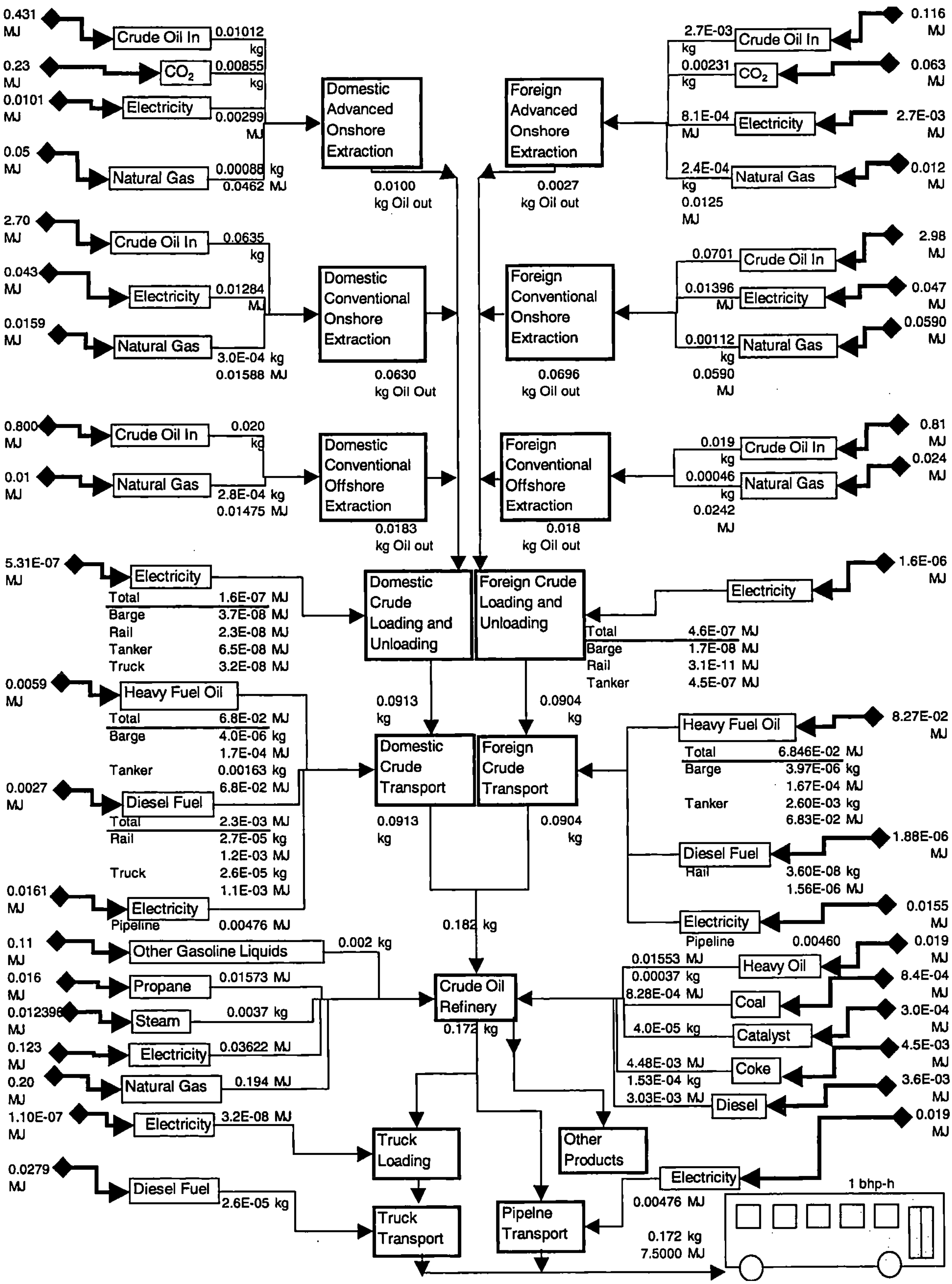


Figure 25: Primary Energy Balance for the Petroleum Diesel Fuel Life Cycle (with Mass Allocation)

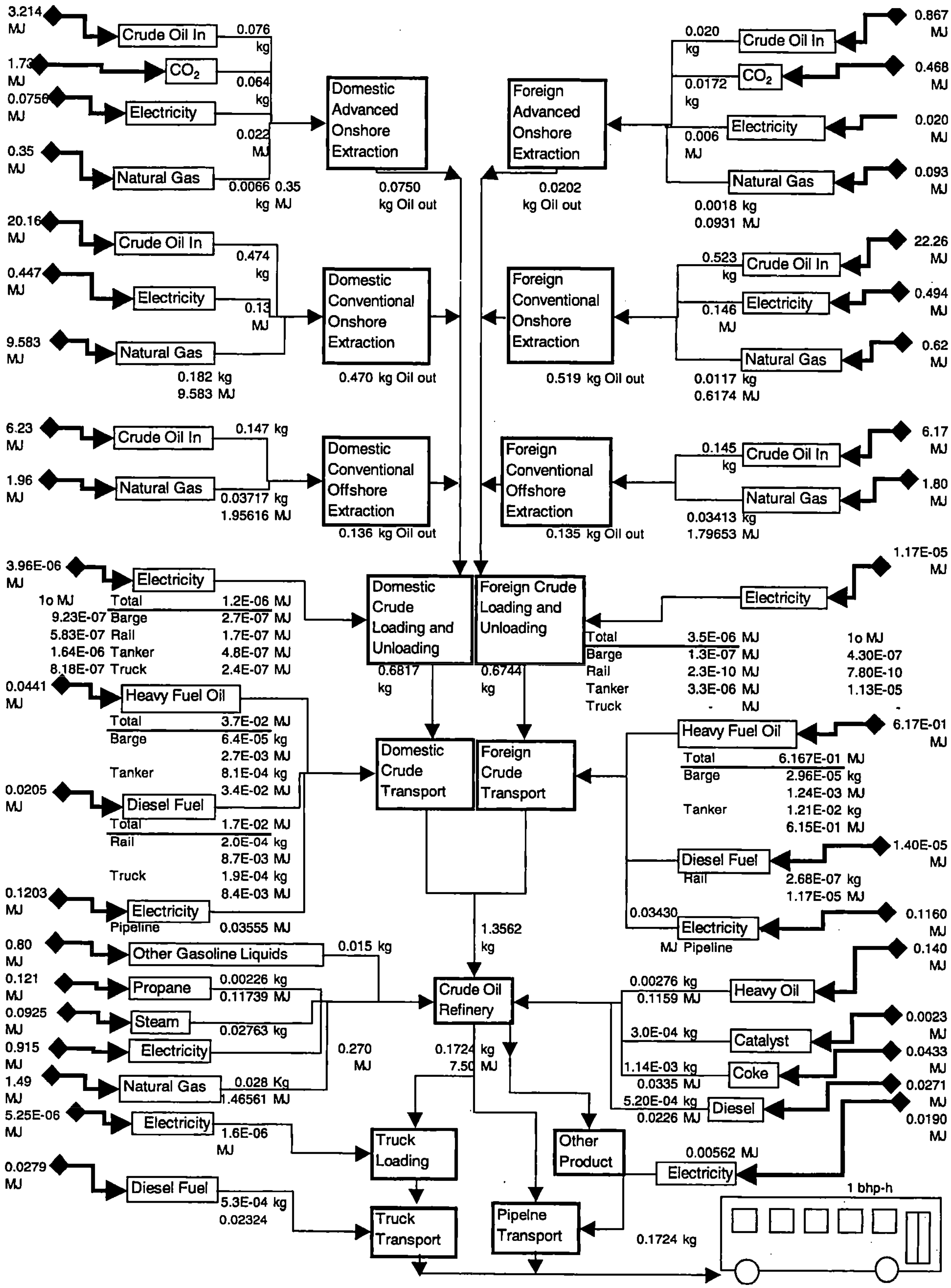


Figure 26: Primary Energy Balance for Petroleum Diesel Fuel Life Cycle (No Mass Allocation)

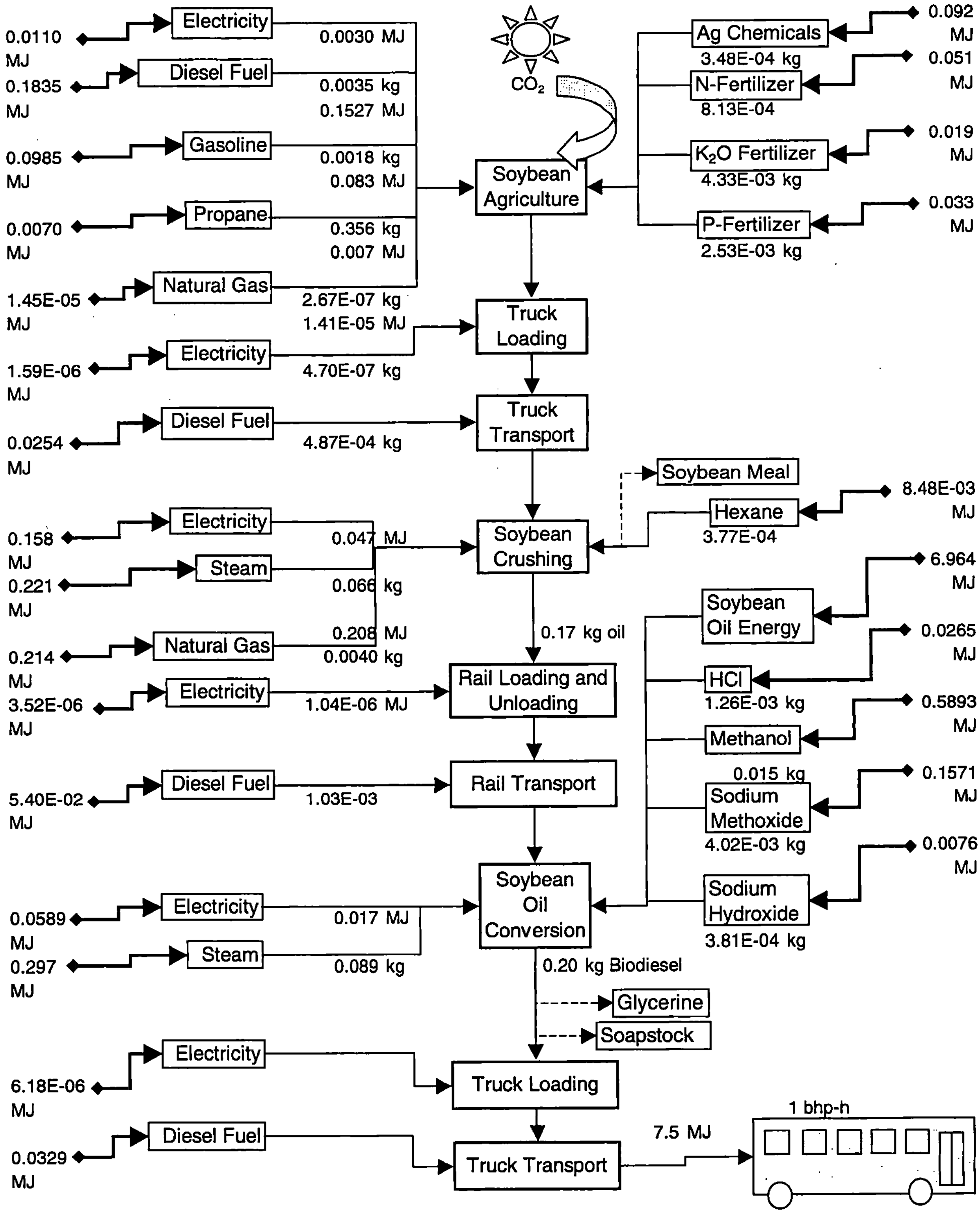


Figure 27: Primary Energy Balance for Biodiesel Fuel Life Cycle (with Mass Allocation)

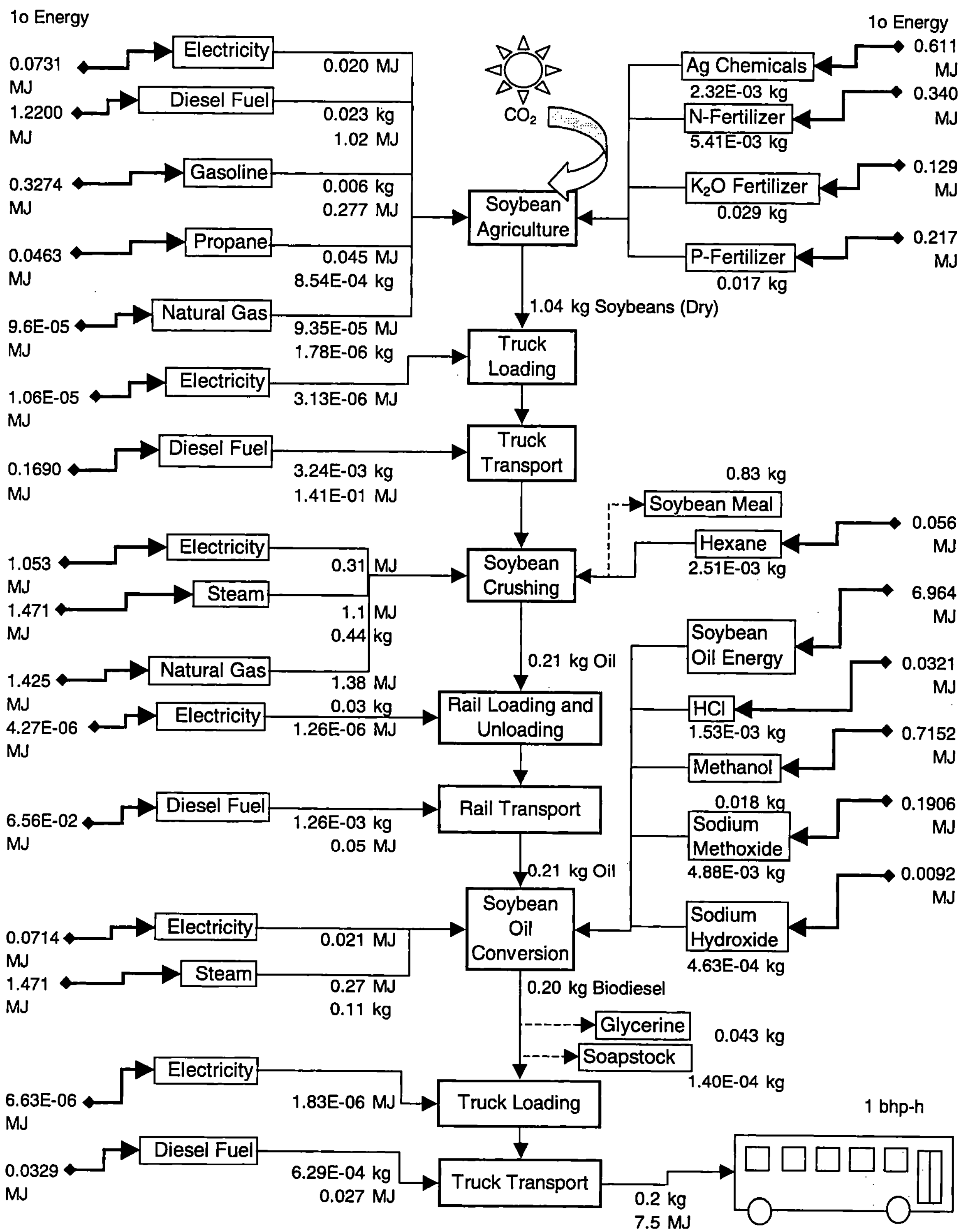


Figure 28: Primary Energy Balance for Biodiesel Fuel Life Cycle (No Mass Allocation)

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13. ABSTRACT *(Maximum 200 words)* This report presents the findings from a study of the life cycle inventories for petroleum diesel and biodiesel. It presents information on raw materials extracted from the environment, energy resources consumed, and air, water, and solid waste emissions generated.

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For more information contact:

Michael Voorhies
Program Manager
Office of Fuels Development
U.S. Department of Energy
1000 Independence Avenue, SW
Forrestal Building
Washington, D.C. 20585-0121

K. Shaine Tyson
Biodiesel Project Manager
National Renewable Energy Laboratory
1617 Cole Blvd
Golden, CO 80401

James Duffield
Office of Energy
U.S.Department of Agriculture
1800 M. Street, NW
Washington, D.C. 20036

John Sheehan
Biotechnology Center for Fuels and Chemicals
National Renewable Energy Laboratory
1617 Cole Blvd
Golden, CO. 80401

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THE CHRISTIAN SCIENCE MONITOR

CURRENTS IN CONTEMPORARY THOUGHT.

ideas

Look who's talking

Parrots and chimps gain new levels of language and raise the question: Can they reason?

Page 13

On scandal

In his new book, William Safire, lead columnist for The New York Times, takes stock of the rumors that destroy presidents and change history.

Page 17

soundings

By Jim Bencivenga

Internal properties

The stuff of a thing can be different from what you expect. Take Silly Putty.

On first contact with it in grammar school, I thought the mushy lump was an eraser pounded out of shape. When I held it and rolled it out into a thin pencil, it felt like clay. But when I bunched it up in my fist and bounced it like a ball, I had found antigravity matter!

How could something so malleable get such bounce? I'm certain similar acts repeated by curious young hands all over the world caused more kids to become chemists than all the chem-

To Geo Frampton / Gene S / Roger Ballentine w/ ... — PS

The long search for plants with optimal material properties starts to pay off.

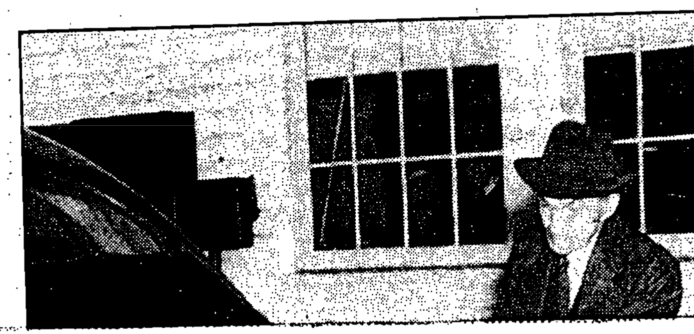
Tough as ~~nails~~ Soybeans

copied
Frampton
Sperling
Ballentine
Podesta

By Lori Valigra
Special to The Christian Science Monitor

CAMBRIDGE, MASS.

Back in 1940, when Henry Ford wanted to test the strength of a car trunk made from an experimental soy-



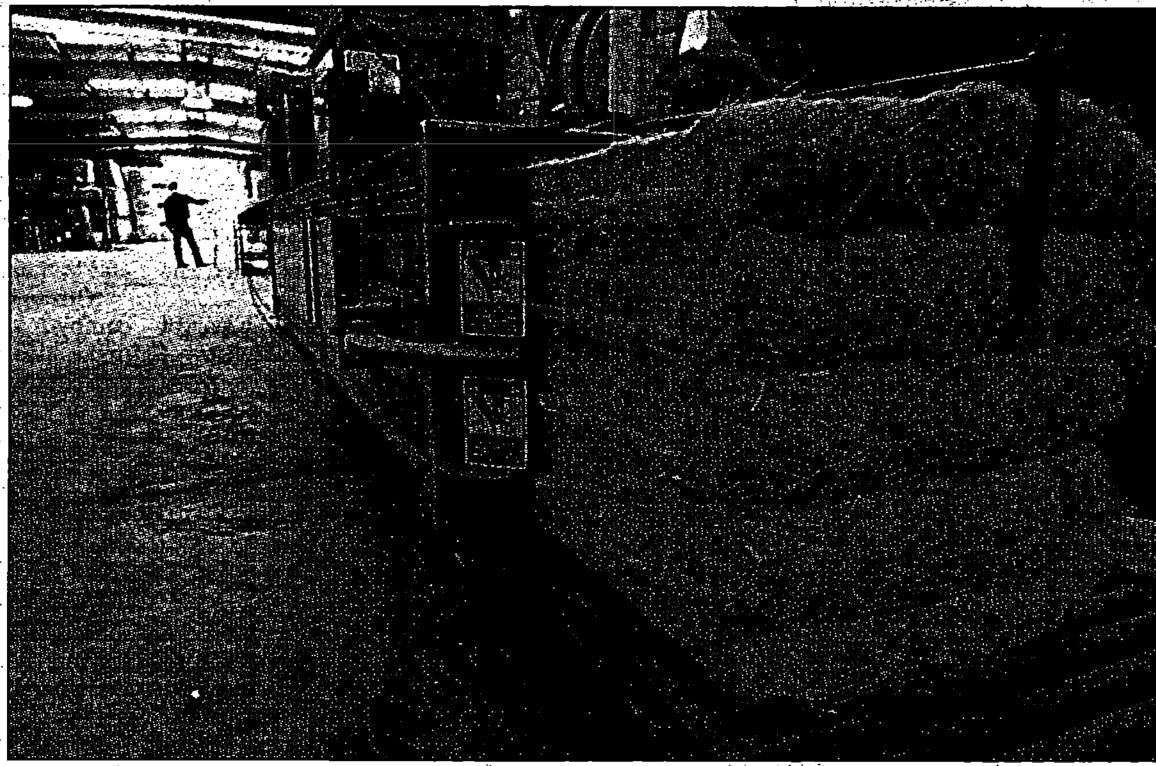
Cheap, versatile, and as strong as wood

GREEN MATERIALS *from page 11*

family. The panels are more shatter-resistant than traditional ones made by mixing polypropylene and wood flour or saw dust. In addition, Deere & Co. is using soy-based fiberglass composites in its tractor panels and hay balers.

"The natural fibers are very ductile and they don't splinter, so they manage energy well during side impacts," says Ken Urolini, area manager for door trim engineering at Visteon Automotive Systems, a Ford Motor Co. enterprise in Utica, Mich. Mr. Urolini says natural-fiber composite components weigh about 30 percent less than traditional wood-based materials. And, they cost less because they take half as long to make. Natural-fiber plastic composites are formed when a fiber sheet is heated along with propylene and molded. The now sticky sheet, which forms a stiff panel backing, is then pressed against the door fabric, eliminating the extra step of applying a toxic adhesive.

"We intend to use these com-



PHOTOS BY ROBERT HARBISON – STAFF

KENAF: Shown here under cultivation (right) and being extruded from a baler (above), it is a new source of fiber for paper, building products, even car parts

grows fully in seven months, tolerates drought, and does not require extensive herbicides. It grows in regions where cotton and tobacco thrive. Kenaf Industries also is using it to make paper for commercial newsprint. It has a 20,000-acre kenaf farm in Raymondville, Texas.

"We're using a crop that is totally renewable on a yearly basis, rather than cutting down 20-year-old forests," says David Agneta, president of Kafus Bio-Composites in Dedham, Mass.

Kenaf isn't the only natural fiber that has caught the imagination of engineers and designers. Global Resource Technologies (GROT) of Madison, Wis., is using jute, sisal, wood, coir, flax, straw, kenaf, and even denim to make everything from plastic wood and tables to shipping pallets and piggy banks. Its products are still in the development stage.

"Fibers are lower cost and stiffer, and you can mold them, which you can't do with pure wood," says Colin Felton, technical manager at GROT. "And, istry sets ever sold. The stuff pushed many young minds to think about internal properties, whether or not they knew what that meant.

We hope our cover story on the development of new materials from organic stuff will set readers thinking the way they did the first time they saw Silly Putty bounce.

Granted, an adult will necessarily be more utilitarian than a child. And an adult will assume a teleology: What can this stuff be used for, what's its purpose? The discovery, fabrication, and utilization of a renewable material from nature that does not degrade the environment is highly valued.

Of course, thinking about internal properties isn't limited to new materials. Radical cultural change can arise out of disparate, social combinations, challenging how things are supposed to work.

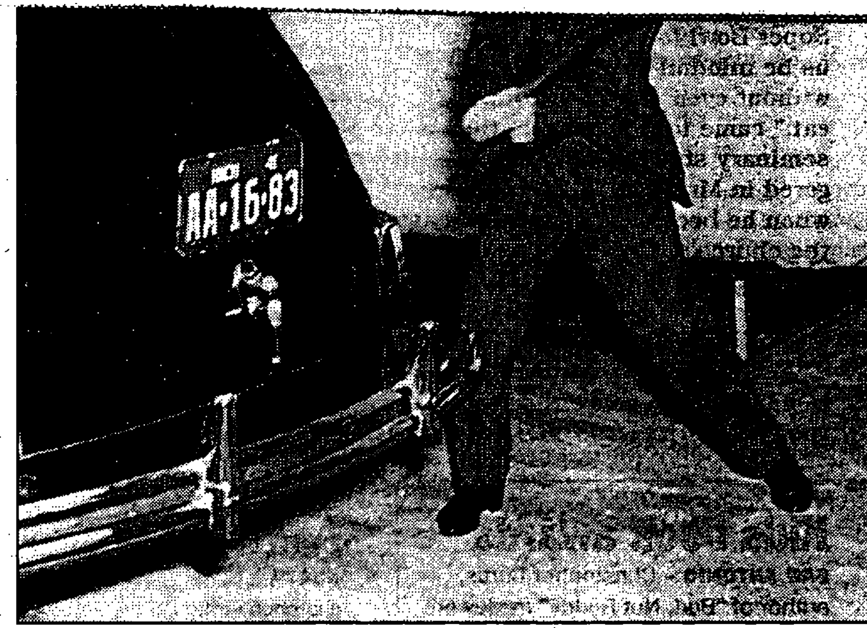
Events in the news: AOL merges with Time Warner; Vermont Supreme Court rules favorably on same sex marriage; young Cuban boy washes up on American soil as his mother drowns while fleeing Cuba.

The stuff of life, on first impression, can bounce like Silly Putty. All the more reason to constantly examine internal properties, material or otherwise.

Send e-mail to: **Ideas@csps.com**

bean-based material, he stunned onlookers by whacking it with an ax.

Mr. Ford may have been an eccentric, but he also was way ahead of his time in trying new materials to improve cars. The trunk was made of soy-protein plastic reinforced with glass, a material that proved to be stronger, lighter, and more flexible than conventional car panels. Ford grew many varieties of soybeans in a field near his company's Detroit auto factory to find a plant with the optimal material properties. By doing so, he planted the seed for the new crop of biomaterial composites that are sprouting up today.



FROM THE COLLECTIONS OF HENRY FORD MUSEUM & GREENFIELD VILLAGE

DON'T TRY THIS AT HOME: Henry Ford takes an ax to a 1941 Ford automobile to demonstate the sturdiness of soybean based materials. Ford was ahead of his time in testing out natural fibers for car parts.

Now, more than six decades later, vehicle, lumber, furniture, housing, and other manufacturers are finally seeing the benefits of such "green" materials. New and better composite materials made from plastic combined with natural fibers or plants such as hemp, kenaf, sisal, or soybeans can be manufactured and used for at least the same cost as conventional materials, and sometimes for much less.

The 1998 Ford Cougar, for example, has a polypropylene plastic and kenaf-fiber composite in its interior door panels, and the 2000 Mustang will have that material in its trunk liners. Kenaf is a 14-foot tall, inedible plant in the hibiscus

See **GREEN MATERIALS** *page 14*

posites in new cars including the Mustang, Escort, and Taurus Sable," Urolini says. The only drawback now, he says, is the technology is so new in the United States that Ford has had to import tooling and other capital equipment for pressing the composite panels from Europe, where automakers are further ahead in using natural-fiber composites.

Richard Wool, professor of chemical engineering and director of the Affordable Composites from Renewable Sources program at the University of Delaware in Newark, says the field of composites came into its own in the past 40 years because of two developments: high-performance fibers and high-performance, petroleum-based plastic resins.

"Advances in the field were dominated by defense priorities until the Berlin Wall came down, and then the big push went in the direction of all-natural composites using agricultural bioproducts," Professor Wool says. At the same time, giant companies like Monsanto and DuPont began to focus on the crop business so they could control the hybrids grown. "There may be crops grown especially for composites, just as there are for animal feeds today. So it may be possible to have your crop and eat it too," quips Wool.

Wool's laboratory is making composites that substitute soybean oil for plastic so that a fiber composite will be all natural.

Composites date back to the middle ages, when builders used straw to reinforce building blocks to make castles. The most common composite today is fiberglass. New composites are being created by combining old materials in new ways.

"People are fusing old materials with different physical treatments to make different materials. It's like old-time alchemy," says George Beylarian, founder and president of the Material Connexion, a combination design gallery, innovation clearing house, and new-materials database in New York.

Liat Margolis, director of research at the Material Connexion, says today's fiber composites are replacing traditional petroleum-based products, such as the resins in thermoset plastics, which are toxic and not readily biodegradable. By comparison, kenaf fiber mixed with a thermal plastic like polypropylene can be remelted and reused more easily.

"Kenaf stalks, which are comparable in strength to carbon or glass, are replacing fiberglass, and polypropylene is replacing liquid resin, which eliminates a lot of the toxic chemicals for workers," Ms. Margolis says.

"We're using a crop that is totally renewable on a yearly basis, rather than cutting down 20-year-old forests."

– David Agneta, Kafus Bio-Composites

For consumers to buy environmental materials, they must be equal or better in performance than traditional products, says David Saltman, vice president of marketing and new-product development at Kafus Industries Ltd. in Calabasas, Calif. "Consumers will buy environmental materials, but they won't pay extra for them," he says.

According to Plastics Technology magazine, prices for natural fibers range from 3 cents per pound for jute to 25 cents per pound for kenaf, while glass fibers are 50 cents to 75 cents per pound. But when natural fibers are made into mats, the price rises to $1 to $1.50 per pound.

Kafus Bio-Composites, a Kafus Industries subsidiary, has an agreement for joint development of biocomposites with Visteon. In October 1999, Kafus began commercial production of natural-fiber composites at its plant in Elkhart, Ind.

The long-fibered kenaf-composite panels that Visteon sells to Ford are more flexible and shatter-resistant during accidents than fiberglass, Mr. Saltman says. Kenaf composites also can be used to make chairs, raised flooring for computer rooms, packaging, and containers, he adds.

Kenaf looks like hemp. It

The company chops fibers and blends them with molten plastic in ratios of up to 70 percent fiber by weight. A table top looks much like today's particle board, but it is as much as half the weight because ribs can be molded to trim heft while retaining strength. And because a round table top, for example, can be molded, there isn't the 30 percent waste that comes with sawing the edges off of a square piece of particle board or natural wood.

"Plastic composites can replace wood in many applications. Although the basic material costs are high, less material is used, so there is much less waste," Mr. Felton says. And the composites can be melted down and reused up to five times.

That's the case with GROT's denim composite shipping pallets, made from jean scraps from nearby Lands' End, the catalog clothing company.

Denim composite pallets are much stronger than wood. They cost about $20 to $30 apiece and last up to 100 trips. Wood pallets cost $7 to $10 apiece and last only about three trips, Felton says.

Besides, Felton adds, "Wood is becoming more scarce, and materials like jute and kenaf are plentiful."

MEMORANDUM

TO: **Roger Ballentine**
FROM: **Dan Reicher**
SUBJECT: **Green Algae (Pond Scum) Produces Hydrogen**

We talked with Sig Gronich in OPT and Mike Seibert at NREL who provided the information on our activities and the connection to the attached news release from Berkeley.

In FY 2000, we have provided $450,000 for work at NREL on hydrogen research related to algae and an additional $200,000 for work at Berkeley on genetic mutations of the organisms. We have asked for approximately the same amount in FY 2001. This is work that supports our bioenergy effort and led to the following announcement (and the attached press release):

> "Scientists Find Key to Producing Hydrogen from Algae: Michael Seibert, Maria Ghirardi and Marc Forestier of NREL's Center for Basic Sciences along with scientists from the University of California at Berkeley have discovered a mechanism for producing significant quantities of hydrogen gas from algae. After allowing algae culture to grow under normal conditions, the research team deprived it of sulfur, causing it to switch to an alternate metabolism that generates hydrogen but not oxygen. Producing hydrogen from algae could eventually provide a cost- effective and practical means to convert sunlight and water into hydrogen for powering fuel cells. The near-term plans for powering fuel cells involve generating hydrogen from fossil fuels such as natural gas, methanol or gasoline. Visit <http://www.urel.berkeley.edu/release> for details."

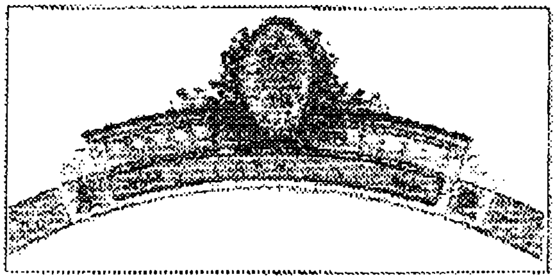
In a nutshell, this research is based on the knowledge that many organisms produce hydrogen, which we have known for 60 years. Theoretically, these green organisms should be a ready source of hydrogen, but the amount produced has been very small and it is very transitory. This recent research has discovered that if we can adjust the photosynthesis process to allow for the cell to used stored energy in a medium that is deprived of sulfur, hydrogen is the byproduct and the hydrogen is produced in an amount that is collectable - approximately 4/10 of a quart from each quart of algae over a few days. There is, however, much work to be done to make this a viable source of hydrogen for fuel cell and other uses.

The principal contact at NREL is :

Michael Seibert, Principal Scientist
Basic Sciences Center
National Renewable Energy Laboratory
Golden, CO 80401 USA

Phone: 1-303-384-6279 (Administrative Assistant (Ext. 6199)
FAX: 1-303-384-6150
E-mail Mike_Seibert@nrel.gov or seibertm@tcplink.nrel.gov

UNIVERSITY OF CALIFORNIA, BERKELEY



Public Affairs, (510) 642-3734

NEWS RELEASE, 02/20/00

UC Berkeley and Colorado scientists find valuable new source of hydrogen fuel, produced by common algae

By Kathleen Scalise, Public Affairs

WASHINGTON, D.C.-- A metabolic switch that triggers algae to turn sunlight into large quantities of hydrogen gas, a valuable fuel, is the subject of a new discovery to be presented by University of California, Berkeley, scientists and their Colorado colleagues during a Feb. 21 press briefing at the annual meeting of the American Association for the Advancement of Science in Washington, D.C.

"I guess it's the equivalent of striking oil," said UC Berkeley plant and microbial biology professor Tasios Melis. "It was enormously exciting, it was unbelievable." He first described the discovery in the January 2000 issue of the journal Plant Physiology.

Melis and postdoctoral associate Liping Zhang of UC Berkeley made the discovery - funded by the U.S. Department of Energy (DOE) Hydrogen Program - with Dr. Michael Seibert, Dr. Maria Ghirardi and postdoctoral associate Marc Forestier of the National Renewable Energy Laboratory (NREL) in Golden, Colorado.

Currently, hydrogen fuel is extracted from natural gas, a non-renewable energy source. The new discovery makes it possible to harness nature's own tool, photosynthesis, to produce the promising alternative fuel from sunlight and water. A joint patent on this new technique for capturing solar energy has been taken out by the two institutions.

So far, only small-scale cultures of the microscopic green alga Chlamydomonas reinhardtii have been examined in the laboratory for their hydrogen production capabilities, Melis said.

"In the future, both small-scale industrial and commercial operations and larger utility photobioreactor complexes can be envisioned using this process," he said.

While current production rates are not high enough to make the process immediately viable commercially, the researchers believe that yields could rise by at least 10 fold with further research, someday making the technique an attractive fuel-producing option.

Preliminary rough estimates, for instance, suggest it is conceivable that a single, small commercial pond could produce enough hydrogen gas to meet the weekly fuel needs of a dozen or so automobiles, Melis said.

The scientific team is just beginning to test ways to maximize hydrogen production, including varying the particular type of microalga used and its growth conditions.

Many energy experts believe hydrogen gas one day could become the world's best renewable source of energy and an environmentally friendly replacement for fossil fuels.

"Hydrogen is so clean burning that what comes out of the exhaust pipe is pure water," Melis said. "You can drink it."

Engineering advances for hydrogen storage, transportation and utilization, many sponsored by the U.S. DOE Hydrogen Program, are beginning to make the fuel feasible to power automobiles and buses and to generate electricity in this country, Seibert said.

"What has been lacking is a renewable source of hydrogen," he said.

For nearly 60 years, scientists have known that certain types of algae can produce the gas in this way, but only in trace amounts. Despite tinkering with the process, no one has been able to make the yield rise significantly without elaborate and costly procedures until the UC Berkeley and NREL teams made this discovery.

The breakthrough, Melis said, was discovering what he calls a "molecular switch." This is a process by which the cell's usual photosynthetic apparatus can be turned off at will, and the cell can be directed to use stored energy with hydrogen as the byproduct.

"The switch is actually very simple to activate," Melis said. "It depends on the absence of an essential element, sulfur, from the microalga growth medium."

The absence of sulfur stops photosynthesis and thus halts the cell's internal production of oxygen. Without oxygen from any source, the anaerobic cells are not able to burn stored fuel in the usual way, through metabolic respiration. In order to survive, they are forced to activate the alternative metabolic pathway, which generates the hydrogen and may be universal in many types of algae.

"They're utilizing stored compounds and bleeding hydrogen just to survive," Melis said. "It's probably an ancient strategy that the organism developed to live in sulfur-poor anaerobic conditions."

He said the alga culture cannot live forever when it is switched over to hydrogen production, but that it can manage for a considerable period of time without negative effects.

The researchers first grow the alga "photosynthetically, like every other plant on Earth," Melis said. This allows the green-colored microorganisms to collect sunlight and accumulate a generous supply of carbohydrates and other fuels.

When enough energy has been banked in this manner, the researchers tap it and turn it into hydrogen. To do this, they transfer the liquid alga culture, which resembles a lime-green soft drink, to stoppered one-liter glass bottles with no sulfur present. Then, the culture is allowed to consume away all oxygen.

After about 24 hours, photosynthesis and normal metabolic respiration stop, and hydrogen begins to bubble to the top of the bottles and bleed off into tall, hydrogen-collection glass tubes.

"It was actually a surprise when we detected significant amounts of hydrogen coming out of the culture," Melis said. "We thought we would get trace amounts, but we got bulk amounts."

After up to four days of generating an hourly average of about three milliliters of hydrogen per liter of culture, the culture is depleted of stored fuel and must be allowed to return to photosynthesis. Then, two or three days later, it again can be tapped for hydrogen, Melis said.

"The cell culture can go back and forth like this many times," said Dr. Maria Ghirardi of NREL in Colorado.

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More Press Releases | More Campus News and Events | UC Berkeley Home Page

Send comments to: *comments@pa.urel.berkeley.edu*

Department of Energy
Washington, DC 20585

OFFICE OF ENERGY EFFICIENCY AND RENEWABLE ENERGY

Facsimile Cover Sheet

To: Roger Ballentine

From: Dan Reicher

Office: ______

Date: ______

Fax Number: 456-~~6704~~ 1736

Fax Number: (202) 586-9260

Phone Number: ______

Phone: (202) 586-9220

Number of pages (including cover): 5

Comments: ______

Bioenergy & Bioproducts Tax Incentives

President Clinton's FY 2001 Budget includes $976 million in tax incentives over 5 years and $2.1 billion over ten years to accelerate the development and use of bio-based technologies, which convert crops, trees, and other "biomass" into a vast array of fuels and products. These tax credits support the President's August 1999 Executive Order 13134 and Memorandum on Promoting Biobased Products and Bioenergy, aimed at tripling U.S. use of biobased products and bioenergy by 2010. This initiative will increase the viability of alternative energy sources, help meet environmental challenges like global warming, support farm incomes, and diversify and strengthen the rural economy.

Cleaner Energy, Cleaner Environment. Bioenergy and bioproducts can dramatically reduce greenhouse gas emissions that contribute to global warming. Since crops absorb carbon during growth, their use for energy and other applications results in near zero net carbon release. Tripling our use of bioenergy and bioproducts by 2010 will reduce annual greenhouse gas emissions by up to 100 million tons – the equivalent of taking over 70 million cars off the road.

New Economic Opportunities for a New Century. The goal of these tax incentives is to take advantage of advances in farm, forestry, and other biological sciences that are making biomass a viable competitor to fossil fuels as an energy source. These advances are fueling a revolution in the use of biomass to make low polluting electricity by burning willows and switchgrass along with coal in existing plants and by converting paper industry by-products into fuel gases. By creating high-tech jobs and new economic opportunities, meeting the President's goal of tripling U.S. use of bioenergy and bioproducts could add $15 billion to $20 billion in new income for farmers and many rural communities.

Tax credits for electricity produced from biomass. This package of credits would:

-- **Extend current "closed-loop" biomass credit.** This proposal, which includes plants and trees specifically grown for use as biomass, extends for 2.5 years the current 1.5 cent per kilowatt hour tax credit (adjusted for inflation after 1992), which covers facilities placed in service before January 1, 2002.

-- **Provide credits for "open loop" biomass facilities.** This proposal expands the definition of biomass eligible for the 1.5 cent tax credit to include certain forest-related resources and agricultural and other sources for facilities placed in service from 2001 through 2005, and provides a 1.0 cent credit for electricity produced from 2001 through 2003 from facilities placed in service prior to July 1, 1999.

-- **Provide a credit for cofiring biomass and coal.** This proposal adds a 0.5 cent per kilowatt hour tax credit for electricity produced by cofiring biomass in coal plants from 2001 through 2005.

-- **Provide credit for methane from landfills**. This proposal adds a 1.5 cent per kilowatt hour credit for electricity produced from landfills not subject to EPA's 1996 New Source Performance Standards/Emissions Guidelines (NSPS/EG) and 1.0 cent per kilowatt hour for landfills subject to NSPS/EG. Qualified facilities would be facilities placed in service after December 31, 2000 and before January 1, 2006.

AP
Ann Gearan
776-9494

Bioenergy/Bioproducts Initiative

FY 2001 Budget
January 13, 2000

President Clinton's FY 2001 Budget includes a new initiative to accelerate the development and use of bio-based technologies, which convert crops, trees, and other "biomass" into a vast array of fuels and products. This initiative supports the President's August 1999 Executive Order 13134 and Memorandum on Promoting Biobased Products and Bioenergy, aimed at tripling U.S. use of biobased products and bioenergy by 2010. The initiative provides an increase of more than $240 million over the amounts available for FY 2000, with $49 million directed towards the Department of Energy (DOE) and $194 million for stepped-up efforts at the Department of Agriculture (USDA). This initiative will increase the viability of alternative energy sources, help meet environmental challenges like global warming, support farm incomes, and diversify and strengthen the rural economy.

The DOE goal for this initiative is making biomass a viable competitor to fossil fuels as an energy source and chemical feedstock. Its efforts will be concentrated on developing " biorefineries" -- integrated systems for processing feedstocks simultaneously into a variety of products such as fuels, chemicals, and electricity. This will require increased collaboration among DOE, USDA, NSF, and other agencies, and will support research partnerships linking industry, university, and government research facilities selected on a competitive basis. The work will build on fermentation, gasification, and other biomass-related activities currently funded by the Energy Department.

Key areas of increased DOE activity will include:

- Development of inexpensive cellulase systems to break down cellulose into low-cost sugars for the production of bio-based chemicals and bioenergy. This will allow woody and grassy crops and agricultural waste such as corn stalks to take the place of high-value grain and food crops as biofuel feedstocks.

- Renewable Bioproducts, using multi-disciplinary and university/industry partnerships to develop and accelerate adoption of possible "leap-frog" technologies for converting crops, trees and residues into chemical feedstocks and consumer products.

- Biopower, promoting both the integration of biomass gasification systems with modern gas-turbine/steam-turbine generation systems, and the co-firing of biomass with coal at levels ranging from 5-15% biomass by heat value.

USDA's goals for the initiative are increasing the economic viability for farmers and foresters to grow biomass products, developing new uses for biobased materials, and providing incentives to use bioenergy. Key areas of increased USDA activity will include:

- The Commodity Credit Corporation providing up to $100 million in FY 2000 and up to $150 million in FY 2001 and 2002 in incentive payments to ethanol and other bioenergy producers to expand production of biobased fuels. Payments would be made on a portion of the increase in agricultural commodities purchased for expanded bioenergy production, with smaller and cooperatively-owned facilities receiving higher payment rates.

- Expanded Forest Service research on faster-growing trees and the use of small-diameter trees for commercial, biobased products.

- The Natural Resources Conservation Service funding methane gas recovery pilots to reduce greenhouse gas emissions from livestock operations, providing a clean energy source to the producer, and providing assistance to farmers that want to produce or market biobased products.

- Expanded Agricultural Research Service research (in association with DOE) to develop biobased materials from commodities and bioproducts, and convert biomass to energy.

- The Cooperative State Research Education and Extension Service providing additional competitive resources for research partnerships involving universities. This will complement the new Initiative for Future Agriculture and Food Systems announced by the Secretary of Agriculture on January 10th.

- Rural Development grants to rural electric cooperatives to develop pilot projects to demonstrate the commercial viability of small-scale biomass fuel generation, grants for technical assistance to cooperatives for processing and marketing biobased products, and loans for facilities and operating capital for organizations engaged in biobased production activities.

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FY 2001 Budget
January 13, 2000

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The President's New Executive Order on Bio-based Products and Bioenergy

August 12, 1999

The Executive Order issued by President Clinton today will coordinate Federal efforts to accelerate the development of 21st century bio-based industries that use trees, crops, and agricultural and forestry wastes to make fuels, chemicals, and electricity. Owing to recent scientific advances, bioenergy and bioproducts have enormous potential to create new economic opportunities for rural America, enhance U.S. energy security, and help meet environmental challenges like global warming. In a separate Executive Memorandum, the President set a goal of tripling U.S. use of bio-based products and bioenergy by 2010. Meeting this goal could create $15 billion to $20 billion in new income for farmers and rural America, and reduce annual greenhouse gas emissions by an amount equal to as much as 100 million metric tons of carbon (MMTCE) – the equivalent of taking over 70 million cars off the road.

BIOMASS

Biomass is trees, crops, and agricultural and forestry wastes that can be used to make fuels, chemicals, and electricity. Biomass is a clean, domestic, and renewable source of energy. It can be used to fuel cars, power factories, and create a host of chemicals and other everyday products.

EXECUTIVE ORDER

Recent scientific advances in farm, forestry, and other biological sciences are making bioenergy and bioproducts more technically feasible and more economically viable. Recent reports and studies – including the just-released National Research Council report, "Biobased Industrial Products" – have concluded that Federal support for research is essential to realizing the economic and environmental potential of bio-based industries. Today's Executive Order acts on this advice to create a powerful new research management team to focus Federal efforts with a goal of tripling U.S. use of bioenergy and bioproducts by 2010. Energy from biomass sources currently accounts for about 3 percent of the total U.S. energy supply – mostly from wood and wood waste.

This Executive Order :

- Establishes a permanent council consisting of the Secretaries of Energy and Agriculture, the Environmental Protection Agency Administrator, and the Director of the National Science Foundation, and other agency heads to develop a detailed research program to be presented annually as part of the annual Federal budget.

- Instructs the council to review major agency regulations, incentives and programs to ensure that they are being used effectively to promote the use of bioproducts and bioenergy. The council's plan will be reviewed by an outside advisory group with representatives from bio-based industries, farm and forestry sectors, universities, and environmental groups.

- Directs DOE and USDA to establish a National Biobased Products and Bioenergy Coordination

Office to manage the preparation of interagency budgets and provide an easy point of entry for anyone interested in Federal work in biobased products and bioenergy.

Today's Executive Order also builds on the Administration's record of strong and consistent support for bio-based industries. This includes the Administration's electricity restructuring bill introduced earlier this year requiring that 7.5 percent of all U.S. electricity come from renewable resources by 2010; Executive Order 13101, signed in September 1998, instructing Federal agencies to make use of biobased products; new proposed tax credits for bio-based electricity production; and increased research funding for the Department of Energy (DOE), the Department of Agriculture (USDA), and the National Science Foundation.

In a separate Executive Memorandum, the President instructed the Secretaries of Energy and Agriculture to prepare a report within 120 days outlining and assessing options for modifying existing DOE and USDA programs with a goal of tripling U.S. use of bio-based products and bioenergy by 2010.

WHAT IS BEING DONE RIGHT NOW IN BIOENERGY AND BIOPRODUCTS

Clean bioenergy and bioproducts are very much here and now. Already DOE and USDA are participating in partnerships on a number of major, breakthrough bioenergy and bioproducts projects, including:

- **Biomass to Ethanol Demonstration Projects.** Last fall BC International broke ground in Jennings, Louisiana on the first commercial plant to produce ethanol from the cellulose in agricultural waste – in this case sugar cane bagasse. A number of other demonstration projects are under development to convert municipal solid waste to ethanol.

- **Biorefinery for Chemicals.** Cargill Corporation, one of the largest privately held company in the United States, has built a prototype biorefinery in Blair, Nebraska. This new facility will use corn to produce a stream of chemical products and also a biodegradable polymer, polylactic acid, used in making films, fibers, rigid materials and coatings.

- **Co-Firing Technologies.** A number of projects are exploring ways to use biomass such as switchgrass and short-rotation wood crops like willows to make electricity by cofiring them with coal. Two of the most prominent projects – the Iowa Chariton Valley project and the New York Salix project – will also investigate the technical and business aspects of biomass gasification, where biomass is made into a fuel gas that can be used for heat or power production.

ECONOMIC POTENTIAL OF USING BIOMASS FOR ENERGY AND PRODUCTS

A robust bioenergy and bioproducts industry in the United States promises tremendous economic benefits for biomass producers – including farmers and the forest products industry – energy producers, chemical manufacturers, and the U.S. economy as a whole.

For rural America, a fast-growing bioenergy market will greatly increase the demand for energy crops and for agricultural and forest residues, or wastes, of all types. Since the cost of transporting the raw materials is high, most of the value-added work would occur in rural communities, providing new revenue streams for farmers and cash-flow for rural economic development. This means that good, high-technology jobs associated with producing biofuels and chemicals can be added in rural communities helping ensure that they will be an integral part of a prosperous 21st century American economy. By creating high-tech jobs and new economic opportunities, meeting the President's goal of tripling U.S. use of bioenergy and bioproducts could add $15 billion to $20 billion in new income for farmers and many rural communities.

Finally, as the President's Committee of Advisors on Science and Technology highlight in their new report – "Powerful Partnerships: The Federal Role in International Cooperation on Energy Innovation" – investments in bioenergy technologies, infrastructures, and markets could increase profitability for U.S. firms competing in global markets, while simultaneously providing for the world's future energy needs in an environmentally sustainable way.

BIO-BASED TECHNOLOGIES HELP MEET ENVIRONMENTAL CHALLENGES

Substituting biomass for fossil fuels can dramatically reduce greenhouse gas emissions that contribute to global warming. Since biomass crops absorb carbon during growth, their use for energy and other applications results in near zero net carbon release.

Meeting the President's goal of tripling our use of bioenergy and bioproducts by 2010 will reduce greenhouse gas emissions by up to 100 MMCTE – the equivalent of taking more than 70 million cars off the road. Substituting for fossil fuels, bioenergy will also reduce emissions of nitrogen oxides (NOx), sulfur oxides (SOx), and other pollutants.

Additionally, the deep-rooted plants commonly used for biomass – such as poplar, willow, and switch grass – are helpful in controlling erosion, filtering chemicals from water runoff, and slowing floodwaters.

PRESIDENT CLINTON'S FY2000 BUDGET ON BIOMASS

The President's FY 2000 budget request contains $242 million for investments in biomass research, development and deployment, including:

- **Advanced Biomass Power and Fuels.** Funding for DOE and USDA to continue developing, testing, and demonstrating high-yield, low-cost biomass feedstocks; cofiring biomass with coal to produce electricity; advanced technologies for biomass gasification using paper industry by-products; and continued work on producing alternative fuels, such as ethanol, from biomass.

- **National Biomass Partnership.** Funding for DOE, USDA and other Federal agencies and private partners to launch a national partnership to develop advanced integrated biomass technologies.

The President has also proposed a package of **biomass tax credits.** The President proposes to extend for 5 years the current 1.5 cent per kilowatt hour tax credit for electricity produced from biomass. The proposal also expands the types of biomass eligible for the credit to include certain forest-related, agricultural and other resources. Finally, the package includes a 1.0 cent per kilowatt hour tax credit for electricity produced by cofiring biomass in coal plants.

To date, Congress has not only failed to enact these proposed new tax credits, but has terminated the current 1.5 cent per kilowatt credit and cut the President's budget request by 14 percent.

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TO: ANGIE MIZEUR
456-1736 FAX
FROM: JOHN WINSKI
690-4653 PHONE

Expanding Production of Biobased Energy

Expanding demand, rather than storing or cutting back production, is the most beneficial way to restore balance to commodity markets. Because the potential to expand food or feed use is limited, expanding the use of farm products in industrial uses offers an advantageous alternative. For that reason, the President's budget proposals for strengthening the farm safety net will include a new program to promote increased production of biobased fuels, including ethanol and soy-based oil additives. The program will help enhance energy security by reducing fossil fuel imports; reduce greenhouse gas ~~emissions; and~~ reduce fuel costs associated with Clean Air Act requirements.

The program will have the dual effect of expanding industrial consumption of agricultural commodities and adding to the supply of bioenergy and biobased lubricants in furtherance of the goals set forth in the ~~President's Executive Order on Biomass~~. Under the program, USDA's Commodity Credit Corporation will provide incentive payments to bioenergy producers to compensate them for a portion of their commodity purchases made to expand existing production of bio-based fuels. The program is designed to encourage the construction of new bioenergy production facilities and full utilization of existing ones. Operationally, processors would request from USDA authorization to participate in the program for a period of between 1 to 3 years. USDA authorization would entitle processors to receive payments on the amount of additional agricultural commodities purchased during the year for the production of bioenergy in excess of the previous year's use. The request for authorization would include the firm's past and projected commodity purchases. Upon the completion of each program year, participating companies would be required to submit documentation of their actual purchases.

In order to have a meaningful effect on demand expansion, all processors would be eligible to participate in the program. However, to target benefits, small- and cooperative-owned processing facilities would receive higher payment rates.

Kevin Galvin

776-9494

Question: **Who would be eligible to participate in the program?**

Answer: Producers of bioenergy would participate in the program. In order to have a meaningful effect on demand expansion, all processors would be eligible to participate in the program. However, to target benefits, small- and cooperative-owned processing facilities would receive higher payment rates.

Question: **What are the benefits of the program?**

Answer: The program will have the dual effect of expanding industrial consumption of agricultural commodities and adding to the supply of bioenergy and biobased lubricants in furtherance of the goals set forth in the President's Executive Order on Biomass. The program will help enhance energy security by reducing fossil fuel imports; reducing greenhouse gas emissions; and reducing fuel costs associated with Clean Air Act requirements.

Question: **When would the program begin?**

Answer: USDA will implement the program under the authority of the Commodity Credit Corporation Charter Act. USDA will issue regulations through the normal rulemaking procedures and the program will be implemented as soon as possible beginning in FY 2000.

Question: **How much will the program cost?**

Answer: The costs of the program could vary, depending on how successful the program is in stimulating demand for bio-based energy products. Assuming the program is moderately successful, USDA estimates the cost at about $100 million in its first year, and $150 million in FY 2001 and FY 2002.

Henry C. Kelly
01/07/2000 07:11:00 PM

Record Type: Record

To: Roger S. Ballentine/WHO/EOP@EOP, Rosina M. Bierbaum/OSTP/EOP@EOP, Samuel F. Baldwin/OSTP/EOP@EOP

cc:
Subject: EO on biomass: these are best fixes I can think of

Background:

A. get the title right:

Executive Order on Bio-based Products and Bioenergy

B. Definitions of biomass from the EO

Section 7. Definitions.

For the purposes of this order

(a) The term "biomass" means any organic matter that is available on a renewable or recurring basis (excluding old-growth timber), including dedicated energy crops and trees, agricultural food and feed crop residues, aquatic plants, wood and wood residues, animal wastes, and other waste materials.

This doesn't specifically rule out corn but its hard to read it in.

C. The argument is over net energy of bioenergy: the newest corn ethanol plants may provide a slight net fuel saving but the average small plant (encouraged by the new program) is probably much less efficient.

D. suggested language changes

====================================

Suggest following edit of sentences claiming environmental/energy benefits: The program will encourage investment in technology which can ~~will~~ help enhance energy security by reducing fossil fuel imports; reduce greenhouse gas emissions; and reduce fuel costs associated with Clean Air Act requirements."

The program will have the dual effect of expanding industrial consumption of agricultural commodities and encouraging investments in technology that could add~~ing to~~ the supply of bioenergy and biobased prod ucts ~~lubricants~~ in furtherance of the goals set forth in the President's Executive order on ~~Biomass~~ B iobased Products and Bioeenergy.

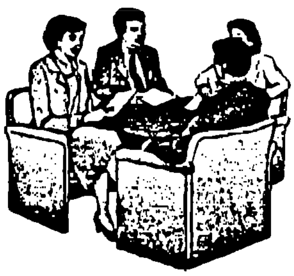
EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF MANAGEMENT AND BUDGET
WASHINGTON, D.C. 20503

DATE: 1/7/00
TIME: 6:15 pm

Natural Resource Division
ENVIRONMENT BRANCH
NEOB/RM: 8026

TO: Roger Ballentine
X 61736

FROM:



- ____R.Fairweather
- ____K.Neyland
- X R.Tuccillo
- ____P.Barr
- ____C.Dennis
- ____N.Glick
- ____N.Shapiro
- ____G.Foster
- ____C.M.Abendroth
- ____Z.Church
- ____D.Gaymon

Fax #202-395-5836
Phone #202-395-6827
Message: Biobased Energy Announcement

NUMBER OF PAGES TO FOLLOW: 5

Ron, Daniel, Neah

WH - draft to Beier 1/6
For possible announcement tomorrow!
Comments by 6:00

Expanding Production of Biobased Energy

Expanding demand, rather than storing or cutting back production, is the most beneficial way to restore balance to commodity markets. Because the potential to expand food or feed use is limited, expanding the use of farm products in industrial uses offers an advantageous alternative. For that reason, the President's budget proposals for strengthening the farm safety net will include $150 million for a new program to promote increased production of biobased fuels, including ethanol and soy-based oil additives. The program will help enhance energy security by reducing fossil fuel imports; reduce greenhouse gas emissions; and reduce fuel costs associated with Clean Air Act requirements.

The program will have the dual effect of expanding industrial consumption of agricultural commodities and adding to the supply of bioenergy and biobased lubricants in furtherance of the goals set forth in the President's Executive Order on Biomass. Under the program, USDA's Commodity Credit Corporation will provide incentive payments to bioenergy producers to compensate them for a portion of their commodity purchases made to expand existing production of bio-based fuels. The program is designed to encourage the construction of new bioenergy production facilities and full utilization of existing ones. Operationally, processors would request from USDA authorization to participate in the program for a period of between 1 to 5 years. USDA authorization would entitle processors to receive payments on the amount of additional agricultural commodities purchased during the year for the production of bioenergy in excess of the previous year's use. The request for authorization would include the firm's past and projected commodity purchases. Upon the completion of each program year, participating companies would be required to submit documentation of their actual purchases.

In order to target benefits toward smaller plants but still have a meaningful effect on demand expansion, all processors would be eligible to participate in the program. However, small- and cooperative-owned processing facilities would receive higher payment rates.

MARK WEATHERLY
395-4941 FAX

Question: **Who would be eligible to participate in the program?**

Answer: Producers of bioenergy would participate in the program. In order to target benefits toward smaller producers but still have a meaningful effect on demand expansion, all bioenergy producers would be eligible to participate in the program. However, small- and cooperative-owned processing facilities would receive higher payment rates.

Question: **What are the benefits of the program?**

Answer: The program will have the dual effect of expanding industrial consumption of agricultural commodities and adding to the supply of bioenergy and biobased lubricants in furtherance of the goals set forth in the President's Executive Order on Biomass. The program will help enhance energy security by reducing fossil fuel imports; reducing greenhouse gas emissions; and reducing fuel costs associated with Clean Air Act requirements.

Question: **When would the program begin?**

Answer: USDA will implement the program under the authority of the Commodity Credit Corporation Charter Act. The program will be implemented as soon as possible, after regulations are issued through the normal rulemaking procedures.

Question: **How much will the program cost?**

Answer: The costs of the program could vary, depending on how successful the program is in stimulating demand for bio-based energy products. Assuming the program is moderately successful, USDA estimates the cost at about $75 million in its first year, and less in subsequent years.

Terri Collins' piece done several months ago (?)

Expanding Industrial Use of Corn and Soybeans

Proposal: Expanding demand, rather than storing or cutting back production, is the most beneficial way to restore balance to commodity markets. Because the potential to expand food demand is limited, expanding the use of farm products in industrial uses offers an advantageous alternative. This program would provide 1 bushel of corn or soybeans to ethanol plants or soybean processors (who convert corn to ethanol and ethanol based fuel additives and soybeans to soydiesel, soybased diesel and fuel additives, and soybased lubricants and greases) for every 2.5 bushels they buy, *in excess of their previous year's purchases*, for a five-year period from 2000 to 2004. (A higher payment rate would be used for small plants, as discussed below.) The base year for calculation of increased purchases would be 1999. A five-year program is proposed to be of sufficient duration to encourage the construction of new processing capacity, with the dual effect of removing more corn and soybeans from the market and adding to the supply of bioenergy and biobased lubricants, in furtherance of the goals set forth in the President's recent Executive Order promoting the use of bioenergy and biobased products.

Operationally, processors would request from USDA authorization to participate in the program for from 1 to 5 years. USDA authorization would entitle processors to receive certificates on the amount of additional corn purchases in excess of the previous year's use for each year of requested participation in the program. Certificate value would be based on the lower of market price or CCC loan rate at the processing plant location. Certificates would be redeemed for CCC-owned corn or soybeans (or possibly for cash). The request for authorization would include the firm's projected increases in anticipated corn or soybean purchases, in each year of program participation, for purposes of producing the bioenergy or biobased lubricant products cited in the previous paragraph. USDA would authorize access to certificates for one program year at a time. Processing firms could draw on certificates authorized for the current program year on a quarterly interval, based on corn or soybean purchases projected under the approved plan. Upon the completion of each program year, participating processors would be required to submit documentation of additional corn or soybeans purchased (as compared to the previous year) and processed into the approved bioenergy and biobased lubricant products. Based on end of year documentation, processing firms could obtain additional certificates to which their processing volume entitled them, or would reimburse USDA for certificates obtained but not utilized in that production year.

Targeting Options: Large ethanol plants and/or large firms could be excluded from the program. One possible size limit could be based existing tax provisions. That is, plants with annual processing capacity of over 30 million gallons of ethanol (12 million bushels of corn) could be excluded. Similarly large soybean processing plants and/or large firms could also be excluded from the program. However that size limit would sharply reduce the ability of the program to lower crop surpluses, since 81 percent of the Nation's ethanol capacity is in plants of over 30 million bushels of annual capacity and more than 80 percent of the Nation's soybean processing capacity is in large scale plants or owned by large firms.

In order to target benefits toward smaller plants but still have a meaningful effect on demand expansion by including the larger plants in the program, an alternative targeting approach is to provide large plants with 1 bushel for every 2.5 they purchase and small plants with 1 bushel for every 1.5 bushels they purchase.

At this point, the Federal government owns only very small amounts of corn and soybeans. Corn and soybeans provided under the certificate program would have to be acquired through forfeiture or purchased by CCC.

Precedent: As one of the numerous initiatives to assist farmers in economic crisis in 1986, USDA issued certificates to ethanol producers that entitled them to one bushel of corn for every 2.5 bushels they removed from the market and converted to ethanol. The program cost $54 million and an estimated 30 million bushels of corn were removed.

Current Rationale: The industrial market has the best potential within the United States to absorb surplus grain, as food and feed uses have little prospect for substantive expansion. By being multiyear, the program would help alter the competitive structure of the market, improving farmers economic position in the future. In addition, supporting ethanol, biodiesel, and biobased lubricants will have the following benefits: 1) Enhanced energy security by reducing fossil fuel imports. 2) Greenhouse gas emission reductions. 3)Reduced cost for fuel in meeting Clean Air Act requirements. This cost reduction would help many states, especially California, interested in reducing use of MTBE as a gasoline oxygenate because of its adverse effects on ground water quality but worried about higher ethanol costs. In addition, the lower corn costs would help offset increased refinery costs of gasoline to be blended with ethanol when Phase II of the Clean Air Act is implemented on January 1, 2000. 4) And, support of expanded production capacity for bioenergy and biobased products as called for in the President's executive order.

Expected Effects: There currently is unused ethanol production capacity in the United States of about 315 million gallons annually, equivalent to 126 million bushels of annual corn utilization. The proportion of unused capacity is believed to be the same for large and for small ethanol plants. The proposed program would reduce processors marginal corn costs for expanded production by 29 percent (and by 40 percent for small plants under the targeting approach). Federal program cost estimates for corn are ranged with the following two scenarios, which assume all ethanol producers are eligible to participate.

Scenario 1: baseline. The current USDA baseline assumes little expansion in ethanol by 2004. Under this assumption, the program would increase corn demand for ethanol plants in 2000 by an estimated 126 million bushels, thus fully using existing capacity, but use could possibly be limited by large ethanol supplies currently on hand. In subsequent years, there would be little added production qualifying for certificates in existing plants. In 2000, then, using a CCC payment rate of 1 bushel for each 2.5 bushels purchased, processing plants would purchase 89.5 million bushels of corn and USDA would provide funding for purchase of another 36.5 million bushels, at a cost of about $69 million, assuming corn is procured at the CCC loan rate of $1.89 per bushel. Additional ethanol production capacity of 123 million gallons per year currently is under construction, all plants of under 30 million gallons annual capacity. Assuming that this added capacity is phased in during 2001-2005, that could add another $67 million in costs, bringing the 5-year CCC costs for corn ethanol to $136 million. There currently are about 35 million gallons of unused soydiesel production capacity, equivalent to additional use of 25 million bushels of soybeans; little expanded use is expected.

Under the small firm targeting option, costs would be slightly higher. Small plants would use 24 million of the 126 million added corn use resulting in a FY 2000 cost to the CCC of $75 million. Assuming future additions to capacity are similarly divided between large and small plants, the 5-year costs would total $147 million.

Scenario 2: MTBE phase out. Demand for ethanol could expand substantially if the EPA's Blue Ribbon Panel recommendation to phase down MTBE for use as an oxygenate in gasoline is implemented and if oxygenate requirements in the Clean Air Act are retained. If ethanol were to become the primary oxygenate additive, the U.S. ethanol production would have to more than double from 1.4 billion gallons to 3.3 billion gallons annually by 2004 to meet projected market demand. The additional ethanol production would utilize an increasing amount of corn as it is phased in between 2000 and 2004, with up to 760 million additional bushels of corn used annually by 2004. Assuming 1 bushel paid out by CCC for every 2.5 bushels purchased, the 5-year CCC cost of providing certificates worth 29 percent of the value of the corn could be as much as $417 million, with corn acquisition cost at the CCC loan rate of $1.89 per bushel, with all ethanol processors participating. With a higher payment rate for small plants, the 5-year cost would be $447 million.

The increase in demand for soydiesel is likely to be moderate, from a small base, resulting in very small CCC costs. A 1-percent additive market and a 20-percent blend market are the most likely uses for soydiesel. Adoption of soybased lubricants for certain uses in agriculture, food processing, recreational boating, and truck and rail transportation could add to demand for these lubricants, and to soybean demand by processors. Soybased lubricants currently are being tested in applications in each of these areas.

DRAFT

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❖Office of Fuels Development
Office of Transportation Technologies
Energy Efficiency and Renewable Energy

FACSIMILE COVER SHEET

Date: 12/1/1999
To: Roger Ballantine –c/o Angie Miser
Tel #:
Fax #: 456-1736

From: John Ferrell
Location:
Tel #: (202)586-6745
Fax #: (202) 586-9815

Number of Pages (including this Cover Sheet): 7

❖❖

MESSAGE:

Dan Reicher's "DRAFT" presentation for visioning meeting.

DOE Bioenergy Vision Review and Adoption Meeting

Dan Reicher

Assistant Secretary

Office of Energy Efficiency and Renewable Energy

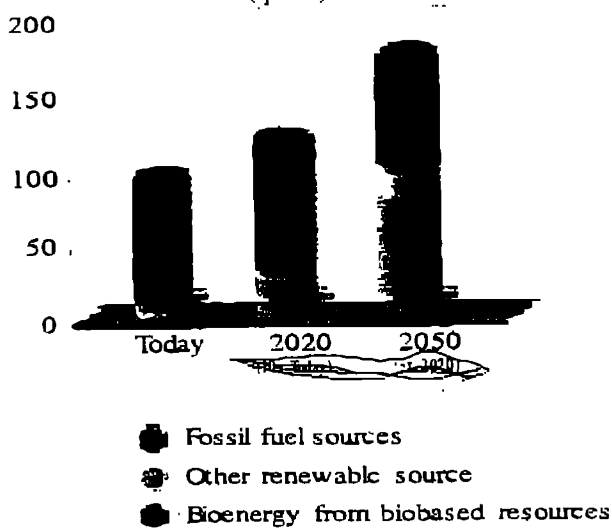
December 1, 1999

Vision Targets

- By 2010, increase bioenergy use 3-fold over today's levels
- By 2020, increase bioenergy use by 10-fold over today's levels
- By 2050, increase bioenergy use by another 3-fold over 2020 levels

Vision Targets

U.S. Demand for Energy and Feedstocks
(quads)



What Would a 10-fold Increase Mean?

- U.S. would vastly increase its self-sufficiency and reduce our reliance on fossil fuels
- U.S. would use 30 quads of bioenergy which is equivalent to replacing all U.S. crude oil imports
- U.S. could rely on bioenergy to satisfy virtually all incremental growth in demand for energy and feedstocks through 2050

Vision Assumptions

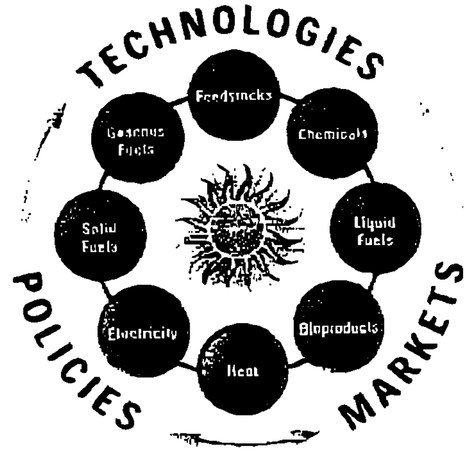
- In the face of escalating U.S. and world energy demand, both renewable and nonrenewable resources will be needed in the 20-year time frame
- Growth in renewables will be required in the 20-year time frame, even though opportunities for improvements in energy efficiency will be broadly exploited by energy producers and by end-use sectors

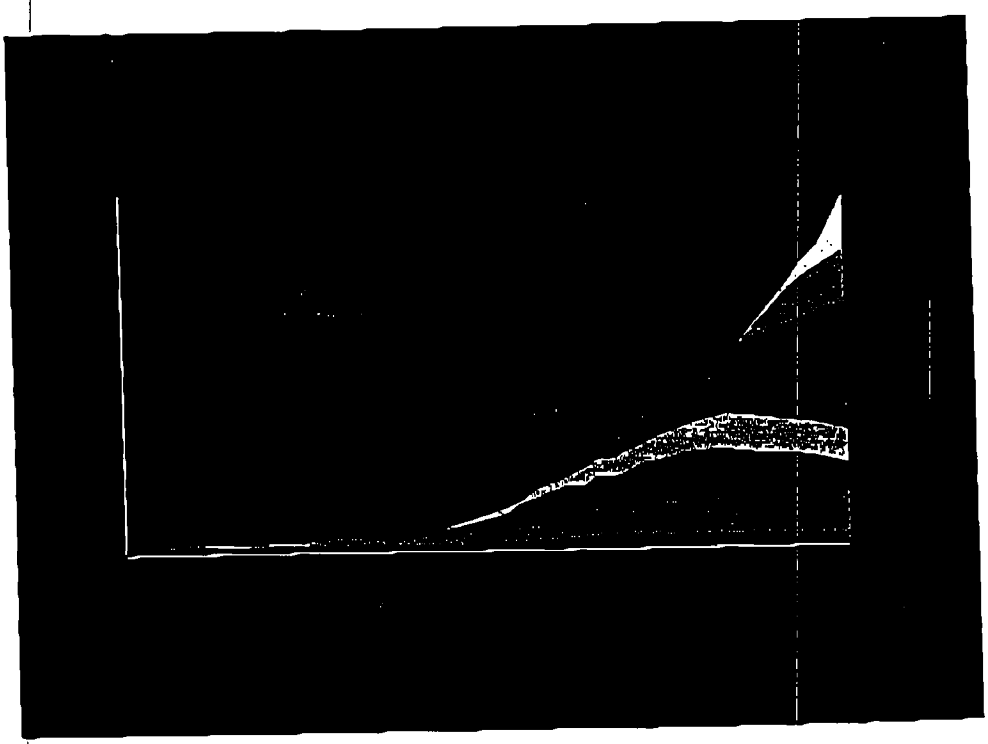
A Call to Action

The realization of the Vision will require action on 3 fronts

- Scientific and technological innovation across multiple disciplines
- Private investment in markets and infrastructure
- Development of supportive government policies

The Challenge





Options for Next Steps

- Selectively choose a larger reviewer group
- Have reviewer group become executive steering committee to solicit and alter vision accordingly
- Hold regional meetings
- Place announcement in Federal Registrar
- Place vision on bioenergy website for public review

FY 2000: $6 Million Plan

- $0.4 million for administration
- $0.4 million for outreach and communication
- $5.2 million for competitive solicitation
  - $0.2 million for EE broad-based solicitation
  - $0.5 million for analysis
  - $4.5 million for R&D

Solicitation Information

- Target Dates
  - Release solicitation by Christmas
  - Make awards by second quarter
- Potential Areas
  - resource assessment
  - XX

White House Climate Change Task Force

734 Jackson Place, N.W. • Washington, DC 20503

November 30, 1999

Re: Bioenergy Event

Dear Roger,

Attached is the agenda and list of attendees at tomorrow's bioenergy event.

This is the 4th of a series of bioenergy industry outreach meetings led by DOE with the new EO, DOE has engaged USDA and their stateholders in the meeting.

You should make brief remarks focussing on the President's commitment and the importance of this partnership with industry.

Also attached FYI is the briefing Reicher gave to OMB last week on FY2001 bioenergy overtarget request.

Sincerely,

spk

Bioenergy Vision Review and Adoption Meeting
December 1, 1999
U.S. Capitol, Room SC-5
Washington, D.C.
10:00 a.m.- 4:00 p.m.

Draft Agenda

10:00 - 10:30 Opening & Welcome

Dan Reicher, DOE Assistant Secretary for Energy Efficiency and Renewable Energy

Miley Gonzalez, USDA Under Secretary for Research, Education, and Economics

White House Representative

10:30 - 10:45 Introductory remarks from attendees

10:45 -11:00 Present Revised Bioenergy Vision- Dan Reicher

11:00 - 12:15 Vision Discussion

12:15 - 1:15 Working Lunch

Executive Order signing ceremony video

Update on Legislation- Congressional staffers

1:15 - 1:45 Next Steps for Vision

1:45 - 3:15 Develop Roadmap Topics and Timing

Denise Swink- Overview of process

3:15 - 3:30 FY 2000 and FY 01 Budget & Solicitation Update - Dan Reicher and Miley Gonzalez

3:30 - 4:00 Wrap Up & Adjourn - Dan Reicher

DOE Bioenergy Vision Review and Adoption Meeting
Attendee List
November 24, 1999

Invitees	Registered	DOE Person To Follow-Up
Martin L. Andreas. Archer Daniels Midland Company 202-586-9232		Bob
Sam Baldwin, NSTC Agency Representative 202-456-6073		
Earl Beaver, Practical Sustainability 314-694-6087	Yes	
Mitch Beaver, Illinois Department of Commerce 217-785-2009		Bob
Tanya Blalock, Southern Company 404-506-0492 tdblaloc@southernco.com		Ray
David Boron, DOE/OIT 202-586-0080		
James Bostic. Georgia-Pacific 404-652-5250 jebostic@gapac.com		Ray
Richard Bradshaw, DOE 202-586-4898		
Joe Bryson, EPA 202-564-9631		
Ron Buckhalt, USDA 202-260-1074	Yes	
Stan Bull, NREL 303-275-3030	Yes	

Gil Gilliland, ORNL 423-574-9920		
David Glassner, NREL 303-384-6820	Yes	
Phil Goldberg FETC	yes	
I. Miley Gonzalez, USDA 202-720-5923		
Robert Harris, DOE/EE 202-586-0484	Yes	
Fred Heineken NSF		
Richard Herrett, ARI 202-544-5534	Yes	Doug
Robert Horn, Detroit Edison 202-347-8420 hornr@dteenergy.com		Ray
Robert Horsch, Monsanto 603-821-3460	Yes	
Patricia Hus, NIPSCO 219-647-5263 pjhus@nipsco.com		Ray
Jack Huttner, Genencor 716-256-5272	Yes	Richard/John
Lynn Jensen, National Corn Growers Association 605-847-4580		Doug
Lennart Johansson, STM 734-995-1755 lenstm@aol.com		Ray

Edan Prabhu, Reflective Energies 949-380-4899 edanprabhu@msn.com	Yes	Ray
Curt Ranger, DTE Biomass Energy Services, Inc. 734-913-2085		
Anda Ray TVA	No	
Delmar Raymond, Weyerhaeuser Company 253-924-6850	No	
Valerie Reed, DOE/OTT 202-586-5618		
Dan Reicher DOE/EE 202-586-9220	Yes	
Don Richardson, DOE 202-586-4591	Yes	
Martha Rollins, TVA 423-751-4712	Yes	
Doug Rundell, BP/Amoco 630-420-4923		??
Jennifer Ryan, Energetics, Inc. 202-479-2748 X108	Yes	
Anthony Schafthauser, ORNL 423-574-4826	Yes	
Jeff Seabright, White House Climate Change Task Force 202-395-2329		Dan
Arthur E. Smith, Jr., NIPSCO 219-647-5252 aesmith@nipsco.com		Ray

Gerald Caughman, Trigen 704-525-5819	Yes	
Marge Cavanaugh NSF		Bob
Gerard Closset, Champion International Corporation 203-358-6497	No	Doug
Raymond Costello, DOE/OPT 202-586-4898		
Chris Demeter, Antares Group 301-731-1900	No	
Gregory Dilworth, DOE/OSC 301-903-2873		
Robert Dixon, DOE/OPT 202-586-9275 robert.dixon@hq.doe.gov		Ray
Robert Dorsch, DuPont 302-695-7600		Bob
Mark Dungan, United Soybean Board 314-579-1580	Yes	
David Durham, United Soybean Board 660-398-4378	Yes	Doug
Doug Faulkner, DOE/OIT 202-586-2119	Yes	
John Ferrell, DOE/OTT 202-586-6745	Yes	
Stephen Gatto, BC International 781-461-5700	Yes	

Henry Kelly, OSTP/EOP 202-456-6033		Bob
Kelly Kirkpatrick, OSTP/EOP 202-456-6037		
Karen Larsen, USDA 202-720-8787		
Steven Lee, DOE 202-586-9273	Yes	
David Leiter, DOE 202-586-9220		Richard
James McLaren, Inverizon International 314-530-6943	Yes	
Richard Moorer, DOE/OTT 202-586-5350	Yes	
David Morris, Institute for Local Self Reliance 612-379-3815 dmorris@ilsr.org		Ray
Edward Neuhauser, Niagara Mohawk Power Company 315-428-3355 neuhausere@nimo.com		Ray
Norman Olson, ASERTTI Representative 515-294-9331	Yes	
Bill Parks, DOE/OIT 202-586-9232		
Robert Perciasepe, EPA 202-260-7400		
Gary Poehlin NSF		Bob

Denise Swink, DOE/OIT 202-586-9232	Yes	
Jill Long Thompson, USDA 202-720-4581		Bob
Joe Visalli, New York State Energy Research and Development Authority 518-862-1090 X3205	Yes	
Carol Werner, Environmental and Energy Study Institute 202-662-1881	Yes	Bob
Bill White EPA 202-260-4724		Bob
James Woolsey, Shea and Gardner 202-828-2056	Yes	
Lynn Wright, ORNL 423-574-7378	Yes	
Jennifer Yezak-Molen, USDA/REE 202-690-0878	Yes	Bob
Total Invited: 71	29	

FY 2001 Overtarget Budget Request for the Biobased Products and Bioenergy Initiative

Briefing to the

Office of Management and Budget

November 12, 1999

The Goal

To triple U.S. use of biobased products and bioenergy by 2010

President Clinton
Executive Memorandum
August 12, 1999

The Vision

"U.S. is the Saudi Arabia of carbohydrates."

David Morris, Institute for Local Self Reliance

"Moving from an economy based on geology to one based on biology."

USDA

"Changes that will have effects comparable to those of the Industrial Revolution… are now beginning."

Phillip Abelson, Science Magazine

The Benefits

- Spur our rural economy
- Reduce our nation's dependence on foreign oil supply
- Improve our environment
- Enhance forest productivity
- Integrate bioenergy and biobased products efforts to better position the U.S. to meet the President's tripling goal

Key Federal Partners

- U.S. Department of Energy
- U.S. Department of Agriculture
- Environmental Protection Agency
- National Science Foundation

Bioenergy Program Status

Vision Process

- Draft industry-vision document prepared
- Technology roadmap development planned
- Vision review and adoption meeting scheduled for 12/1/99

Related Industry Visions and Roadmaps Completed

- Biobased products: "Plant/Crop-based Renewable Resources 2020"
- Forest products industry: "Agenda 2020"

Early Stages of Implementing Executive Order

- Interagency Council on Biobased Products & Bioenergy
- Advisory Committee
- Coordination Office

Political Status

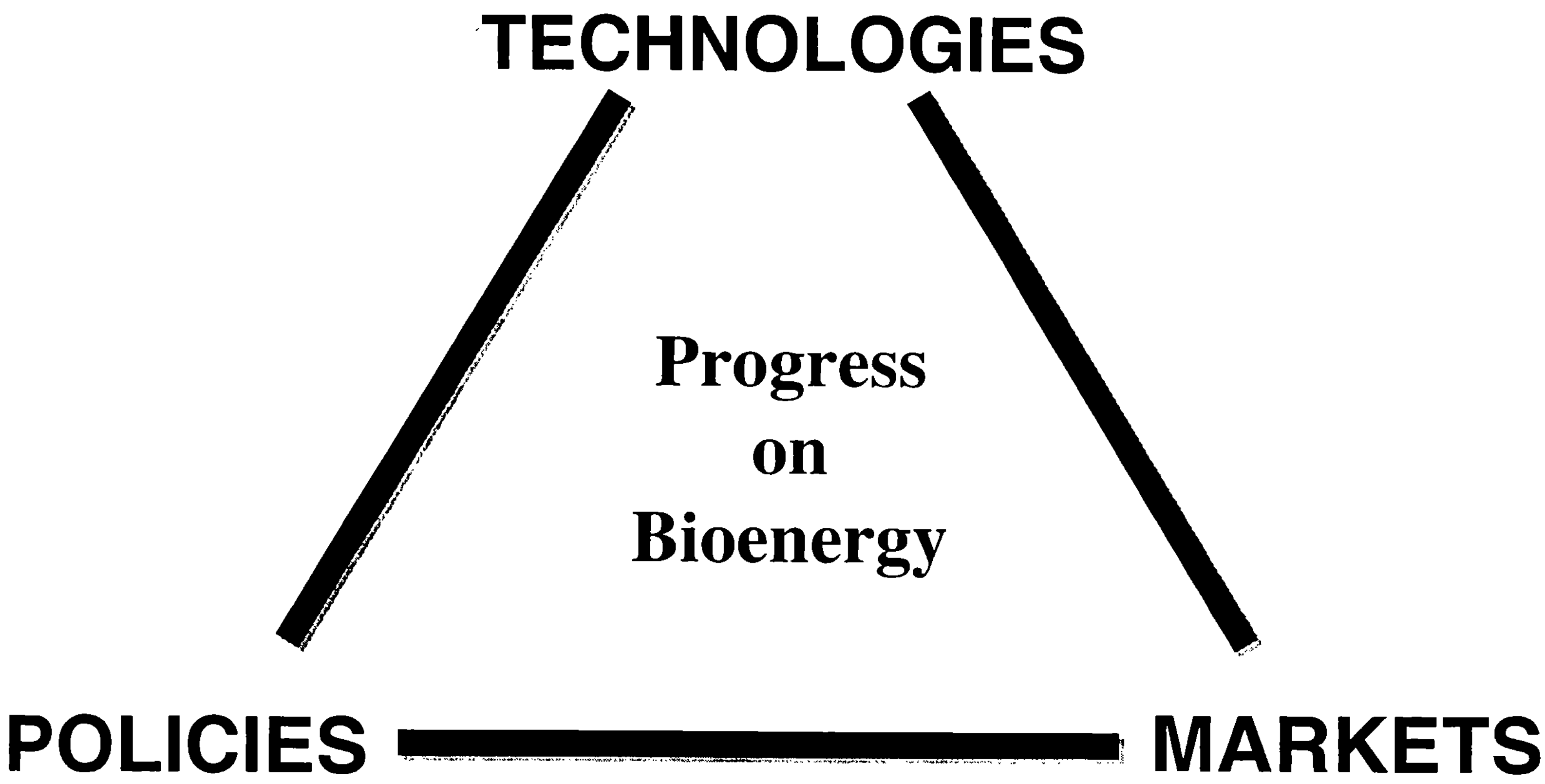
- Administration Support
  - Executive Order 13134- "Developing and Promoting Biobased Products and Bioenergy" and Executive Memorandum
- Bipartisan Legislative Support
  - 3 biomass bills introduced this Congress
    - S. 935 - Senator Lugar (R-IN)
    - H.R. 2827 - Representative Ewing (R-IL)
    - H.R. 2819 - Representative Udall (D-CO)
- NRC Study "Biobased Industrial Products: Research and Commercialization Priorities"
- Broad-based constituency support

Biobased Products and Bioenergy

- Sustainable raw materials from:
  - Crops
  - Trees
  - Residues

- Converted into:
  - Fuels
  - Power
  - Chemicals
  - Building materials and consumer goods

Success Factors



Key Challenges

- Increasing farm and forest income
- Securing a reliable source of competitively-priced feedstocks
- Reducing feedstock conversion and manufacturing costs and developing new production, delivery, and processing systems
- Selecting viable technologies for commercial demonstration
  - Ensuring a sound science and technology base for these systems
- Effective technology transfer

Strategy Highlights

To meet the President's tripling goal:

Integrate government/industry efforts for bioenergy on RD&D

Benefits of Integration

- Dramatic acceleration of technology
- Leveraging of opportunities

FY 2001 Funding Request
($ millions)

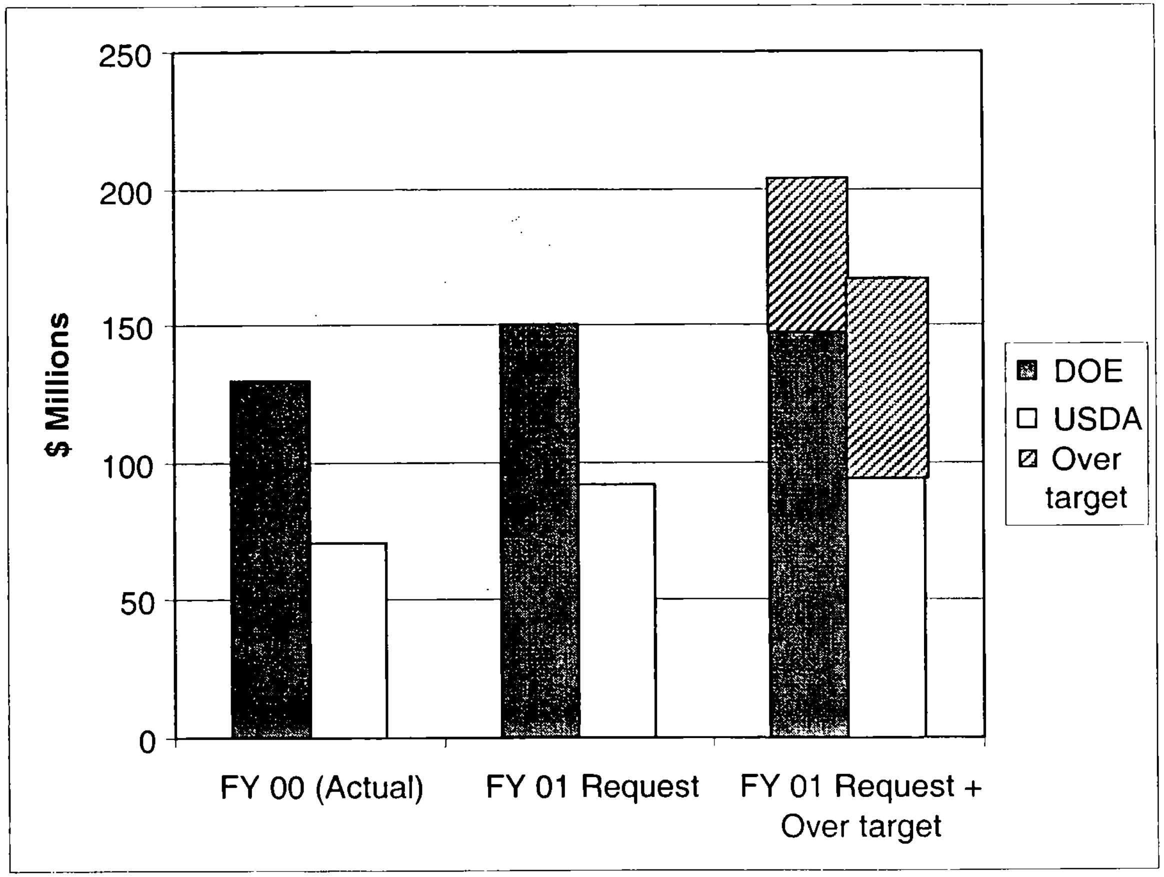
Activity Areas	*Research & Development*		*Demonstration & Commercialization*		*Analysis*		*Outreach & Education*		*Totals*	
	DOE	USDA	DOE	USDA	DOE	USDA	DOE	USDA	DOE	USDA
Feedstocks	33.1	55.9	0.5	3.6	0.5	1.2	0	1.0	34.1	61.7
Conversion	83.9	14.0	24.9	0	2.0	0.3	1.9	0	112.7	14.3
Products	1.5	3.5	0	10.2	0	0.7	2.0	1.7	3.5	16.1
Totals	118.5	73.4	25.4	13.8	2.5	2.2	3.9	2.7	150.3	92.1
									TOTAL: 242.4	

FY 2001 Funding Requirements for Biobased Products & Bioenergy Initiative

($ millions)

Activity Areas	*Research & Development*		*Demonstration & Commercialization*		*Analysis*		*Outreach & Education*		*Totals*	
	DOE	USDA	DOE	USDA	DOE	USDA	DOE	USDA	DOE	USDA
Feedstocks	5.0	10.4	0	19.7	0	1.5	0	0.3	5.0	31.9
Conversion	30.0	7.2	14.0	10.7	2.0	1.4	2.0	0.4	48.0	19.7
Products	0	3.1	0	13.6	0	2.3	0	4.4	0	23.4
Totals	35.0	20.7	14.0	44.0	2.0	5.2	2.0	5.1	53.0	75.0
									TOTAL: 128.0	

DOE & USDA FY 2000 - 01
Bioenergy and Biobased Products
Budget Information



How Will Funds Be Used?

- Develop science and technology base to support the biorefinery concept
  - Feedstocks
  - Conversion
  - Biobased Products
- Facilitate commercial deployment of biorefineries and associated technologies
- Outreach and Education

Feedstocks

- Research and Development
  - Fundamental plant genomics
  - Plant biotechnology
  - Resource-efficient feedstock production and delivery processes
- Demonstration and Commercialization
  - Significant new acreage for dedicated energy crops
  - Processes to recover added-value products
  - Developing new cropping systems

Conversion

- Research and Development
  - Biocatalyst development
  - Gas conditioning for power/chemicals
  - Separations
  - Composite matrices
- Demonstration and Commercialization
  - Biomass and black liquor gasification integrated gasification combined cycle
  - Bridge to corn ethanol
  - Co-firing and distributed power systems
  - Molded fiber products

Products

- Research and Development
  - New high-value products linked more to basic plant structure
- Demonstration and Commercialization
  - Demonstrate new and substitution products
  - Biorefinery concept

Analysis & Outreach

- Analysis
  - Integrate predictive models
  - Conduct market analyses
    - Develop supply and demand projections
- Outreach and Education
  - Use newest information technology
    - Rapid dissemination of information
  - Build on existing DOE/USDA regional programs
  - Promote multi-disciplinary programs in universities
  - Raise consumer awareness

DOE Exemplary Milestones by 2005

Milestones without Initiative

Biomass sugars cost 6 cents/lb

Ethanol production cost is $1.15 per gallon, resulting in annual use of 280 million gallons of cellulosic ethanol in the oxygenate and octane markets

Replace 3 GWe of coal-based generating capacity with biomass co-firing

Demonstrate successful integration of biomass gasification and gas turbine power systems

Build 1 gasification plant

Milestones with Initiative

- Biomass sugars cost 5 cents/lb
- Ethanol production cost is $0.85 per gallon, allowing cellulosic ethanol use in the oxygenate and octane markets to increase to 360 million gallons
- Replace 4 GWe coal-based generating capacity with biomass co-firing
- Replace 250 MWe of generating capacity in the forest products industry with biomass gasification
- Build 1-2 gasification plants
- Increase dedicated energy crops by 500,000 acres

DOE Exemplary Milestones for 2010

Milestones without Initiative

- Biomass sugars cost 5 cents per pound
- Ethanol production cost is $1.02 per gallon, with ethanol use in the oxygenate and octane markets reaching 2.2 billion gallons per year
- Replace 4 GWe of coal-based generating capacity with biomass co-firing
- Replace 150 MWe of generating capacity in the forest products industry with biomass gasification
- Build 4 gasification plants

Milestones with Initiative

- Biomass sugars cost 4 cents per pound
- Ethanol production cost is $0.73 per gallon, allowing celluolosic ethanol use in the oxygenate and octane markets, and in E85 (in the Midwest) to increase to 3 billion gallons per year
- Replace 8 GWe of coal-based generating capacity with biomass co-firing
- Replace 2 GWe of generating capacity in the forest products industry with biomass gasification
- Build 10-12 gasification plants

DOE Exemplary Milestones for 2020

- 10% of chemical building blocks from plant-derived renewables by 2020- a five-fold increase from today (*Plant/Crop-based Renewable Resources 2020*)

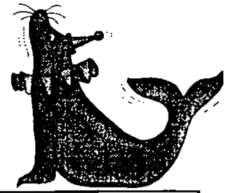
- Increase growth rates for trees by 2020 by 4 times current rates (*Agenda 2020*)

Initiative Priorities

- Use existing programs to accelerate commercialization of technologies
- Lower cost of production and processing of feedstock
- Develop new crops and new products from existing crops
- Facilitate and expand Federal Purchase of bioenergy and biobased products
- Ongoing economic analysis to measure success and develop priorities

USDA Exemplary Milestones

Kenaf



Growers of commodity crops in Texas, Arizona, Mississippi, New Mexico, Florida and as far north as Kentucky will have an alternative crop, kenaf, that converts more greehouse gases to plant fiber than trees or any other suitable paper-making crop. This will reduce global warming, reduce chemicals used in paper-making and increase income to farmers.

	Milestones without Initiative	Milestones with Initiative
2005	◆ Build one demonstration plant for converting 30,000 tons/year of kenaf from about 3500 acres into paper and 15,000 tons per year of kenaf lignin into glue and fertilizer	◆ Build two commercial plants for converting 120,000 tons per year of kenaf from about 28,000 acres into paper and coproducts including glue, fertilizer, and others
2010	◆ Reduce the burning of lignin (production of greenhouse gases) as a result of paper production by 5%	◆ Reduce the burning of lignin (production of greenhouse gases) as a result of paper production by 20% of kenaf paper development

USDA Exemplary Milestones

Biobased Materials

Develop biocatalytic process to convert agricultural residues and byproducts and low-value starches into valuable substitutes for imported gums, biodegradable polymers, coatings and adhesives. Over 6 billion pounds of petroleum-based adhesives are produced in the U.S. each year.

With initiative in 2005:

- Could penetrate 5% of the food and industrial gums market and 1% of the petroleum-based adhesives and provide $70 million in sales and the same in reduced imports.

With initiative in 2010:

- Could penetrate 10% if the food and industrial gums market and 10% of the petroleum-based adhesives market which would provide $680 million in new sales and reduced imports and increase revenues to thousands of farmers and create hundreds of jobs in the food and industrial products manufacturing sector

USDA Exemplary Milestones

Agricultural Materials to Biofuels

Over 450 billion pounds of corn stover are produced in the U.S. each year. Stover contains valuable phytochemicals, including chlosterol lowering phytosterols and other natural products. Extracting 2% of these chemicals would mean 10 billion pounds of products for human and animal foods, pharmaceutical intermediates, and industrial chemicals.

With the initiative in 2005:

- Create technology leading to utilization of 5% of available stover biomass for production of $10 million worth of phytochemicals and $10 million worth of polysaccharide based paint and coatings ingredients thus increasing farm and forest revenue by millions of dollars and creating scores of new jobs.

With initiative in 2010:

- Create technology leading to utilization of 20 % of available stover biomass, $30 million of phytochemicals, $100 million of industrial paints and coatings, $50 million in reduced imports, tens of millions of increased farm revenue and hundreds of new jobs. Also, a savings of $100 million in savings from improved efficiencies in using non-engineered microorganisms.

Initiative Highlights

The initiative is designed to reshape and build on ongoing programs in USDA and DOE

USDA & DOE have strong complementary programs in crop productivity, harvesting, and product conversion. The initiative suggests increasing bioproduct and biofuel feedstock research funding, from $55.9M to $66.3M

Existing USDA programs and authorities can be expanded and modified to support technology transfer, demonstration & commercialization activities from $3.6M to $23.3M

DOE has strong programs in electric and cellulosic chemical biofuel conversion. The initiative suggests increasing DOE cellulosic conversion funding from $78M to $108M. USDA programs would pursue supporting work in cellulosic and other conversion increasing from $14M to $21.2M

Supplementary Briefing

4 Detailed examples of how to meet the 3X goal:

- Reducing energy feedstock costs while increasing farm income
- Reducing the cost of converting biomass to sugars and ethanol
- Reducing the cost of converting biomass to electricity
- Convert raw materials into competitive biobased products

Example 1: Reducing Energy Feedstock Costs While Increasing Farm Income

- Limited amounts of biomass feedstock, such as urban mill wood residue, is available at $10-20 per ton, but most biomass crops and agricultural waste costs $30-$50 per ton
- Competitive bioproducts require biomass delivered at prices in the range of $20-$40 per ton
- Achieving this goal would require
  - Increasing the productivity of biomass crops from 4 dry tons per acre per year to 7.5 dry tons per acre per year
  - Cutting the cost of harvesting and delivering residues from $20/ton to $17/ton with new equipment
- It will be very difficult to reach these goals in less than 15-20 years with the base program; with enhanced funding, goals can be met in 10 years

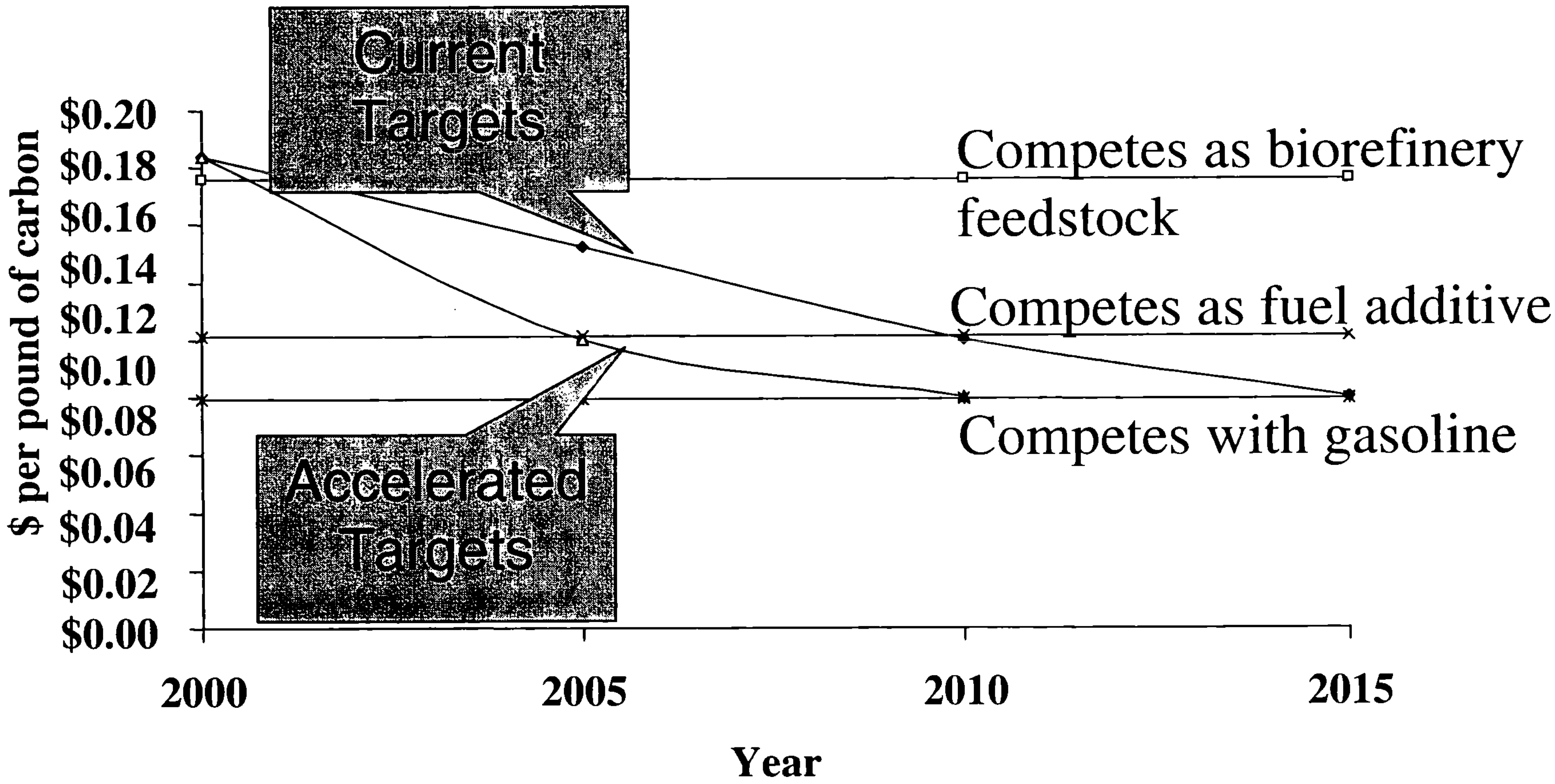
Funding Strategy

- Increased funding in the area of energy feedstock development allows for:
  - Initiating efforts to apply plant biotechnological methodology to increase feedstock yields and study co-production of higher value products within the feedstock
  - The increase in demonstration acreage of dedicated energy crops to 500,000 acres by 2005

Example 2: Reducing the Cost of Converting Biomass to Sugars and Ethanol

- The cost of delivering a pound of carbon in gasoline from petroleum could range from 8-18 cents, while the cost of delivering a pound of fuel carbon in ethanol from biomass is 28-38 cents
- Biomass conversion must be reduced to about 18 cents per pound for carbon to be competitive as a chemical feedstock, assuming feedstock goals are met
- Biomass conversion must be reduced to 8 cents per pound of carbon to compete with gasoline
- Under existing funding, the needed cost reduction will be achieved in 15-20 years; under the new funding, the cost goals can be met in under 10 years

The cost of carbon: Research targets and market values



Funding Strategy

- Increased funding in the area of sugar cost reduction allows for:
  - By 2010, design and create 60 new enzymes suitable for biobased chemical processes
  - By 2010, ethanol production costs are 73 cents/gallon, allowing ethanol use in oxygenates, octane, and E85 markets to increase to $3 billion gallons/year

Example 3: Reducing the Cost of Converting Biomass to Electricity

- Electricity produced from biomass now costs 50-75% more than conventional electricity
- Reducing costs requires improved gasification of biomass and high efficiency turbines (or fuel cells) compatible with these gases
- Under current funding levels, and assuming the feedstock goals are met, biomass electricity will not be competitive outside of niche markets until 2015. With the new funding, biomass may be competitive in broad markets by 2010

Funding Strategy

- Increased funding in the area of electricity production allows for:
  - The replacement of 4 GWe of coal-based generating capacity with biomass cofiring
  - The replacement of 250 MWe of generating capacity in the forest products industry with biomass gasification
  - 20 MW of distributed generation of village power systems in operation

Example 4: Convert Raw Materials into Competitive Biobased Products

- As a replacement for petroleum, biobased industrial products, harvesting, handling, and processing costs remain high

- Raw materials are bulky and processing must occur near the "farm gate" or forestry source

- Quantifying the broad-ranging and important positive energy and environmental benefits

Funding Strategy

- Increased funding in the area of developing competitive industrial biobased products allow for:
  - Improved competition
  - Development new crops and cropping systems
  - Commercialization of new uses for existing commodities
  - Reduction in imports by $1 billion a year

TALKING POINTS FOR THE INDUSTRY BRIEFING
ON
BIOBASED PRODUCTS AND BIOENERGY INITIATIVE
FOR
ROGER BALLANTINE

DECEMBER 1, 1999
4:30 pm
OEOB 472

- Welcome to Washington. I would like to take this opportunity to thank you all for joining us today to discuss our proposed Administration Biobased Products and Bioenergy Initiative.
- Your expertise and advice on how we proceed is critical to the success of this R&D initiative.
- As you know, the President signed a Biobased Products and Bioenergy executive order and memorandum on August 12, 1999 to accelerate the development of these 21st century technologies to bring bio-based technologies from farms, forests and labs to the marketplace. I think I saw most of you at the signing ceremony – we appreciated your support then!
- The President has set a very challenging goal of tripling America's use of bioenergy and bio-based products by 2010. This goals has the potential of $20 billion a year in new income for farmers and rural communities, while reducing greenhouse gas emissions by as much as 100 million tons a year – the equivalent of taking more than 70 million cars off of the road.
- Now it's time for us to figure out which steps we should consider taking to achieve this goal. Since the EO signing, the WHCCTF and OSTP have been working very closely with the Federal agencies – DOE and USDA in particular as well as EPA and NSF-- to develop a set of crisp goals for a R&D strategy with a competitive, peer-reviewed process to accomplish the goal set forth by the President.
- Today we would like to share our proposed Biobased Products and Bioenergy Initiative with you and candidly hear from you about any of its strengths, weaknesses or errors of omission. With that, I will turn the table over to Henry Kelly to outline the specifics of this initiative.

Biobased Products and Bioenergy Initiative

Industry Briefing

December 1, 1999

The Goal

To triple U.S. use of biobased products and bioenergy by 2010

DRAFT

President Clinton
Executive Memorandum
August 12, 1999

The Benefits

- Spur our rural economy
- Reduce our nation's dependence on foreign oil supply
- Improve our environment
- Enhance forest productivity
- Integrate bioenergy and biobased products efforts to better position the U.S. to meet the President's tripling goal

Key Federal Partners

- U.S. Department of Energy
- U.S. Department of Agriculture
- Environmental Protection Agency
- National Science Foundation

Bioenergy Program Status

Vision Process

- Draft industry-vision document prepared
- Technology roadmap development planned
- Vision review and adoption meeting scheduled for 12/1/99

Related Industry Visions and Roadmaps Completed

- Biobased products: "Plant/Crop-based Renewable Resources 2020"
- Forest products industry: "Agenda 2020"

Early Stages of Implementing Executive Order

- Interagency Council on Biobased Products & Bioenergy
- Advisory Committee
- Coordination Office

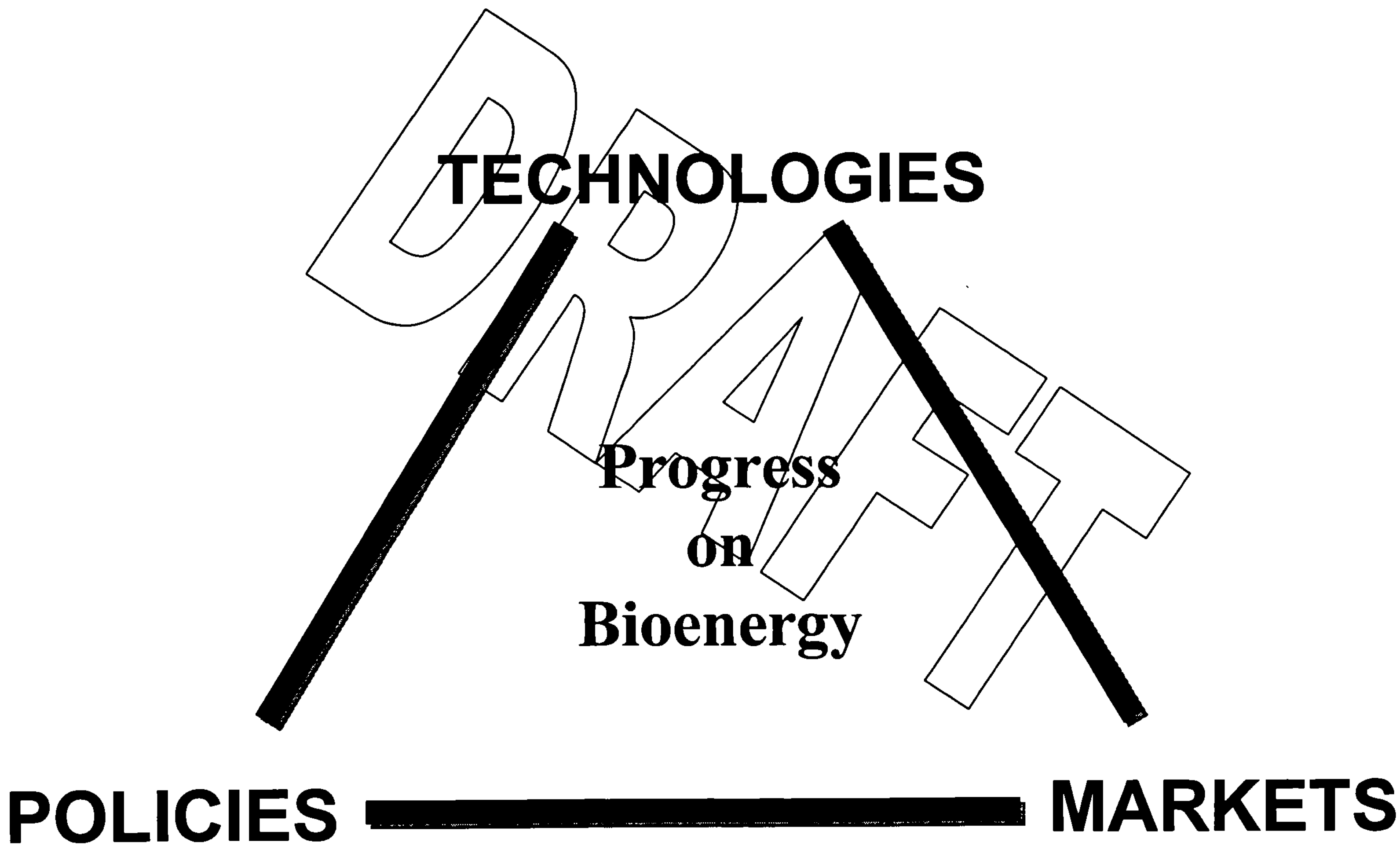
Political Status

- Administration Support
  - Executive Order 13134- "Developing and Promoting Biobased Products and Bioenergy" and Executive Memorandum
- Bipartisan Legislative Support
  - 3 biomass bills introduced this Congress
    - S. 935 - Senator Lugar (R-IN)
    - H.R. 2827 - Representative Ewing (R-IL)
    - H.R. 2819 - Representative Udall (D-CO)
- NRC Study "Biobased Industrial Products: Research and Commercialization Priorities"
- Broad-based constituency support

Biobased Products and Bioenergy

- Sustainable raw materials from:
  - Crops
  - Trees
  - Residues
- Converted into:
  - Fuels
  - Power
  - Chemicals
  - Building materials and consumer goods

Success Factors



Key Challenges

- Increasing farm and forest income
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- Selecting viable technologies for commercial demonstration
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Analysis & Outreach

- Analysis
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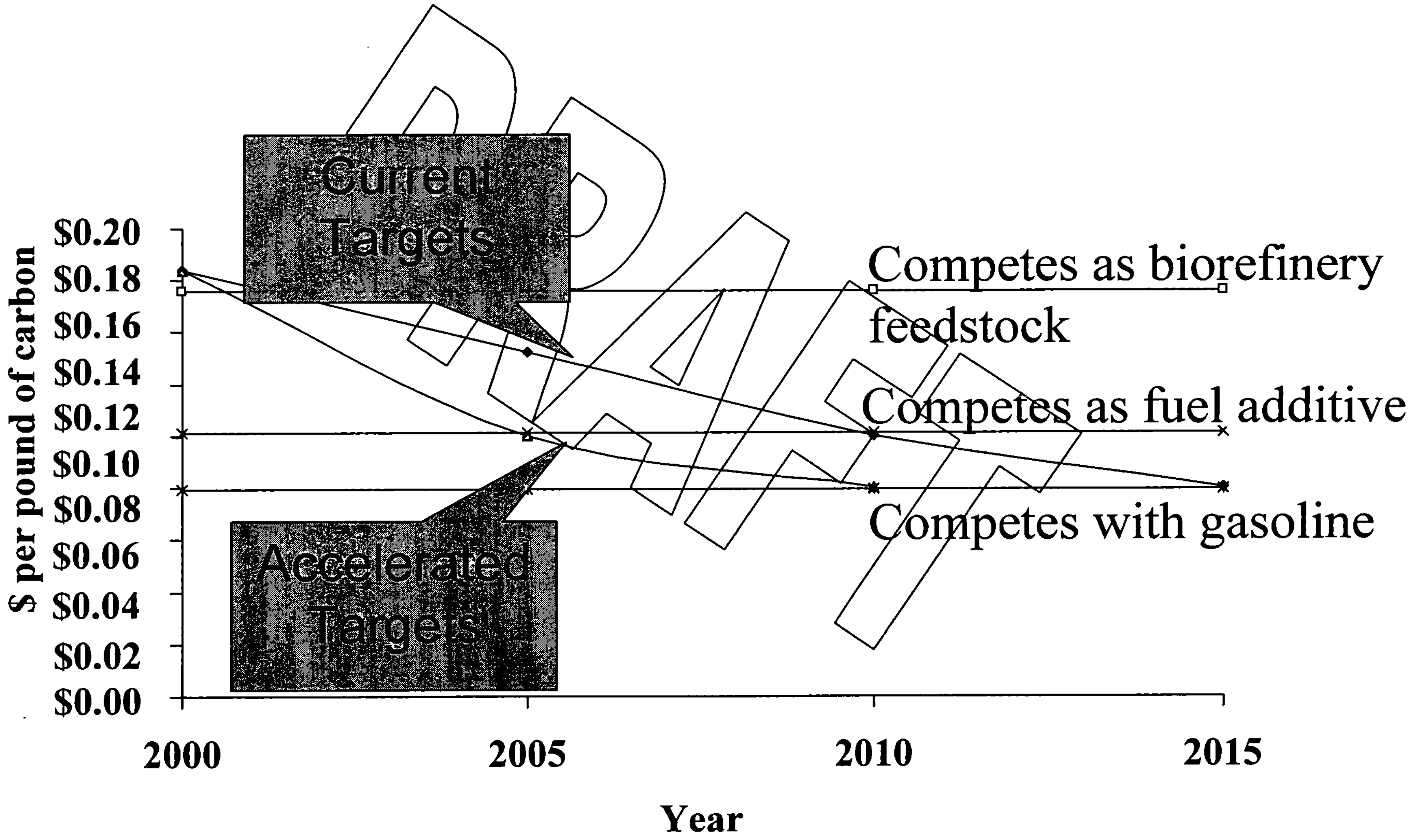

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ENERGETICS

501 School Street, S.W., Suite 500 Washington, DC 20024
PHONE (202) 479-2748
FAX (202) 479-0229

Date: November 30, 1999

To: Roger Ballentine
c/o Angie Miser

Fax Number: 456-1737

From: Jennifer Ryan

Attached is a DRAFT copy of Dan Reicher's presentation for DOE's Bioenergy Vision meeting tomorrow.

12 ***Pages (including cover)***

DOE Bioenergy Vision Review and Adoption Meeting

Dan Reicher

Assistant Secretary

Office of Energy Efficiency and Renewable Energy

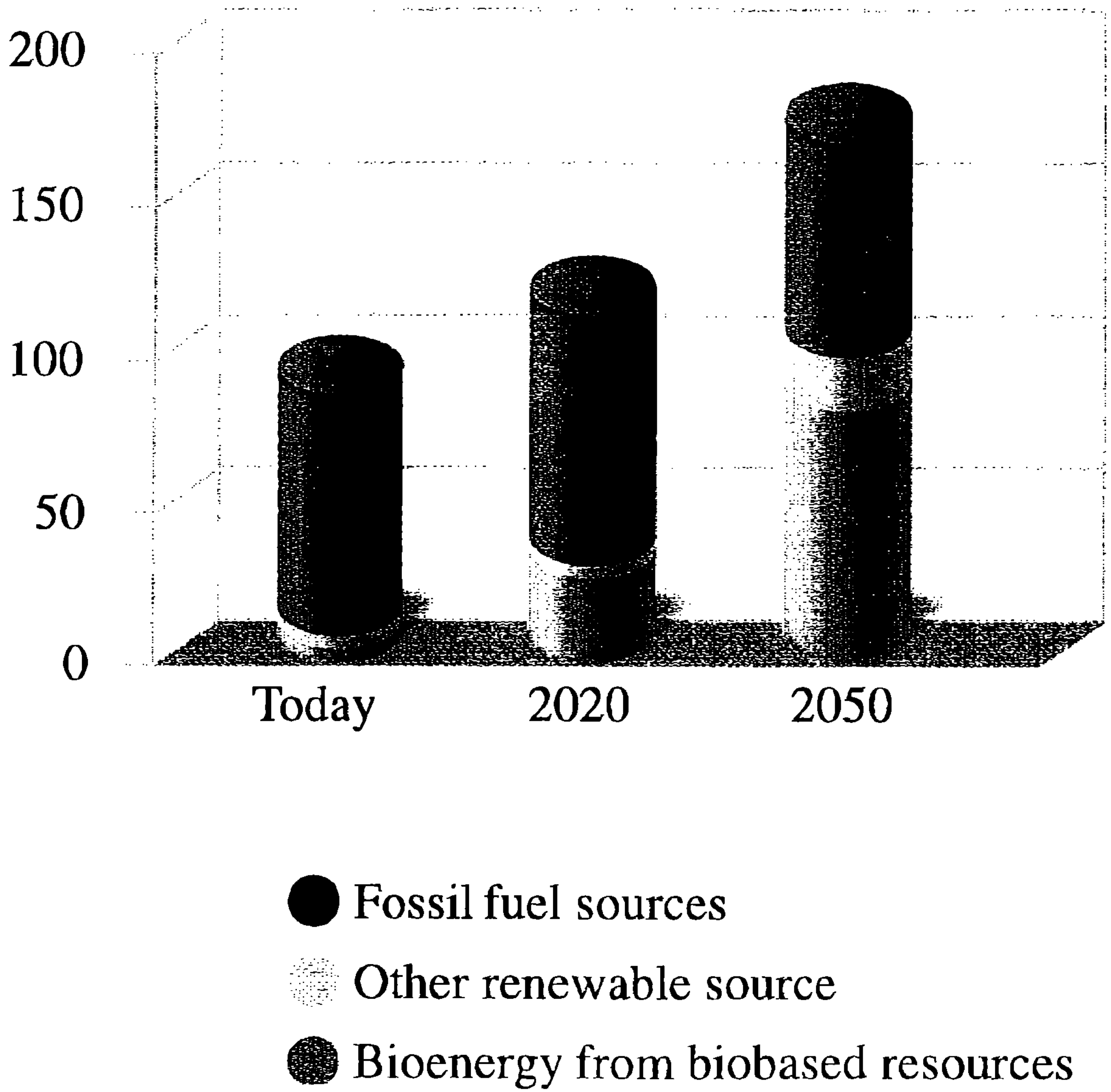
December 1, 1999

Vision Targets

- By 2010, increase bioenergy use 3-fold over today's levels
- By 2020, increase bioenergy use by 10-fold over today's levels
- By 2050, increase bioenergy use by another 3-fold over 2020 levels

Vision Targets

U.S. demand for energy and feedstocks (quads)



What Would a 10-fold Increase Mean?

- U.S. would vastly increase its self-sufficiency and reduce our reliance on fossil fuels
- U.S. would use 30 quads of bioenergy which is equivalent to replacing all U.S. crude oil imports
- U.S. could rely on bioenergy to satisfy virtually all incremental growth in demand for energy and feedstocks through 2050

Vision Assumptions

- In the face of escalating U.S. and world energy demand, both renewable and nonrenewable resources will be needed in the 20-year time frame

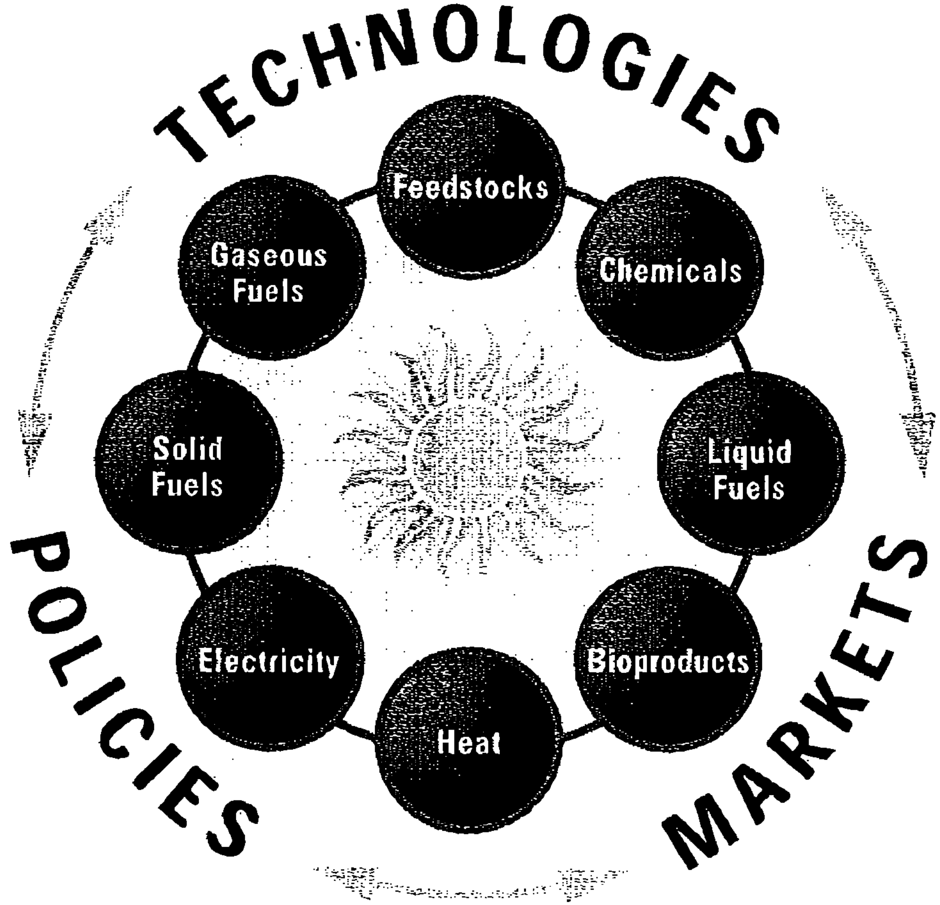
- Growth in renewables will be required in the 20-year time frame, even though opportunities for improvements in energy efficiency will be broadly exploited by energy producers and by end-use sectors

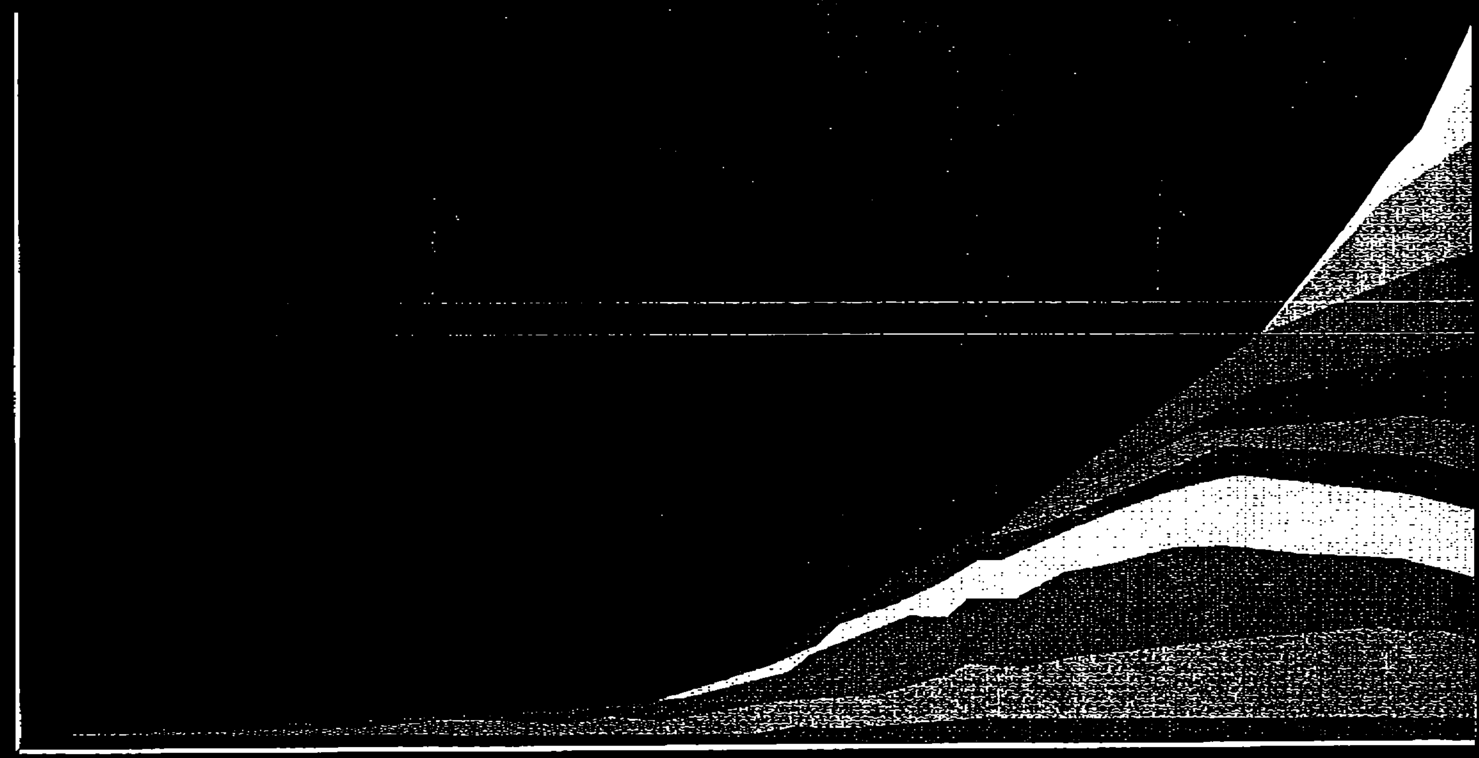
A Call to Action

The realization of the Vision will require action on 3 fronts

- Scientific and technological innovation across multiple disciplines
- Private investment in markets and infrastructure
- Development of supportive government policies

The Challenge





Options for Next Steps

- Selectively choose a larger reviewer group
- Have reviewer group become executive steering committee to solicit and alter vision accordingly
- Hold regional meetings
- Place announcement in Federal Registrar
- Place vision on bioenergy website for public review

FY 2000: $6 Million Plan

- $0.6 million for administration
- $0.4 million for outreach and communication
- $5.0 million for competitive solicitation
  - $0.2 million for EE broad-based solicitation
  - $0.5 million for analysis
  - $4.3 million for R&D

Solicitation Information

- Target Dates
  - EE solicitation was released in November
  - Release bioenergy solicitation 1st quarter 2000
  - Make awards by 2nd quarter 2000

- Potential Topic Areas
  - EE broad-based solicitation
    - Outreach
  - Analytical
    - Potential for bioenergy
  - R&D
    - Integrated systems with multiple products

JEFF'S ITINERARY
AMERICAN PETROLEUM INSTITUTE CONFERENCE
Houston, Texas – Nov. 30-Dec. 2, 1999

TUESDAY, NOV. 30, 1999

LV: **WASH/NATIONAL @ 7 p.m. VIA CO 1461**

AR: **HOUSTON @ 9:19 p.m.**

THURSDAY, DEC. 2, 1999

LV: **HOUSTON @ 7:48 a.m. VIA CO 1450**

AR: **WASH/NATIONAL @ 11:40 a.m.**

Lodging and Meeting Site

Adam's Mark Hotel
2900 Briar Park Drive

713/978-7400
713/735-2739 fax

Pager # 1-888-369-4934

The New York Times
THURSDAY, AUGUST 12, 1999

Clinton to Seek Using Farm Products in Lieu of Fossil Fuel

By MATTHEW L. WALD

WASHINGTON, Aug. 11 — President Clinton will announce a long-term effort on Thursday to help replace coal, oil, natural gas and uranium with farm products, crop wastes and trees to make things as diverse as electricity, pharmaceuticals and car fuel and forks.

In an executive order, the President will set a goal of working with various industries to triple the amount of energy generated from such products by 2010. The order, White House officials said, will also instruct the Secretaries of Agriculture and Energy and the Administrator of the Environmental Protection Agency to write plans to coordinate research, create markets and take other steps to nurture "renewable technologies."

The Administration also plans to develop proposals for research grants and tax credits to promote such technologies.

Administration officials predict that developing more uses for agricultural products will result in $15 billion to $20 billion in additional farm income by 2010 and less use of imported oil.

"Essentially all of society in the last 100 years has been built on petroleum as the energy and raw material," said a participant in the effort, Dr. Robert R. Dorsch, director of biotechnology development at Du Pont.

"We need to go from black gold to green gold," Mr. Dorsch said.

Du Pont is working on an improved polyester based on natural sugars instead of petroleum, and is hoping that with Federal research money and coordination, the price of such sugars will fall.

Other companies that have been working with the Government over the last nine months contend that motor fuels, solvents and electricity can be made from natural materials, known as biomass, on a cost-effective basis, with a reduction in pollution. The discussions have included major companies in agriculture, chemicals, oil, natural gas and forestry, as well as genetic engineering and other high-tech companies.

'We need to go from black gold to green gold,' a Du Pont official says.

"We're looking at taking things we currently just throw away, making them profitable, fighting global warming and cleaning the environment at the same time," said Roger Ballentine, the deputy assistant to the President for environmental initiatives.

Vice President Al Gore, who has emphasized Federal promotion of new technology as well as environmentalism and support for farmers, said today in a telephone interview that the initiative would "help insure that the agricultural economy is part of the new economy."

The Vice President said that the effort did not yet involve allocating money but that some money would be redirected from other programs, mostly in the Energy and Agriculture Departments. More Federal attention could encourage use of natural materials, he said, and would be "a very significant step forward."

Past efforts to use natural materials have been stymied in part by falling prices for oil and natural gas. But proponents of the idea say the drive to reduce pollution and technological advances in biology and materials science will help them.

Biomass now accounts for about 3 percent of national energy use, including processes as simple as home heating with wood.

Some agricultural processing companies expect big markets if they can make new products that have environmental benefits, at equal cost. Cargill Inc., for example, has a venture with Dow Chemical to produce polylactic acid, a polymer that can be used instead of petroleum-based products like polystyrene in insulated cups, and polyethylene in soft drink bottles. The acid can also be used for garbage bags or for clothing fibers. Unlike plastics, it breaks down completely in a compost heap.

"It could be made from any kind of organic biomass," said Robert R. Parmelee, president of bioscience division of Cargill.

Polylactic acid is now made from sugar from corn kernels and other high-value products, but with a few technical advances it could be made from parts of the plant with lower value or none at all, like corn stalks, Mr. Parmelee said.

"Over time, if you really want to make this big, then raw material costs are going to have to come down," he said.

The Government is already involved in many biomass projects, but the participants see greater potential. For example, the Energy Department contributed $1.3 million to pay for equipment at the Northern Indiana Power Company's Bailly Generating Station in Burns Harbor to mix wood chips with the coal. The result was less nitrogen oxide, which contributes to smog, less sulfur dioxide, which makes acid rain, and less carbon dioxide, which is believed to cause climate change. But the company would like to try a different system of using wood, cooking it into a gas that can be burned at very high efficiencies in a turbine, said Arthur E. Smith, Jr., the environmental officer at Nisource, which is Northern Indiana's corporate parent.

The New York Times
THURSDAY, AUGUST 12, 1999

Errors Turn Fund-Raising Coup Into Giuliani Embarrassment

By DAN BARRY
and ABBY GOODNOUGH

The aides handling Mayor Rudolph W. Giuliani's fund-raising operations bragged of scoring a coup in March when a New Jersey developer, best known for his ties to President Clinton and other national Democrats, agreed to hold a fund-raising event for the Republican Mayor.

Making the fund-raising coup all the more delicious, the $100,000 raised at the party would probably be spent thwarting the First Lady, Hillary Rodham Clinton, the Mayor's likely opponent in the race for the United States Senate in 2000.

Since then, however, the sweet taste of that event has soured a bit. Because of technical mistakes and violations of the Federal election laws, the Mayor's fund-raising committee has returned $57,000, more than half the total raised at the March party held by the New Jersey developer, Charles J. Kushner.

Aides to the Mayor said that the return of contributions reflected nothing more than the minor mistakes so frequently made by political donors and campaigns when trying to comply with Federal election laws. For example, one official said, many of the checks were returned because they did not specify whether the contribution was being designated for a primary or a general election, as required.

The aides and a spokesman for Mr. Kushner also said that the donors were correcting the errors, and that the Giuliani exploratory campaign for the Senate would eventually get the contributions back.

But the mistakes made in collecting the money at the New Jersey party are so elementary as to be stunning, considering that it was put together by Mr. Kushner, a veteran fund-raiser who has organized big-money political events for Mr. Clinton, Vice President Al Gore and others. In March, for example, he helped to arrange a lavish fund-raiser in Newark for Senator Robert G. Torricelli of New Jersey, at which Mr. Kushner was publicly thanked by President Clinton, the event's honored guest.

For the Giuliani event later in March, Mr. Kushner's brother, Murray Kushner, wrote out four checks from four different companies — but all in his own name — to the Giuliani campaign, for a total of $8,000.

Fred Wertheimer, the president of Democracy 21, a nonprofit public-policy organization based in Washington, said that those contributions violated a basic law regarding Federal campaigns: no one can contribute a total of more than $2,000 to any candidate during an election cycle.

"No, he can't do that," Mr. Wertheimer said. "He can't keep making contributions under different professional positions. Anyone who raises money at the Federal level *knows* an individual can't give more than $2,000 for a race."

Mr. Kushner referred questions about the Giuliani event to Peter Rosenthal, a public-relations consultant, who described the developer as "embarrassed." He acknowledged that the errors were highly unusual, given Mr. Kushner's experience in fund-raising.

"It's embarrassing, but it's not complicated," Mr. Rosenthal said. The employee "who was in charge of this, from an administrative point of view, really messed up."

These gaffes marred what otherwise would have been a gleeful Giuliani raid into Clinton territory.

Charles Kushner, 45, heads the Kushner Companies, a family-owned real-estate empire that owns and manages more than 10,000 apartment units in New York, New Jersey, Pennsylvania and Florida. But he has also been one of the go-to people for the Democratic National Committee when it wants to raise money in New Jersey — as evidenced by the Torricelli event in Newark, which raised $2.15 million.

Mr. Kushner possesses many photographs showing him standing alongside President Clinton, Vice President Gore and other prominent Democrats. And when the President appointed 10 people to the United States Holocaust Memorial Council in December, Mr. Kushner was among those so honored.

But Mr. Kushner also has a friendly relationship with Bruce Teitelbaum, the Mayor's chief fund-raiser and former chief of staff; both men are active in Jewish-American affairs. "He's a friend of mine," Mr. Teitelbaum said. "I asked him if he would support the Mayor, and he said he would."

Mr. Rosenthal said that Mr. Kushner "has significant involvement in New York City, both owning property and in a variety of philanthropic activities, and he thinks the Mayor has done a terrific job and supports his goals for the future."

Violations of basic campaign finance rules force the return of most donations.

In late March, Mr. Giuliani left City Hall for Livingston, N.J., where he gave a talk at the Joseph Kushner Hebrew Academy, a school that Mr. Kushner and his siblings established in honor of their late father. The event segued into a fund-raising event in the Mayor's honor, attended by various friends and relatives of the Kushners.

The event appeared to be among the most successful of the year for the Mayor. It took more than 25 pages in a campaign-contribution report filed by Friends of Giuliani with the Federal Election Commission to list all the donors who gave at least $1,000, and often $2,000. To a person, they all listed the same address, that of Mr. Kushner's office complex in Florham Park, N.J.

But the Mayor's aides soon realized that the event was fraught with technical problems. They immediately sent letters to many of the party's guests, asking them to write a letter back that would stipulate how much of their donation was earmarked for a primary, and how much for a general election, as required by law.

None of those requests were answered. The Mayor's aides said they did not know whether those letters were all sent to the address of the Florham Park office complex.

Eventually, the aides said, they had no choice but to return $43,000 to the donors because the checks did not include the required information. They also returned $14,000 because Murray Kushner and three others, including Charles Kushner's wife and sister, had contributed money beyond the $2,000 cap allowed by campaign-finance laws.

Mr. Teitelbaum declined to comment on the Kushner event. But officials who insisted on anonymity said that the campaign had done nothing wrong and everything right; aides sought to address the problems as soon as they surfaced, and returned any check that was in question.

They also said that such matters are routine, particularly in campaigns that handle millions of dollars. (The Giuliani exploratory campaign has raised more than $3 million so far.) For example, they recently returned a donation after learning that it came from a son of Paul Castellano, the late leader of the Gambino crime family.

Mr. Rosenthal said that while Mr. Kushner regretted the mishap, it would not stop him from organizing more fund-raising events. Asked whether the longtime supporter of Mr. Clinton would also hold a fund-raiser for the First Lady, he answered: "We'll say that's a rhetorical question, right?"