

**COMMENTS ON EPA RFS2
PREAMBLE AND
DRAFT REGULATORY IMPACT ANALYSIS**

Prepared For:

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EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency is proposing revisions to the National Renewable Fuel Standard program (commonly known as the RFS program). The proposed rule intends to address changes to the Renewable Fuel Standard program as required by the Energy Independence and Security Act of 2007 (EISA). The revised statutory requirements establish new specific volume standards for cellulosic biofuel, biomass-based diesel, advanced biofuel, and total renewable fuel that must be used in transportation fuel each year. The revised statutory requirements also include new definitions and criteria for both renewable fuels and the feedstocks used to produce them, including new greenhouse gas emission (GHG) thresholds for renewable fuels.

As part of proposed revisions to the National Renewable Fuel Standard program (commonly known as the RFS program), EPA analyzed lifecycle greenhouse gas (GHG) emissions from increased renewable fuels use. The Energy Independence and Security Act of 2007 (EISA) establishes new renewable fuel categories and eligibility requirements. EISA sets the first U.S. mandatory lifecycle GHG reduction thresholds for renewable fuel categories, as compared to those of average petroleum fuels used in 2005. The regulatory purpose of the lifecycle greenhouse gas emissions analysis is to determine whether renewable fuels meet the GHG thresholds for the different categories of renewable fuel.

Lifecycle GHG emissions are the aggregate quantity of GHGs related to the full fuel cycle, including all stages of fuel and feedstock production and distribution, from feedstock generation and extraction through distribution and delivery and use of the finished fuel. The lifecycle GHG emissions of the renewable fuel are compared to the lifecycle GHG emissions for gasoline or diesel (whichever is being replaced by the renewable fuel) sold or distributed as transportation fuel in 2005.

EISA defines lifecycle GHG emissions as follows:

The term ‘lifecycle greenhouse gas emissions’ means the aggregate quantity of greenhouse gas emissions (including direct emissions and significant indirect emissions such as significant emissions from land use changes), as determined by the Administrator, related to the full fuel lifecycle, including all stages of fuel and feedstock production and distribution, from feedstock generation or extraction through the distribution and delivery and use of the finished fuel to the ultimate consumer, where the mass values for all greenhouse gases are adjusted to account for their relative global warming potential.

This work reviews, comments and provides alternative data on the petroleum lifecycle analysis and the soybean biodiesel analysis that is provided in the Preamble, the Rule and the Draft Regulatory Impact Analysis (DRIA) that has been released by the EPA.

The concept of life-cycle assessment emerged in the late 1980's from competition among manufacturers attempting to persuade users about the superiority of one product choice over another. As more comparative studies were released with conflicting claims, it became evident that different approaches were being taken related to the key elements in the LCA analysis:

- boundary conditions (the “reach” or “extent” of the product system);
- data sources (actual vs. modeled); and
- definition of the functional unit.

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In order to address these issues and to standardize LCA methodologies and streamline the international marketplace, the International Standards Organization (ISO) has developed a series of international LCA standards and technical reports under its ISO 14000 Environmental Management series.

The approach taken by the EPA in their analysis of the GHG emissions of biofuels broadly follows the guidance of the ISO standards but there are several deviations that do create some concern.

The first is that many of the models employed by the EPA are complex economic models which compromises the scientific approach to undertaking LCA work. Since ISO established their standards, there has been a growing body of work that has incorporated economic approaches to help understand some of the more complex issues such as valuing co-products and trying to predict what future systems may look like. There are advantages and disadvantages to this type of analysis. These economic models tend to have less transparency (another fundamental ISO principle), the economic models usually cannot be validated since they are estimates of future scenarios, and there is a far greater likelihood that two models will produce vastly different outputs. All of these points are true with the EPA body of work.

The reporting of the EPA on their methodology and findings also lacks transparency. This has hampered the analysis of the work since many of the important details have not been included in the Draft Regulatory Impact statement or the Preamble to the Rule Making.

There are issues with the relative approach employed by the EPA. They are comparing the GHG emissions of petroleum fuels, nominally in the year 2005, to the difference between two future scenarios in 2022. Not only are the time periods of comparison different, but also the system boundaries are very different. This is a fundamental breach of the ISO principles.

Unlike many systems, agricultural is constantly changing with new varieties of seeds being developed, yields changing year over year, fertilizer requirements dropping, new management practices being developed and deployed, and market demands can also change as eating habits change and different rates of population growth being experienced in different regions of the world.

The EPA has tried to accommodate some of these changes into their modelling but other changes have essentially been ignored, either deliberately or de facto, because of the models used. In the case of soybean production, it has been assumed that yields in some countries, including the United States increase from about 42 bu/acre in 2005 to 50 bu/acre in 2022. The reference case assumes 71.5 million acres of soybeans in 2022, about the same as in 2005. The disposition of the extra 570 million bushels of soybeans is not explicitly detailed in the EPA documentation. There is enough oil in this increased production to produce 830 million gallons of biodiesel, almost three times the increased scenario that is modelled in 2022, but this increased productivity is not factored into the analysis. The modelling assumes that this material is either used domestically or exported. Given that domestic demand has been flat or falling for several years, the most likely scenario that is modelled is one of increased exports. It is against this increased export scenario that the land use impacts of increased soybean biodiesel are measured against, not the current land use in the United States or internationally.

Two major quantifiable issues have been identified that have a large impact on the results. Numerous other issues have been identified that are difficult to quantify but nevertheless introduce errors and biases in the results presented by the EPA. These errors and issues are summarized below.

The Reference Case

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The EPA is estimating the GHG emissions from the production and use of biofuels in the year 2022. The land use emissions in 2022 are estimated based on the difference in a business as usual scenario and an expanded biofuels scenario. These emissions are then compared to petroleum GHG emissions purportedly for the year 2005. The data used for estimating the petroleum emissions is actually older than 2005. No estimate of land use emissions is included for the petroleum emissions.

The comparison in GHG emissions is therefore based on a different time period and uses different system boundaries. The models used to calculate the petroleum emissions and biofuel emissions are different in both structure and concept. These factors all introduce great uncertainty into the analysis and make meaningful comparisons almost impossible.

The methodology employed by the EPA almost totally negates any impact of agricultural productivity and ignores fundamental shifts in product demand from conventional markets. The probability of the 2022 scenarios realistically representing actual conditions in 2022 is extremely low.

Petroleum Baseline

The petroleum baseline emissions rely on the GREET model developed for the DOE by Argonne National Laboratory. While GREET has many positive features it is poorly documented and much of the data is old and in need of an update. As a result the model will tend to underestimate emissions from processes that are in decline, such as crude oil production, and overestimate emissions from technologies that are still developing such as biofuels.

The review has estimated that GREET underestimates the emissions for the production and use of diesel fuel by about 3%. Furthermore the data presented shows that these emissions are increasing and can be expected to be significantly higher in the year 2022.

The petroleum baseline emissions do not include any emissions associated with land use change. This source of emissions has not been seriously researched and some estimates developed here suggest that for some regions of the world they may not be as low as many have suggested.

The EPA also has baseline information developed by NETL. Some aspects of this baseline are better than the GREET data but the NETL information has deficiencies as well. A combination of the data and data sources from NETL and the use of the GREET model would provide the best baseline data (this would still not include land use emissions).

Domestic Agriculture Emissions

There is a large and serious error in the estimate of the domestic agricultural emissions for the production of soybeans. The FASOM model is calculating N₂O emissions from the production of nitrogen fixing crops in addition to N₂O emissions from the application of nitrogen fertilizer and the decomposition of crop residues. It is now widely accepted by most soil scientists and the IPCC that these emissions do not exist. The EPA has not calculated these emissions for soybeans grown internationally and they should not be calculated for domestic soybean production. These emissions account for about 20,000 g CO₂ eq/mm BTU, more than 20% of the lifecycle emissions of diesel fuel.

The domestic agricultural emissions are also based on very high energy consumption rates, 50% higher than those used in the GREET model and 300% higher than a recent survey of Iowa soybean producers. Because of the structure of the FASOM model it is difficult to quantify the impact of high energy consumption on the soybean biodiesel scenario. It appears that the impact will be relatively small, perhaps under 2,000 g CO₂ eq/mm BTU.

International Agricultural Emissions

The data used to estimate international agricultural emissions is very weak. Fertilizer use looks to be similar to that in the United States, after adjustment for yield, but the use of herbicides and pesticides is very low. This indicates an obvious potential to increase agricultural productivity internationally without bringing new land into production. These opportunities are not addressed in the EPA work.

The estimates of energy used for crop production internationally are extremely weak. Even though the US data shows different energy requirements for different crops the assumptions used for international production are that within a given country all cropland requires the same amount of energy. This approach will clearly overestimate emissions attributable to soybean production.

Domestic land Use Change

The FASOM model is projecting a small reduction in GHG emissions for domestic land use from changing management practices. This is consistent with data that the EPA reports to the UN climate change program annually.

Biodiesel Production

There is another methodology error in the biodiesel production emission calculations and the process data used for the biodiesel production is higher than current industry performance and thus far above the expected performance in the year 2022.

There is no mention of the glycerine co-product and allocation of any of the emissions to that product. The use of the economic models FASOM and FAPRI, in theory, should eliminate the need for allocation of the emissions between the feed products and the biofuels. The models do not appear to have the capacity to do the same for the glycerine co-product. Using the displacement approach to allocating emissions (the same approach used by FASOM and FAPRI), there should be an emissions credit for the glycerine. On the basis that the crude glycerine from biodiesel displaces the emissions embedded in the feedstock for synthetic glycerine these emissions amount to 16,957 g CO₂ eq/mm BTU.

Transportation Emissions

The transportation emissions for feedstock and fuel are calculated from the GREET model using the model defaults. The concern here is that the feedstock transportation emissions may also be included in the FASOM emission estimates because this energy is included in farm energy. These emissions would amount to 2,615 g CO₂ eq/mm BTU and could be double counted.

International Land Use Change

The EPA estimates that the largest contributor to the biodiesel lifecycle emissions is produced by international land use changes. The calculation of these emissions for the biodiesel scenario is not very transparent and it is not possible to determine if there have been any errors in the calculations. There are several issues with the methodology used.

The fundamental issue, as mentioned previously is that the scenario modelled by the EPA does not really factor in improvements in agricultural productivity. The basic assumption of the economic models is that the world is always in equilibrium and the underlying assumption is essentially that demand will increase at the same rate as productivity. It has been shown that this has not been the case for soybeans in the short and medium terms recently. The opportunity to use biodiesel to balance supply and demand and thus support the farm price of soybeans is lost in the analysis.

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With respect to the calculations of emissions from bringing new land into production there are some fundamental assumptions made by the EPA that may not be supportable. These include:

1. The calculation of the type of land being converted is based on the loss of land to crops in the recent past. This loss of forestland may not have been caused by increased demand for crops but rather after land had been deforested the lowest cost option was to plant crops rather than reforest. This lack of causation is a major concern and the calculations may not reflect land use change patterns resulting from an increase in demand. Since loss of forestland drives the emission calculation small changes here can create large differences in the results.
2. The statement that harvested wood products would not significantly impact the results is a concern. The numbers presented for the quantity of harvested wood products that could be recovered compared to the biomass present are shockingly low compared to recovery rates in North America.
3. The lack of discussion about the ultimate fate of carbon stored in a forest and how it is cycled through the atmosphere naturally is a large gap in the logic. Some of the forests of the world are lost each year to fire, pests, disease and old age. This carbon is released back to the environment and thus carbon can only be considered to be stored in forests temporarily yet a permanent charge is made against biofuels without recognition that what is really happening might just be a difference in the timing of the carbon emissions.
4. Soil carbon changes assume that new agricultural production uses full tillage. Many of the countries that are projected to see increased agricultural land use have very high rates of penetration of no till management. Soil carbon emissions will be significantly lower with no till management.

Summary

The EPA projected that soybean biodiesel would have a 22% reduction in GHG emissions using a 100 year time frame and a 2% discount rate. The impacts of the two largest issues with the EPA analysis are shown in the following table using the same format as Table VI.C.1-10 in the Preamble.

Table ES- 1 Summary Of Biodiesel GHG Emissions

Lifecycle Stage	Petroleum Diesel	EPA Reported Soy Biodiesel	Soy Biodiesel w/o domestic N ₂ O emissions	Soy Biodiesel w/o domestic N ₂ O emissions and glycerine co-product credit
	g CO ₂ eq/mm BTU			
Net Domestic Agriculture (w/o land use change)		-423,206	-1,295,306	-1,295,306
Net International Agriculture (w/o land use change)		195,304	195,304	195,304
Domestic Land Use Change		-8,980	-8,980	-8,980
International Land Use Change		2,474,074	2,474,074	2,474,074
Fuel Production	749,132	838,490	838,490	107,677
Fuel and Feedstock Transport		149,258	149,258	149,258
Tailpipe Emissions	3,424,635	30,169	30,169	30,169
Net Total Emissions:	4,173,768	3,255,109	2,383,009	1,652,196
% Change		-22.0	-42.9	-60.4

Correcting these issues will increase the GHG emission reduction for biodiesel to over 60% even without making any changes to the indirect land use emission calculations.

This report has identified issues with the petroleum baseline that if addressed would increase those emissions. There are other issues raised with energy use in the soybean production cycle domestically and internationally that could increase the GHG emission reduction potential of soy biodiesel. Finally, the approach and methodology of the international land use emission estimates is questionable. Compared to the current soybean supply and demand situation and the projected increase in agricultural productivity the methodology overestimates the demand for new land. The assumptions used to estimate the carbon loss from this new land are not well supported and the effect is to overestimate these losses.

TABLE OF CONTENTS

EXECUTIVE SUMMARY	I
TABLE OF CONTENTS	VII
LIST OF TABLES.....	IX
LIST OF FIGURES.....	IX
1. INTRODUCTION	1
1.1 SCOPE OF WORK.....	1
1.2 LIFECYCLE ANALYSIS	2
1.2.1 Life Cycle Perspective.....	2
1.2.2 Environmental Focus	3
1.2.3 Relative Approach and Functional Unit.....	3
1.2.4 Iterative Approach.....	3
1.2.5 Transparency	3
1.2.6 Comprehensiveness	3
1.2.7 Priority of Scientific Approach	3
1.3 THE EPA APPROACH.....	4
2. THE PETROLEUM BASELINE	5
2.1 GREET DEFAULTS.....	5
2.2 CRUDE OIL PRODUCTION	5
2.3 OIL SANDS	8
2.3.1 Mining and Extraction.....	8
2.3.2 In Situ Production.....	9
2.3.3 Bitumen Upgrading	10
2.4 CRUDE OIL TRANSPORTATION	13
2.5 REFINING	13
2.6 FUEL TRANSPORTATION.....	14
2.7 NETL BASELINE.....	14
2.8 OTHER EMISSIONS.....	15
2.9 SUMMARY PETROLEUM BASELINE.....	16
3. AGRICULTURAL EMISSIONS	17
3.1 DOMESTIC SOYBEAN PRODUCTION.....	17
3.1.1 Yield.....	18
3.1.2 Fertilizer	18
3.1.3 Energy Requirements	18
3.1.4 Domestic GHG Emissions.....	19
3.1.5 N ₂ O Emissions.....	19
3.1.6 Other Domestic Agriculture GHG Emissions.....	20
3.1.7 Summary Domestic Agriculture GHG Emissions	20
3.2 INTERNATIONAL AGRICULTURAL EMISSIONS	21
3.2.1 Yield.....	21
3.2.2 Fertilizer	22
3.2.3 Energy Requirements	23

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3.2.4 Fertilizer and N₂O Emissions 23

3.2.5 Total International Direct GHG Emissions..... 23

4. BIODIESEL PRODUCTION 24

4.1 SOYBEAN CRUSHING 24

4.1.1 Energy..... 24

4.1.2 Materials 24

4.2 BIODIESEL PRODUCTION 24

4.2.1 Energy..... 25

4.2.2 Materials 25

4.2.3 Glycerine..... 25

4.3 RESULTS..... 26

5. FEEDSTOCK AND FUEL TRANSPORTATION 27

5.1 FEEDSTOCK..... 27

5.2 BIODIESEL TRANSPORTATION 27

6. INDIRECT LAND USE 28

6.1 THE REFERENCE CASE 28

6.2 ABOVE GROUND BIOMASS LOSS..... 30

6.3 SOIL CARBON LOSS 32

6.4 FOREGONE SEQUESTRATION..... 33

7. OTHER ISSUES 34

8. DISCUSSION AND SUMMARY 35

8.1 THE REFERENCE CASE 35

8.2 PETROLEUM BASELINE..... 35

8.3 DOMESTIC AGRICULTURE EMISSIONS..... 36

8.4 INTERNATIONAL AGRICULTURAL EMISSIONS 36

8.5 DOMESTIC LAND USE CHANGE 36

8.6 BIODIESEL PRODUCTION 36

8.7 TRANSPORTATION EMISSIONS 37

8.8 INTERNATIONAL LAND USE CHANGE 37

8.9 SUMMARY 38

9. REFERENCES 39

LIST OF TABLES

TABLE 2-1 ENERGY REQUIREMENTS FOR HYDROCARBON PRODUCTION 6
TABLE 2-2 ADJUSTED DEFAULT VALUES FOR DIESEL FUEL 7
TABLE 2-3 REPORTED GHG EMISSIONS FOR MINING AND EXTRACTION OPERATIONS 9
TABLE 2-4 ESTIMATED ENERGY USE AT SHELL MINING AND EXTRACTION OPERATIONS 9
TABLE 2-5 REPORTED GHG EMISSION INTENSITY FOR UPGRADERS..... 12
TABLE 2-6 PROPOSED UPGRADER INPUT VALUES..... 12
TABLE 2-7 ADJUSTED DEFAULT VALUES FOR DIESEL FUEL 13
TABLE 2-8 GREET DEFAULTS VS. ACTUAL 13
TABLE 2-9 COMPARISON OF NETL AND GREET BASELINE EMISSIONS 14
TABLE 3-1 CHANGES IN DOMESTIC LAND USE 17
TABLE 3-2 SOYBEAN PRODUCTION ENERGY REQUIREMENTS..... 18
TABLE 3-3 DOMESTIC GHG EMISSIONS – PRODUCTION INPUTS 19
TABLE 3-4 DOMESTIC AGRICULTURE EMISSIONS..... 21
TABLE 3-5 COMPARISON OF FERTILIZER INPUTS 22
TABLE 4-1 COMPARISON OF SOYBEAN CRUSHING DATA..... 24
TABLE 4-2 COMPARISON OF BIODIESEL PROCESSING ENERGY 25
TABLE 4-3 GHG EMISSIONS FROM BIODIESEL CHEMICALS..... 25
TABLE 4-4 BIODIESEL PRODUCTION GHG EMISSIONS 26
TABLE 6-1 TYPES OF LAND CONVERTED 31
TABLE 6-2 NO TILL CULTIVATION PRACTICES 32
TABLE 8-1 SUMMARY OF BIODIESEL GHG EMISSIONS..... 38

LIST OF FIGURES

FIGURE 2-1 CHANGE IN ENERGY CONSUMPTION 7
FIGURE 2-2 BITUMEN MINING SCHEMATIC..... 8
FIGURE 2-3 REPORTED SOR FOR SAGD PROJECTS..... 10
FIGURE 2-4 DELAYED COKER SCHEMATIC 11
FIGURE 3-1 INTERNATIONAL SOYBEAN YIELDS 22
FIGURE 6-1 US SOYOIL PRODUCTION AND DEMAND..... 29
FIGURE 6-2 SHORT TERM SOYOIL DEMAND 30

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1. INTRODUCTION

The U.S. Environmental Protection Agency is proposing revisions to the National Renewable Fuel Standard program (commonly known as the RFS program). The proposed rule intends to address changes to the Renewable Fuel Standard program as required by the Energy Independence and Security Act of 2007 (EISA). The revised statutory requirements establish new specific volume standards for cellulosic biofuel, biomass-based diesel, advanced biofuel, and total renewable fuel that must be used in transportation fuel each year. The revised statutory requirements also include new definitions and criteria for both renewable fuels and the feedstocks used to produce them, including new greenhouse gas emission (GHG) thresholds for renewable fuels. The regulatory requirements for RFS will apply to domestic and foreign producers and importers of renewable fuel.

EISA established new renewable fuel categories and eligibility requirements, including setting the first ever mandatory GHG reduction thresholds for the various categories of fuels. For each renewable fuel pathway, GHG emissions are evaluated over the full lifecycle, including production and transport of the feedstock; land use change; production, distribution, and blending of the renewable fuel; and end use of the renewable fuel. The GHG emissions are then compared to the lifecycle emissions of 2005 petroleum baseline fuels (base year established as 2005 by EISA) displaced by the renewable fuel, such as gasoline or diesel.

As part of proposed revisions to the National Renewable Fuel Standard program (commonly known as the RFS program), EPA analyzed lifecycle greenhouse gas (GHG) emissions from increased renewable fuels use. The Energy Independence and Security Act of 2007 (EISA) establishes new renewable fuel categories and eligibility requirements. EISA sets the first U.S. mandatory lifecycle GHG reduction thresholds for renewable fuel categories, as compared to those of average petroleum fuels used in 2005. The regulatory purpose of the lifecycle greenhouse gas emissions analysis is to determine whether renewable fuels meet the GHG thresholds for the different categories of renewable fuel.

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1.1 SCOPE OF WORK

This work reviews, comments and provides alternative data on the petroleum lifecycle analysis and the soybean biodiesel analysis that is provided in the Preamble, the Rule and the Draft Regulatory Impact Analysis (DRIA) that has been released by the EPA.

1.2 LIFECYCLE ANALYSIS

The concept of life-cycle assessment emerged in the late 1980's from competition among manufacturers attempting to persuade users about the superiority of one product choice over another. As more comparative studies were released with conflicting claims, it became evident that different approaches were being taken related to the key elements in the LCA analysis:

- boundary conditions (the “reach” or “extent” of the product system);
- data sources (actual vs. modeled); and
- definition of the functional unit.

In order to address these issues and to standardize LCA methodologies and streamline the international marketplace, the International Standards Organization (ISO) has developed a series of international LCA standards and technical reports under its ISO 14000 Environmental Management series. In 1997-2000, ISO developed a set of four standards that established the principles and framework for LCA (ISO 14040:1997) and the requirements for the different phases of LCA (ISO 14041-14043).

By 2006, these LCA standards were consolidated and replaced by two current standards: one for LCA principles (ISO 14040:2006); and one for LCA requirements and guidelines (ISO 14044:2006).

The ISO 14040:2006 standard describes the principles and framework for life cycle assessment including: definition of the goal and scope of the LCA, the life cycle inventory analysis (LCI) phase, the life cycle impact assessment (LCIA) phase, the life cycle interpretation phase, reporting and critical review of the LCA, limitations of the LCA, the relationship between the LCA phases, and conditions for use of value choices and optional elements. ISO 14040:2006 covers life cycle assessment (LCA) studies and life cycle inventory (LCI) studies. It does not describe the LCA technique in detail, nor does it specify methodologies for the individual phases of the LCA. The intended application of LCA or LCI results is considered during definition of the goal and scope, but the application itself is outside the scope of this International Standard.

It is useful to consider seven basic principles in the design and development of life cycle assessments as a measure of environmental performance. The seven principles outlined below are the basis of ISO Standard 14040:2006:

- Life Cycle Perspective (the entire stages of a product or service);
- Environmental Focus (addresses environmental aspects);
- Relative Approach and Functional Unit (analysis is relative to a functional unit);
- Iterative Approach (phased approach with continuous improvement)
- Transparency (clarity is key to properly interpret results)
- Comprehensiveness (considers all attributes and aspects)
- Priority of Scientific Approach (preference for scientific-based decisions)

1.2.1 Life Cycle Perspective

LCA considers the entire life cycle stages of a product or service, including: extraction and acquisition of all relevant raw materials, energy inputs and outputs, material production and manufacturing, use or delivery, end-of-life treatment, and disposal or recovery. This systematic overview of the product “system” provides perspective on the potential differences in environmental burden between life cycle stages or individual processes.

1.2.2 Environmental Focus

The primary focus of a LCA is on the environmental aspects and impacts of a product system. Environmental aspects are elements of an activity, product, or service that cause or can cause an environmental impact through interaction with the environment. Some examples of environmental aspects are: air emissions, water consumption, releases to water, land contamination, and use of natural resources. Economic and social aspects are typically outside the scope of an LCA, although it is possible to model some of these elements. Other tools may be combined with LCA for more extensive analysis.

1.2.3 Relative Approach and Functional Unit

LCA is a relative analytical approach, which is structured on the basis of a functional unit of product or service. The functional unit defines what is being studied and the life cycle inventory (LCI) is developed relative to one functional unit. An example of a functional unit is a light-duty gasoline vehicle driving an average distance (with other details of time, geography, trip characteristics, and potential fuels added). All subsequent analyses are then developed relative to that functional unit since all inputs and outputs in the LCI and consequently the LCIA profile are related to the functional unit.

An LCA does not attempt to develop an absolute inventory of environmental aspects (e.g. air emissions inventory) integrated over an organizational unit, such as a nation, region, sector, or technology group.

1.2.4 Iterative Approach

LCA is an iterative analytical approach. The individual phases of an LCA (Goal and Scope Definition; Inventory Analysis; Impact Assessment; and Interpretation) are all influenced by, and use the results from, the other phases. The iterative approach within and between phases contributes to a more comprehensive analysis and higher quality results.

1.2.5 Transparency

The value of an LCA depends on the degree of transparency provided in the analysis (for example: the system description, data sources, assumptions and key decisions). The principle of transparency allows users to understand the inherent uncertainty in the analysis and properly interpret the results.

1.2.6 Comprehensiveness

A well-designed LCA considers all stages of the product system (the “reach”) and all attributes or aspects of the natural environment, human health, and resources. Tradeoffs between alternative product system stages and between environmental aspects in different media can be identified and assessed.

1.2.7 Priority of Scientific Approach

It is preferable to make decisions from an LCA analysis based on technical or science reasoning, rather than from social or economic sciences. Where scientific approaches cannot be established, consensual international agreement (e.g. international conventions) can be used. The power of the technical or scientific approach lies in the proper attribution of facts to sources and the potential reproducibility of these facts under scientific conditions.

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While the scientific approach is typically more objective than economic or social values, it does not preclude the use economic or social values for informing LCA decisions.

1.3 THE EPA APPROACH

The approach taken by the EPA in their analysis of the GHG emissions of biofuels broadly follows the guidance of the ISO standards but there are several deviations that do create some concern.

The first is that many of the models employed by the EPA are complex economic models which compromises the scientific approach to undertaking LCA work. Since ISO established their standards, there has been a growing body of work that has incorporated economic approaches to help understand some of the more complex issues such as valuing co-products and trying to predict what future systems may look like. There are advantages and disadvantages to this type of analysis. These economic models tend to have less transparency (another fundamental ISO principle), the economic models usually cannot be validated since they are estimates of future scenarios, and there is a far greater likelihood that two models will produce vastly different outputs. All of these points are true with the EPA body of work.

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Each of the chapters in the report reviews a different aspect of the EPA GHG emission analysis. The next chapter considers the petroleum baseline fuels.

2. THE PETROLEUM BASELINE

Since the objective of the rulemaking is to identify the reductions in GHG emissions it is necessary to compare the emissions of biofuels to a reference fuel. The reference fuel that the EPA is using is the 2005 average emissions of petroleum and diesel fuel used in the United States. The EPA is using the GREET model to determine these emissions. Furthermore they are relying mostly on the defaults values within version 1.8b of the GREET model. An alternative analysis of the gasoline and diesel fuel emissions has been developed by the National Energy Technology Laboratory and the EPA is inviting comments on this alternative approach.

This section provides comments on the GREET default values, the changes that the EPA has made to GREET for this analysis and the NETL approach.

2.1 GREET DEFAULTS

GREET (Greenhouse gases, Regulated Emissions, and Energy use in Transportation) is a full life-cycle model developed by Argonne National Laboratory with sponsorship from the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE). It allows researchers and analysts to evaluate various vehicle and fuel combinations on a full fuel-cycle/vehicle-cycle basis. While GREET is an excellent lifecycle assessment tool, like all models, the results are dependent on the model inputs and with thousands of input variables that typically are found in a single pathway it is important that these be reviewed to ensure that they accurately portray the existing industry.

The critical inputs for estimating the GHG emissions for gasoline and diesel fuel are the emissions associated with crude oil production, crude oil transport, refining, and fuel transportation.

2.2 CRUDE OIL PRODUCTION

The default value in GREET assumes that the energy efficiency of crude oil production is 98%. It would appear that the EPA has used this value for 72% of the oil used in the model. They have assumed that 5% of the crude oil is bitumen derived product from Canada and these emissions are calculated in GREET and are discussed below. The remainder of the crude oil is composed of 1% very heavy crude oil mostly from Venezuela and the remaining 23% is heavy oil. The energy requirements for the heavy oil are scaled with heavy oil using 1.07 times the energy of conventional oil and the Venezuela extra heavy oil using 2.4 times the energy of conventional oil. This suggests that the average scaling factor is 1.042 for the non oil sands material, or an energy efficiency of 97.91% of the energy in the crude oil. Using this value in GREET produces a result close to that reported in Table 2.4-10 of the DRIA.

There is very little supporting data in the GREET documentation for the 98% default value. The California Air Resources Board, in their use and modification of the GREET model have used a value of 93.0% based on the weighted average of the 98% value for crude oil produced outside of the State of California and their calculated value for California heavy crude oil.

The International Association of Oil and Gas Producers (OGP) has for several years been publishing the direct energy requirements and emission data from their members. The data for the year 2005 is available (OGP, 2006). That data is probably the most complete set of information on the upstream oil and gas industry worldwide but it does only cover about 34% of the global population of hydrocarbon production. They report an average energy

Draft

requirement of 1.40 GJ/tonne of hydrocarbons produced. This varied by region as shown in the following table.

Table 2-1 Energy Requirements for Hydrocarbon Production

	% Coverage	GJ/tonne
Africa	66	0.84
Asia/Australasia	46	1.48
Europe	98	1.02
FSU	4	1.16
Middle east	16	1.29
North America	29	2.28
South America	53	1.74
Overall	34	1.40

This value of 1.4 GJ/tonne is equivalent to 96.7% efficiency. The members of the OGP are among the worlds largest oil companies and include Shell, BP, ExxonMobil and others. The 2005 data is aggregated from 28 companies working in 55 countries. Given the size of the companies involved the data set probably under represents the total energy requirements for all oil production because these large companies would not typically operate smaller, older oil fields, which usually are less efficient. Nevertheless, this is the best number available, it is documented and it should be used in place of the 97.9% value in the EPA version of GREET. This source is the original source of data for the NETL calculations (although they used data from 2002).

GREET also has a default assumption that 16,800 BTU of natural gas are flared for each million BTU of crude oil produced. Again the source of the information is difficult to determine. The World Bank has sponsored work on the quantification of emissions from gas flaring and venting. A quantification of the emissions has been undertaken by NOAA using satellite imagery. They reported that in 2005, 160 billion cubic metres of gas were flared. The world oil production in 2005 was 30.87 billion barrels (EIA). This would suggest that on average, 4.11 cubic metres of natural gas are flared for each barrel of oil produced or 26,227 BTU/million BTU.

The combustion of this gas is not completed and the emission factor ($\text{CO}_2\text{eq/cubic metre of gas}$) is typically about 1.4 times higher than gas combustion in a furnace. In GREET the emission factor used for natural gas flared is not significantly different and thus GREET underestimates the GHG emissions from the flaring of associated gas by underestimating the quantity of gas flared and underestimating the unburned methane component of that gas. Cell H12 on sheet EF should be increased to 1,140 g methane/million BTU from 49 g/million BTU to properly account for these emissions.

GREET also assumes methane emissions from oil production of 13.15 g/million BTU. Segmented data is presented by OGP for 2005 which indicates that the methane emissions from sources other than flaring totals 0.745 kg methane per tonne of production or 18.43 g/million BTU, 40% higher than the GREET value.

Combining these three factors produces the values summarized in the following table.

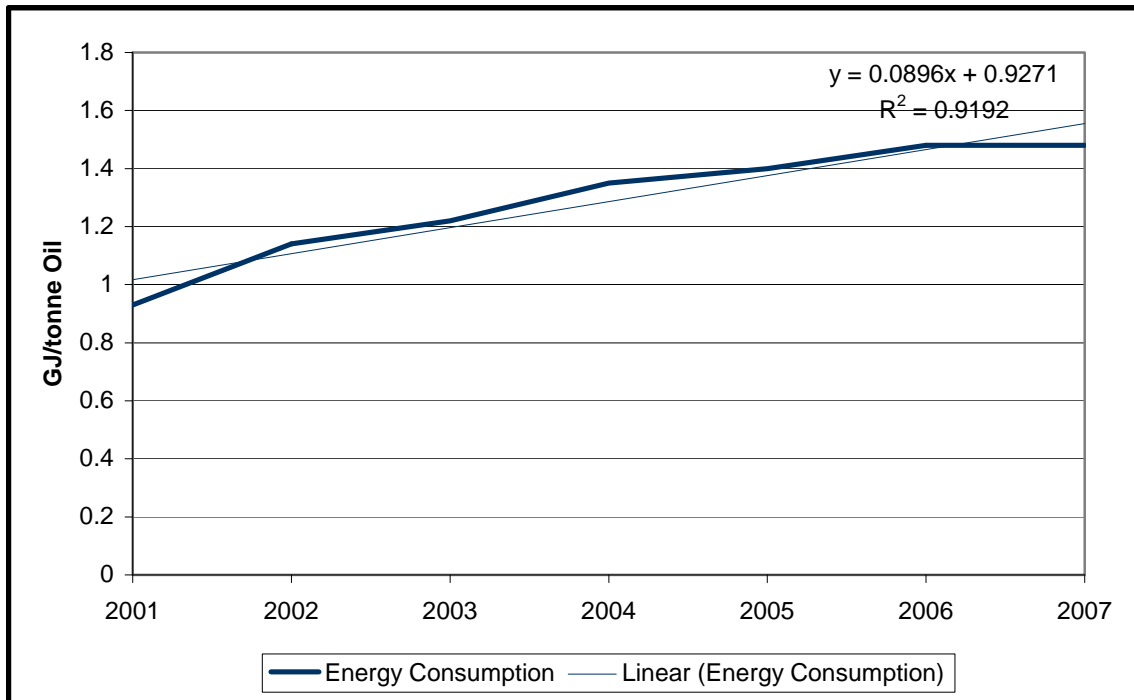
Table 2-2 Adjusted Default Values for Diesel Fuel

	Table 2.4-10	Base GREET 1.8b	Revised GREET conventional oil
g/MM BTU			
Methane	106	103	141
Nitrous Oxide	0.25	0.24	0.27
CO ₂	15,074	14,881	16,581
CO ₂ eq	17,381	17,123	19,621

These emissions are 12.9% higher than proposed in the DRIA and while this doesn't include the refinery or end use emissions this increase will flow through to the lifecycle emissions result and increase these emissions by about 2.5%.

What is more concerning, however, is that the OGP data indicates a very significant trend in the energy used for crude oil production. The energy used in oil production is a function of the depth of the reservoirs, their internal pressure, the amount of co-produced water and other factors. It is known that as reservoirs age the energy required to produce the oil increases. Data from OGP is available for the years 2001 to 2007 and the average energy requirements are shown in the following figure. This figure could be influenced by different participation rates and different companies participating but other than the Americas the participation rates have been steady through the time period.

Figure 2-1 Change in Energy Consumption



Extrapolating the trend through to 2022 would indicate that the energy requirements could increase from the 1.40 GJ/tonne in 2005 to 2.70 in 2022. This would increase the baseline emissions by approximately a further 2,500 g/mm BTU.

2.3 OIL SANDS

The EPA has modelled 5% of US oil supply coming from the oil sands of Alberta. GREET does have two pathways for modelling in-situ production and mined production and upgrading to synthetic oil. The portions of the 5% that are produced in-situ versus mined production are not specified in the documents. We have used the GREET defaults of 68% mined and 32% produced in-situ. The default GREET upgrades the mined bitumen but does not upgrade the product produced in situ. We have made the same assumption.

2.3.1 Mining and Extraction

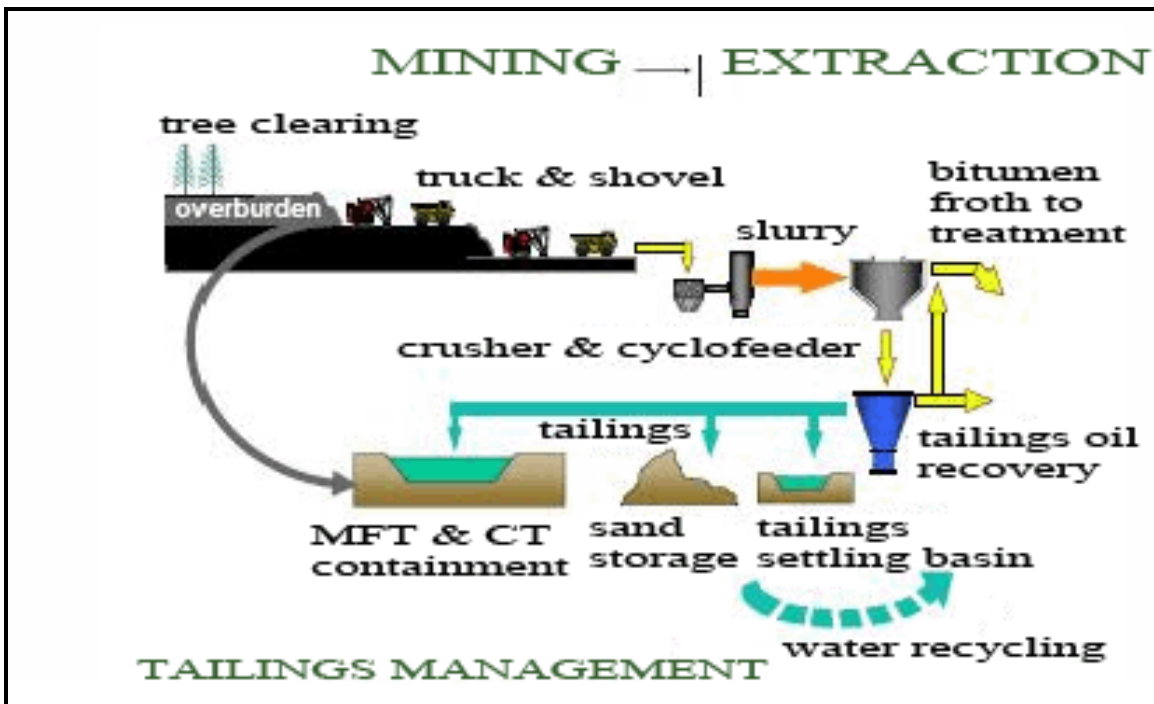
The GREET default energy efficiency for mining oil sands is 94.8% or 2.2 MM BTU/tonne of oil.

When the oil sand is not deeply buried, surface mining is the most viable method of recovery. In this process;

- Layers of muskeg and earth are removed first. Suitable soil materials are used in ongoing reclamation.
- Beneath the muskeg is a layer of overburden, which is removed to expose the thick deposit of oil sand.
- Today, trucks and shovels remove the overburden and mine the oil sand.
- The oil sand is trucked to crushers, where large chunks are broken down for transport via hydro-transport or conveyor to bitumen extraction facilities.

The process is shown in the following figure.

Figure 2-2 Bitumen Mining Schematic



Since mined bitumen production is a relatively new standalone process, information on the energy requirements are not widely available. Flint (2005) estimates that GHG emissions are about 250 kg CO₂ eq/cubic metre of bitumen produced. The Pembina Institute (2008)

Draft

reported on the GHG emissions for a number of mining and extraction operations and the results are summarized in the following table. These emissions are reported to cover the mine fleet, mine face, fugitive emissions, processing plants, electricity production (on or offsite), tailings ponds, and facility heating.

Table 2-3 Reported GHG Emissions for Mining and Extraction Operations

Operation	GHG Emissions	
	Kg CO ₂ eq/bbl	Kg CO ₂ eq/m ³
Albian Sands - Muskeg Existing	24.44	153.7
Albian Sands - Muskeg Expansion	44.44	279.5
Canadian Natural - Horizon	23.34	146.8
Imperial Oil - Kearl	40.39	254.0
Petro Canada - Fort Hills	40.50	254.7
Shell - Jackpine Phase 1	36.14	227.3
Syneco - Northern Lights	41.56	261.4
Average	35.38	225.3

For GREET we need the energy requirements and the most detailed information on mining and extraction emissions was found in the Environmental Impact Assessments for the Shell Jackpine expansion (including the Pierre River deposits) and the Total Joslyn mine.

The Shell information contains GHG emissions for mining and extraction by emission source for two different mining operations. From that information the following energy consumption rates have been calculated. The Shell data also has some options for reduced natural gas but increased asphaltene use. The energy use for the Total operation has similar natural gas and gasoline consumption, almost twice the rate of diesel fuel use, and power consumption more than an order of magnitude higher. Each individual mine will have unique situations that dictate energy use.

Table 2-4 Estimated Energy Use at Shell Mining and Extraction Operations

		Jackpine Phase 1	Jackpine Expansion	Pierre River	Average	%
Natural gas	BTU/mm BTU	69,700	69,700	65,800	68,400	79.2%
Gasoline	BTU/mm BTU	184	184	138	169	0.2%
Diesel Fuel	BTU/mm BTU	18,320	18,320	15,504	17,381	20.1%
Power	BTU/mm BTU	253	253	757	421	0.5%
Total	BTU/mm BTU	88,400	88,400	82,200	86,400	100.0%

Based on this data the values used in GREET should be 91.35% efficiency and with less power purchased and more diesel fuel consumed.

2.3.2 In Situ Production

There are two primary in-situ approaches being employed today, Cyclic Steam Stimulation (CSS), and Steam Assisted Gravity Drainage (SAGD). Other approaches are being developed that utilize solvents to supplement or replace steam (VAPEX), and controlled underground combustion to heat the reservoir (THAI).

Only a small portion of the oil sands can be recovered through surface mining, and other in situ extraction techniques are required for the majority of the resource. The development of

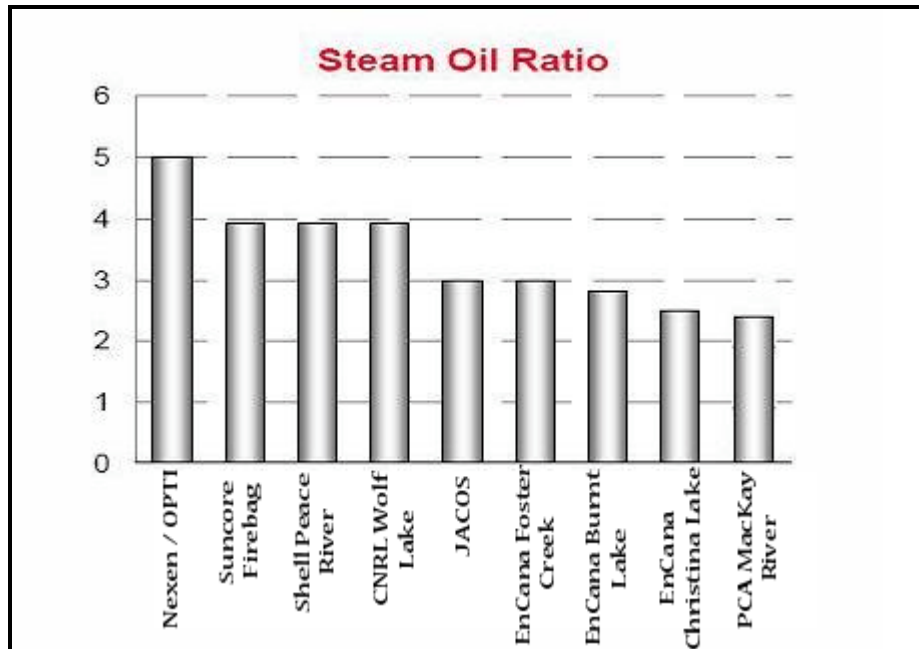
steam assisted gravity drainage (SAGD) dramatically increases the economical viability of oil sands reserves.

Whereas cyclic steam stimulation works best in formations like those near Cold Lake with good horizontal permeability, SAGD works better in deposits with good vertical permeability, like the Athabasca deposits near Fort McMurray.

Both CSS and SAGD use significant amounts of natural gas to make the steam necessary to extract the bitumen.

A critical component of determining the energy efficiency of bitumen production is the SOR. The SOR will vary from project to project depending on the characteristics of the oil sands. Petro Canada (2006) reported that their MacKay River project had one of the lower SOR in the industry as shown in the following figure. As can be seen in the figure the SOR can range from 2.5 to 5.0, although other references show values as low as 2.0 and as high as 10.0 for some demonstration projects.

Figure 2-3 Reported SOR for SAGD Projects



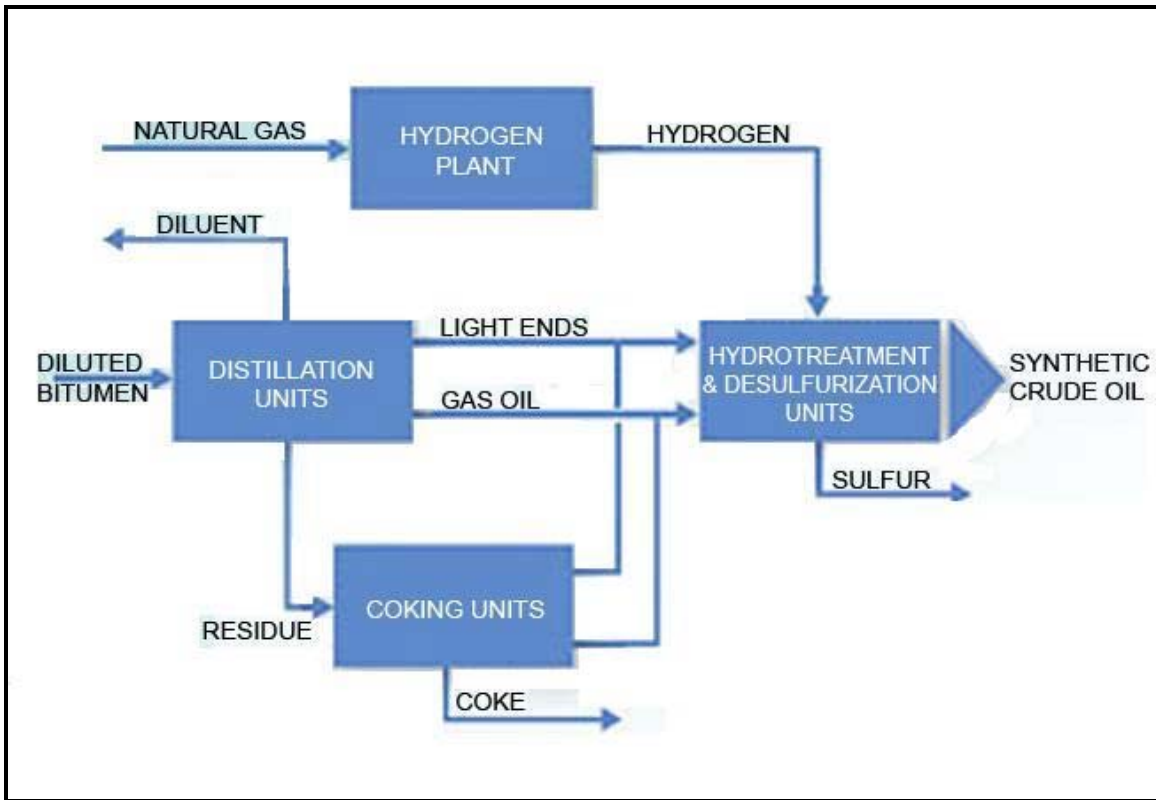
The typical value is a SOR of 3.2 produces a natural gas consumption rate of 9.0 million BTU/tonne of oil produced (225,000 BTU/million BTU). The electric power consumption will be 205,000 BTU/tonne of oil produced (5,125 BTU/million BTU). The electric power in GREET is approximately correct but the natural gas rate is low by about 10%. This variance is not that large given the uncertainty of the actual values for the various projects.

2.3.3 Bitumen Upgrading

Bitumen can be blended with a diluent to allow it to be transported through the pipeline system and then refined or it can be upgraded to a lighter crude oil. There are two fundamental approaches used for upgrading, either carbon can be removed from the bitumen to reduce the density and viscosity, or hydrogen can be added to the product. Most upgraders are employing the first approach with a delayed coker system but Shell is using

the later approach (hydrocracking) at its upgrader near Edmonton. A delayed coker schematic is shown in the following figure.

Figure 2-4 Delayed Coker Schematic



Several variations of this basic process can be developed including systems that utilize the gasification of the coke to produce hydrogen rather than using natural gas, the utilization of produced fuel gas hydrogen production, the inclusion of cogeneration systems to produce power as well as thermal energy and other systems.

The Petro Canada (2006), Northwest Upgrading (2006), and Shell (2007) EIA statements have been reviewed to determine the proposed mass and energy balances of the two approaches to upgrading. The information is summarized in the following table.

Table 2-5 Reported GHG Emission Intensity for Upgraders

Project	Comments	Direct Emissions Intensity	Indirect Emission Intensity	Total Emission Intensity
		kg/bbl	kg/bbl	kg/bbl
Scotford Upgrader	Hydrocracking	33.6	5.8	39.4
Scotford Upgrader after expansion	Hydrocracking	32.9	10.5	43.4
Scotford Upgrader 2	Hydrocracking	60.9	19.1	80.3
Northwest Upgrader	Delayed coking	92.8	Not available	
Northern Lights Upgrader	Delayed coking/gasification	141.4	Not available	
PC Sturgeon Phase 1	Delayed coking	40.7	Not available	
PC Sturgeon Phase 2	Delayed coking	62.6	Not available	
Opti/Nexen	Integrated/gasification	180-200	Not available	
BA Energy	New technology	14.0	Not available	
Husky Lloydminster	Delayed coking	65.6	Not available	
Suncor	Integrated	108.7	Not available	
Syncrude	Integrated	106.0	Not available	

It is apparent from the table that there is a wide range of reported emissions for upgraders. None of these emissions are lifecycle emissions in that the emissions associated with the production of purchased fuel is not included in the totals. Even within a complex the emissions can vary with stage. The fuel used can also vary with some operations using natural gas and others choosing to gasify coke or asphaltenes.

For the default values for GREET we have chosen inputs that produce lifecycle emissions of 70 kg/bbl (~11,000 g/mm BTU). These values are not from any specific project but were determined from considering the range of fuels and inputs from a number of projects. The input values were then adjusted to provide the emission target. These are summarized in the following table.

Table 2-6 Proposed Upgrader Input Values

	Energy Consumed, BTU/mm BTU
Natural gas	50,000
Electric power	13,750
Fuel gas	87,500
Petroleum coke	27,500
Total	178,750

This energy is about double that which is included in GREET when the hydrogen requirements are included. This is a significant variation. The energy efficiency is 82.2% rather than the 98.6% but the higher value doesn't include the extra hydrogen requirements. In the following table the upstream emissions when the oil sands emission factors are adjusted are compared to the previous changes and the original value.

Table 2-7 Adjusted Default Values for Diesel Fuel

	Table 2.4-10	Base GREET 1.8b	Revised GREET conventional oil	Revised GREET conventional oil and oil sands
	g/MM BTU			
Methane	106	103	141	142
Nitrous Oxide	0.25	0.24	0.27	0.28
CO ₂	15,074	14,881	16,581	17,031
CO ₂ eq	17,381	17,123	19,621	20,102

Even though the oil sands material only contributes 5% of the crude oil supply utilizing input values that are closer to actual operating conditions does increase the average upstream emissions by a further 2.5%. The combined impact of more realistic input values will add 2,700 g/mm BTU (2.9%) to the lifecycle emissions for diesel fuel.

In the future oil sands material is expected to be a larger share of the US refining mix and thus this is a second reason why the 2005 base line will underestimate the emissions from gasoline and diesel fuel in the future.

2.4 CRUDE OIL TRANSPORTATION

There is little information in GREET to support the default transportation distances. It is noted that the sources of crude oil modelled do not correlate with the actual source of oil in 2005 according to EIA data, as shown in the following table.

Table 2-8 GREET Defaults vs. Actual

	GREET	EIA
	%	%
Domestic Alaska	7	6
48 States	35	28
Imported (total)	58	66
Total	100	100

In addition to underestimating the quantity of imported oil the transportation distance would also appear to be low. An analysis of the weighted average distances for imported crude oil by ship produced a distance of 6,600 miles rather than 5,500 miles. Increasing the fraction and distance of crude shipped would increase the lifecycle emissions of diesel fuel by a further 104 g/mm BTU.

It is not clear that GREET makes any allowance for crude oil transportation in the country of origin prior to being shipped to the United States. Most oil producing countries have extensive pipeline systems to gather the oil and move it to port.

2.5 REFINING

The refining emissions in GREET have been updated recently and there are no comments.

2.6 FUEL TRANSPORTATION

The fuel transportation emissions are not as critical as the crude oil transportation emissions since the biofuels will also need to be transported along with the petroleum products.

2.7 NETL BASELINE

There are advantages and disadvantages of using the NETL approach to determining the baseline emissions for gasoline and diesel fuel. The primary advantage is that the approach used by NETL is very well documented compared to the data values that are used in GREET. However, there are a few assumptions with respect to the data that have been made by NETL that are probably not appropriate. The primary disadvantages are that the energy system is so interconnected and the GREET values have been used for so many other emissions estimates in the calculations for biofuels that consistency is lost and it would not be appropriate to use one model for petroleum emissions and a second model for biofuels. The NETL report, while well documented, is not particularly transparent and there do appear to be some issues with some of the emission factors chosen by NETL.

The baseline value calculated by the EPA using GREET for diesel fuel is 79,461 g CO₂ eq/mm BTU for the vehicle and 17,382 g CO₂ eq/mm BTU for the upstream emissions for a total diesel fuel lifecycle emissions of 96,843 g CO₂ eq/mm BTU. It has been shown in this section that the upstream emissions should be higher, at least 20,227 for a total lifecycle emissions of 99,688 g CO₂ eq/mm BTU.

The NETL report suggests that the diesel fuel baseline for the year 2005 should be 95,000 g CO₂ eq/mm BTU for diesel fuel. Of this 18,400 are the upstream emissions and 76,600 g CO₂ eq/mm BTU are the vehicle emissions. The vehicle emissions are a function of the carbon content of the fuel and the exhaust emissions of methane and N₂O. NETL are using the more recent IPCC GWPs of 1, 25, and 298, which accounts for 0.9 kg/mm BTU for the upstream emissions and little effect on the vehicle emissions, but the largest contributor to the difference is probably the assumption about the carbon content of the diesel fuel.

The comparison of the values from each approach is shown in the following table based on the stages that have been chosen by NETL.

Table 2-9 Comparison of NETL and GREET Baseline Emissions

	GREET	NETL	Difference
	kg/mm BTU		
Crude Oil Production	4.2	6.6	-2.4
Crude Oil Transport	2.3	1.3	1.0
Refining	10.3	9.5	0.8
Fuel Transportation	0.5	0.9	-0.4
Sub Total	17.3	18.4	-1.1
Fuel Use	79.5	76.6	2.9
Total	96.8	95.0	1.8

The NETL upstream emissions are higher because they have estimated these on a regional basis using a purchased GaBi database. The GaBi data is in turn derived from the OGP data for the year 2002. While NETL states that the 2002 data should be applicable to 2005, it has been shown here that the energy requirements for crude oil production were actually 23% higher in 2005 than they were in 2002. NETL also uses more up to date data for estimating the venting and flaring emissions than the default values in GREET. In summary the NETL

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data on emissions from crude oil production is more reflective of actual emissions than the data in GREET, it still underestimates emissions by using data from 2002 and not 2005 and as noted earlier the OGP data probably underestimates the total emissions by only having data from some of the worlds largest producing companies.

Crude oil transportation emissions in NETL are lower than they are in GREET even though NETL included the emissions associated with crude oil transportation within the country of origin, a source of emissions that is not included in GREET. The energy intensity for ocean transport used by NETL is 5.5 BTU/barrel nautical mile (43 BTU/ton-mile) versus the 42 value used in GREET. The transportation distance calculated in NETL averages 6,500 miles versus 5,500 miles in GREET. There appear to be two reasons for the lower emissions in NETL, they do not include methane emissions during loading and shipping and they use an emission factor for residual oil that only includes the combustion and not the production related emissions. This should be corrected.

The NETL calculations for the refining energy are lower for diesel fuel than the GREET values. The methodologies are similar but there are differences in allocation between the products.

The NETL emissions are higher for product transportation. This is in spite of using emission factors that do not include the emissions for fuel production. The higher emissions appear to be a function of better data on the distances and modes of transportation that are in GREET.

The NETL emissions from fuel use are derived from MOVES, the same source used by EPA. It is not clear why the emissions are not the same but different assumptions regarding the carbon content of the diesel fuel would appear to be the primary factor.

In summary, neither the EPA nor NETL determined baseline emissions for diesel fuel are ideal. There are shortcomings in both sets of information. Some of the NETL data does verify the comments made in the earlier sections with respect to the baseline emissions currently underestimating actual practices. It would appear that much of the information developed by NETL could be used in GREET to provide a better estimate of the baseline emissions of diesel fuel. To do this the crude oil emission energy consumption should be updated to 2005 data.

2.8 OTHER EMISSIONS

There are no land use emissions calculated for crude oil production in the EPA proposal nor the NETL baseline report. There is significant land that is disrupted during exploration, drilling, production and transport. We are not aware of any global accounting of these emissions but some estimates have been made in individual countries.

Some preliminary work on land use impacts of crude oil production has been carried out for California crude oil and some Alberta oil sands projects (Yeh et al, 2009). Their preliminary analysis suggest that the GHG emissions associated with land use conversion are in the range of 25 to 1,400 gCO_{2e}/mm BTU for conventional oil production, 1,500–3,100 gCO_{2e}/mm BTU for oil sands surface mining and up to 4,000 gCO_{2e}/mm BTU for in situ productions of oil sands. The conventional oil calculations were performed in a region with low carbon intensity vegetation and very old oil fields so some of the initial impacts of seismic activity and road building would no longer be visible.

Some estimates of surface disturbances have been made for conventional oil production in the forested areas of Alberta, Canada. During oil exploration seismic activities must be carried out. In forested areas the vegetation must be removed to place the charges and the data collection sensors. In Canada, an average of 57,750 kilometres of seismic lines were

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deployed between 1979 and 1995 in forested areas (Alberta Centre for Boreal Studies). Each line is 6-8 metres in width resulting in 40,000 hectares per year being deforested with hardly any recovery of wood for lumber or pulp. Regeneration in these areas is very slow and studies have found that after 20 years almost 90% is still not regenerating. With an average of 50 tonnes/ha of carbon in the standing forest and the assumption that oil discoveries equal oil production (~1.5 million barrels/day in Canada) which is a reasonable assumption, then the CO₂ emissions per barrel of oil would amount to 13,400 g/bbl or about 2,600 g CO₂/mm BTU. Using the methodology employed for the land use calculations for biofuels the lost sequestration capacity of this land would also have to be calculated.

Each oil well also requires some land surrounding it to be cleared of vegetation. This results in a one time loss and the lost ongoing sequestration capacity. The Alberta Centre for Boreal Studies has estimated that 1 ha is required for each well and that in 2000, almost 12,000 new wells were drilled. Using the same approach as above this would result in a further 800 g/mm BTU of CO₂ emissions.

Each well will have a road leading in to it and a pipeline right of way away from it. Each of these is likely to have a cleared right of way of 40 to 50 metres and so even if each well only needed 5 km of new road and pipeline right of way, this would result in 240,000 ha of land clearing annually or 15,600 g of CO₂ eq/mm BTU. Total direct land use change emissions could approach 20,00g CO₂ eq/mm BTU for some oil production systems. This is 20% of the other direct GHG emissions that are calculated for petroleum fuels.

Not all oil is produced on land and not all land based oil production is undertaken in forested areas but the land emissions from oil production would not appear to be as trivial as some have suggested and further investigation is definitely warranted.

2.9 SUMMARY PETROLEUM BASELINE

The petroleum products baseline results for 2005 underestimate the actual emissions associated with gasoline and diesel fuel in the United States. This statement applies to both the EPA and NETL proposed baselines. The underestimation is primarily due to the difficulty of accessing data on production practices in foreign countries. The NETL baseline is better documented than the GREET baseline but it uses data from a subset of oil producers in 2002. A combination of updated NETL data being used in the GREET model would produce a baseline emissions value that is about 3% higher than is suggested in the DRIA. This would increase slightly more if the latest IPCC GWPs were used rather than the values from 1995.

Furthermore the available data suggests that the emissions for the petroleum fuels are increasing annually and can be expected to be significantly higher in 2022 than they were in 2005.

In addition to underestimating the emissions from various stages of the lifecycle, the direct land use emissions related to crude oil production, which are not accounted for in either the EPA or the NETL baseline estimates, may not be as low as some have suggested. These emissions could add a further 2 to 5% to the lifecycle emissions of gasoline and diesel fuel.

While 3-8% may not appear to be a significant variation for a baseline value it factors into both the numerator and denominator of the percent reduction in GHG emissions, a 20% reduction in GHG emissions becomes a 24% reduction when the baseline increases by 5%.

3. AGRICULTURAL EMISSIONS

Unlike the petroleum fuel base line analysis, the EPA has not used the traditional attributional LCA approach in developing the lifecycle GHG emissions for biofuels. Instead they have employed economic models to determine the changes in economy wide agricultural practices and then applied a combination of model results and emission factors to determine the changes in the total agricultural GHG emissions caused by the change in demand for the agricultural products.

This approach complicates the analyses of the emission results, as the results for soybean biodiesel are a function not only of the production of soybeans but also the crops that are displaced by the soybeans and the estimated relative efficiency of the international producers compared to domestic producers for each crop. For example if the inputs for producing soybeans are correct but some corn acres are displaced and the inputs for corn were underestimated then the emissions attributed to soybeans would be overestimated.

In the EPA analysis of the increased soybean biodiesel production scenario, there is a decrease in corn, wheat, hay, rice, oats, and sorghum acres and an increase in soybean and cotton acres. The increase in soybean acres (for the biodiesel only case) is not as large as the decrease in soybean acres resulting from the increased corn ethanol demand. Thus soybean acres are reduced from the 2022 baseline case and it is assumed that the changes in the non-fuel market demand and the international acres would adjust to compensate for the lost domestic acres.

In the documents the emissions associated with feedstock production are calculated separately for domestic and international programs. Comments on the data used for each is presented below.

3.1 DOMESTIC SOYBEAN PRODUCTION

The scenario modelled by the EPA forecasts an increase production of soybean oil in the US to meet the demand for an additional 300 million gallons of biodiesel, but a decrease in the quantity of soybeans produced in the United States. This would mean a reduction in exports. There is some confusion about the exact scenario because the 300 million gallons is mentioned in Tables 2.1-1 and 2.3-1 but Table 2.6-1 implies that 400 million gallons of soybean biodiesel is modelled. The world demand for soybeans (or soybean oil) is met with increased production from other countries. The domestic land use change for the control scenario is summarized in the following table.

Table 3-1 Changes in Domestic Land Use

	Million Acres	Percent Change
Corn	3.2	3.9%
Hay	-0.6	-1.1%
Rice	-0.2	-3.8%
Soybeans	-0.4	-0.5%
Sugarcane	0.7	55%
Switchgrass	2.8	N/A
Wheat	0.7	-1.5%

The FASOM model predicts that domestic soyoil production and consumption would increase by 0.4 million tons and exports would fall by 1.3 million tons as a result of the

biodiesel scenario modelled. One million, seven hundred thousand tons of soyoil should produce 460 million gallons of biodiesel, this is clearly inconsistent with the scenarios being modelled. The FAPRI model results are projecting a drop in exports of 2.9 billion pounds; this would produce 400 million gallons of soy biodiesel. This inconsistency between models and the increased demand is concerning because it directly impacts how much new land is needed.

Nowhere in the DRIA is the actual change in domestic land use presented for the biodiesel only case except in Figure 2.6-1, which has insufficient detail to check any of the calculations. All of the tables indicate that domestic agricultural GHG emissions decrease for the biodiesel only case.

The emissions associated with soybean production are a function of fertilizer production and application, field energy expenditures and land use changes. These are discussed below.

3.1.1 Yield

The soybean yield in 2022 is projected to be 50 bu/acre. This is a reasonable projection based on historical trends. Some of the seed companies have suggested that the soybean yield could increase faster in the future as a result of their breeding programs.

3.1.2 Fertilizer

The only information on the fertilizer inputs is for the nitrogen use. This is stated to be less than 10 lbs/acre in 2022. According to USDA data the average nitrogen applied per acre has been below 5 pounds/acre since 1962. The actual number used in the modelling work is not provided but Figure 2.6.3 would indicate that about 6 pounds/acre has been used. The trend line would suggest that nitrogen use in 2022 could be 5.3 pounds/acre.

The fertilizer application rates for potassium and phosphorus are not provided in the documentation so it is not possible to comment on those values. The emissions from fertilizer manufacture account for almost 20% of the emissions of growing soybeans so it is important not to over estimate the application rates. The application of P and K fertilizers have also been dropping on a per bushel produced basis and this should be factored into the 2022 cases.

3.1.3 Energy Requirements

The energy requirements for soybean production in the DRIA are presented in a series of figures. The estimated values are summarized in the following table.

Table 3-2 Soybean Production Energy Requirements

	Gallons/acre	BTU/acre
Diesel	9.7	1,246,000
Gasoline	3.4	395,000
Electricity	7.4 kWh/acre	25,271
Total		1,666,271

Assuming 50 bushels/acre then the energy requirements per bushel of soybeans are 33,325 BTU/bu. This is 50% higher than the value in GREET of 22,087 BTU/bushel. The GREET inputs are based on a 2007 USDA survey (ANL, 2008).

The determination of crop energy use has always been a challenging exercise and questions remain about the accuracy of the various estimates and measurements. The Iowa Soybean Board worked with 51 individual members to determine their energy crop budgets (Iowa Soybean Board, 2009). These members used a total of 116 different crop scenarios (combination of land and management practices). While this is not a very large sample, and the results from the individual scenarios varied widely, the average filed energy use was only 11,160 BTU/bushel. This includes production, harvesting and transport energy to the farm. The highest value reported was 18,250 BTU/bushel, which is still less than the GREET or FASOM values. Furthermore, as production energy is more a function of area than yield, this energy value would be expected to be lower in 2022 than it was in 2006 and 2007.

3.1.4 Domestic GHG Emissions

As noted earlier, the biodiesel only scenario (an attempt to isolate the biodiesel related impacts) shows a reduction in domestic agricultural emissions. The changes in the inputs are summarized in the following table along with the emission factors that are found in GREET to arrive at the estimated total emission change.

Table 3-3 Domestic GHG Emissions – Production Inputs

Input	Unit	Change	GHG Emission Factor	GHG Emissions, tons
Total N use	Tons	-97,581	2.724 tons/ton	-265,810
Total P ₂ O ₅ use	Tons	-4,454	0.935 tons/ton	-4,165
Total K ₂ O use	Tons	-17,678	0.626	-11,066
Total Lime Use	Tons	-39	0.572	-22
Herbicide Use	Tons	-328	19.46	-6,383
Pesticide Use	Tons	-383	22.50	-8,617
Total Diesel Fuel use	gal	379,967	0.0124 tons/gal	4,711
Total Gasoline use	gal	605,625	0.0114 tons/gal	6,904
Total Electricity Use	kWh	129,994	.000685 tons/kWh	89
Total Natural Gas Use	10 ⁶ Btu	-3.5E+6	0.0687 tons/10 ⁶ BTU	-240,450
Total				-524,809

In Table 2.6-12 of the DRIA the domestic emission reduction excluding N₂O emissions is estimated to be -555,978 tonnes for on farm combustion, fuel production upstream, and fertilizer production. This is reasonably close to that estimated here but the increase in emissions due to fossil fuel use could be a function of the very high energy demand that is apparently in the FASOM model. It could be that FASOM models the total farm energy (energy to move the product to market, energy related to household activities, etc.) and not just the energy required to produce the crop. If so, this is inconsistent with the system boundaries used in the petroleum baseline emission estimates, and the emissions calculated elsewhere in the fuel production system.

The increased production of soybeans and cotton and the reduced production of corn, wheat, rice, sorghum, oats and hay result in lower GHG emissions associated with crop inputs.

3.1.5 N₂O Emissions

The application of nitrogen fertilizer and the growth of nitrogen fixing crops results in increased N₂O emissions. The soybean production only uses a small quantity of nitrogen so

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most of the N₂O emissions result from nitrogen fixation and the decomposition of crop residues. Figure 2.6-12 indicates that a total of about 750 kg CO₂ eq/acre of N₂O are released during soybean production. Five hundred kg CO₂ eq/acre are due to nitrogen fixing.

There has been some debate in the scientific community in the last decade about the generation of N₂O from nitrogen fixing crops. This was resolved several years ago when the IPCC released their 2006 Guidelines for National Greenhouse Gas Inventories. In Volume 4, Section 11.2 it is stated that:

Biological nitrogen fixation has been removed as a direct source of N₂O because of the lack of evidence of significant emissions arising from the fixation process itself (Rochette and Janzen, 2005). These authors concluded that the N₂O emissions induced by the growth of legume crops/forages may be estimated solely as a function of the above-ground and below-ground nitrogen inputs from crop/forage residue (the nitrogen residue from forages is only accounted for during pasture renewal). Conversely, the release of N by mineralisation of soil organic matter as a result of change of land use or management is now included as an additional source. These are significant adjustments to the methodology previously described in the 1996 IPCC Guidelines.

It appears that FASOM has not been updated with this latest guidance. Thus the DRIA grossly overstates the N₂O emissions by a factor of three compared to that which would be calculated by the IPCC guidelines (which are stated as the methodology being followed). The domestic net N₂O emissions reported for the biodiesel only case of 654,000 tons should actually be -245,000 tons, a difference of 899,000 tons per year.

3.1.6 Other Domestic Agriculture GHG Emissions

There are estimates made of GHG emissions related to grain drying, domestic rice production, domestic residue burning, and domestic livestock production. It is difficult to provide meaningful comments on the soybean scenario case given the lack of detail provided for the scenarios.

3.1.7 Summary Domestic Agriculture GHG Emissions

The domestic GHG emissions reported in Table 2.6-13 are overstated because of the incorrect treatment of nitrogen fixing crops. The emissions from the on farm combustion of fossil fuels may also be overstated due to the very high energy consumption factors used for soybean production in FASOM. In the following table the original table for the soybean biodiesel case is compared to what it should be.

Table 3-4 Domestic Agriculture Emissions

Emission Source	Soybean Biodiesel Case			
	DRIA Values		Corrected N Fixation	
	Tonnes CO ₂ -eq.	g/MMBtu CO ₂ -eq.	Tonnes CO ₂ -eq.	g/MMBtu CO ₂ -eq.
On-Farm Combustion	-228,655	-5,147	-228,655 ¹	-5,147 ¹
Fuel Production Upstream	-31,032	-698	-31,032	-698
Farm Chemical Production / Transport Upstream	-296,291	-6,669	-296,291	-6,669
Livestock Change	-181,679	-4,089	-181,679	-4,089
Rice Production Changes	-354,897	-7,988	-354,897	-7,988
Fertilizer Application / Soil N ₂ O Emissions	654,440	14,730	-244,560	-5,504
Residue Burning	1,851	42	1,851	42
Total	-436,263	-9,819	-1,335,263	-30,053

The draft RIA overstates GHG emissions due soybean cultivation by 20,234 g/MMBtu CO₂-eq. This is a very significant error as it represents more than 21% of the reported diesel fuel lifecycle GHG emissions.

3.2 INTERNATIONAL AGRICULTURAL EMISSIONS

The FAPRI model does not provide as much information about the agricultural sector as the FASOM model does and thus there is a lot more “manual” calculations that must be done to calculate the change in GHG emissions internationally. The EPA has relied on data from the UN FAO, the IEA, emission factors from GREET, their own calculations in order to produce an estimate of GHG emissions from International agriculture. The data used and resulting GHG emission estimates are even less precise than they are for domestic agriculture.

The majority of the international land use change for the biodiesel only case appears to be an increase on soybean production (675,000 acres out of a total change of 880,000 acres). There are smaller increases in rapeseed, cotton, sunflower, corn, sorghum, rice, sugar beets and palm area and decreases in wheat, barley, peanuts and sugar cane. This is somewhat surprising since it means that there is an increase in the availability of protein meal that results from the increase in demand for vegetable oils. One would have thought that an increase in demand for vegetable oils (and a decrease in livestock production from the higher prices) would have shifted production to crops that produced more oil and less protein such as rapeseed and palm. The fact that this doesn't happen may indicate a serious limitation in the modelling.

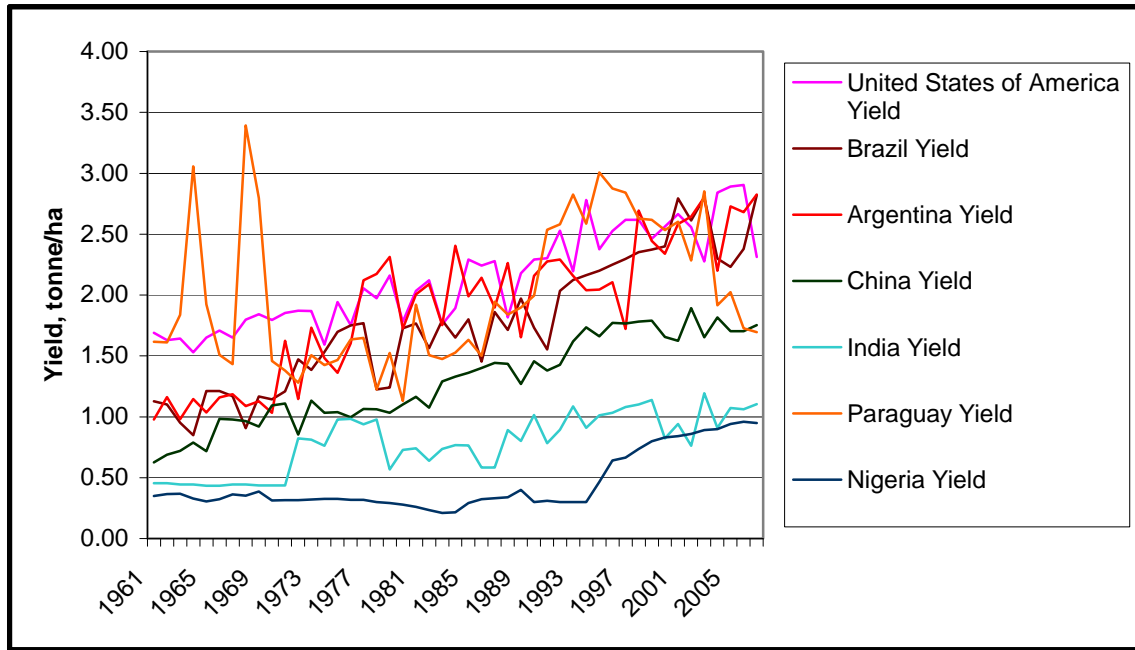
The increase in acres is largest in Paraguay, Brazil, India, Nigeria, and China.

3.2.1 Yield

The only information on yield that is presented in the DRIA is for Argentina and Brazil and the expected soybean yield in 2022 is 48 to 50 bu/acre. There is little information on the yields in the other countries that are expected to see area changes. The FAO data on soybean yields in the major countries identified by the EPA are shown in the following figure.

¹ Probably too high as well, but there is insufficient detail to determine proper value.

Figure 3-1 International Soybean Yields



It can be seen that yields in Nigeria, India, and China are well below the yields in the other countries and this will increase the quantity of land that must be converted to produce the required crop. There can be a number of reasons for the low yields but nutrient application, varieties planted and management practices can be addressed in short periods of time. India and China, for example do not use genetically modified soybean seeds and that has a detrimental impact on yield, China imports GM soybeans and India produces GM cotton so it is not unreasonable to consider that they could decide to produce GM soybeans before 2022 and thus have a significant impact on the world supply and demand and the estimated indirect land use change which is being attributed to soybean biodiesel.

3.2.2 Fertilizer

The fertilizer requirements for the soybean only case are presented for the total of all of the crops that are changed. The methodology followed is reported to have taken fertilizer use by crop data from the FAO. Given the lack of information provided it is difficult to comment on the application rates. In the following table the application rates per acre are compared to those in the GREET model for soybeans assuming that the yield is 50 bushels/acre.

Table 3-5 Comparison of Fertilizer Inputs

	EPA		GREET
	Tons	g/bushel	g/bu
Nitrogen	3,627	75	61.2
Phosphorus	9,495	196	186.1
Potash	8,640	179	325.5
Herbicide	57	1.2	47.8
Pesticide	58	1.2	0.48

The fertilizer application rates are reasonable if the yield is 50 bushels/acre but if the yield is lower, then the fertilizer application rates may be too high. The interesting metric is the low application of herbicides and pesticides, which is consistent with low yields caused by a loss of productivity due to insects and diseases. This also points out the gains that can be made in agricultural productivity through the use of modern crop production practices without bringing new land into production.

3.2.3 Energy Requirements

There is very little data available on energy use by crop internationally. The methodology used total agricultural energy use reported by the IEA divided by the total agricultural land in each country. No data is presented with respect to the results, just the total change for each biofuel scenario modelled. The same energy consumption per acre is applied to each crop. This approach is inconsistent with the domestic energy use data, which does vary with crop. The domestic data showed that soybeans use less energy per acre than corn and most of the other crops do. The use of a single factor for all crops therefore overestimates the GHG emissions for soybeans.

3.2.4 Fertilizer and N₂O Emissions

Unlike the emissions estimated by the FASOM model the international N₂O emissions have been calculated manually using the IPCC guidelines and Tier 1 default values. In this case there are no emissions calculated for nitrogen fixing crops, other than those related to fertilizer application and crop residues. This is further evidence of the error in the FASOM estimates for soybean production.

3.2.5 Total International Direct GHG Emissions

The international direct GHG emissions for agriculture are a relatively small portion of the emissions burden calculated by the EPA. Farm energy use is the largest portion and this may be overstated. Changes in livestock and rice emissions essentially offset each other. The remainder of the direct international emissions are related to fertilizer production and N₂O emissions from fertilizer and crop residues.

The concern with respect to the international direct emissions is whether the basic scenario is correct. The DRIA states that FAPRI predicts a reduction in soybean oil exports of 2.9 billion pounds. This is enough oil to produce 390 million gallons of biodiesel, not the 300 million gallons that is supposed to be required. Furthermore the increased net land requirements are estimated at 900,000 acres. With a biodiesel yield of 75 gallons per acre, this land would only produce 67 million gallons of biodiesel. Higher yields are possible with palm oil production and this would offset the extra soybean meal that would otherwise be available but the figures in the report show very little land being converted in Southeast Asia. These discrepancies are concerning, as they could indicate that direct foreign GHG emissions should be higher.

It may also be that the protein meal offsets account for the difference in land, if the oil is 20% of the seed then the effective soybean yield would be 375 gallons/acre and the net land would be sufficient. The lack of transparency in the documentation makes it difficult to determine the actual scenario modelled in any detail.

Note that the combination of domestic and international agricultural emissions are negative for the biodiesel case modelled by the EPA.

4. BIODIESEL PRODUCTION

The GHG emissions from biodiesel production reported in the DRIA are 19,455 g CO₂eq/mm BTU. They are larger than the total of the non land use change emissions. In spite of the significance the description of the emissions amounts to one page in the DRIA. There is no discussion of the glycerine co-product that is produced during the biodiesel production process.

4.1 SOYBEAN CRUSHING

The DRIA indicates that EPA relied on information from USDA Aspen modelling for the energy and material inputs into the process.

4.1.1 Energy

The assumptions made for soybean crushing include an oil yield of 11.2 lbs/bushel (18.7%) and energy use of 14,532 BTU/gal of biodiesel for natural gas and an electrical consumption of 2740 BTU/gal of biodiesel. All of this energy is attributed to the biodiesel in the analysis since it is assumed that FASOM has accounted for a reduction in protein meal and oil demand in other sectors. The DRIA does not state if FAPRI makes the same allowances.

In the following table this information is compared to the industry performance data recently obtained from NOPA. The EPA has assumed that one gallon of vegetable oil produces one gallon of biodiesel.

Table 4-1 Comparison of Soybean Crushing Data

	EPA	NOPA
Oil Yield	18.7%	19.1%
Natural gas	14,532 BTU/gal Biodiesel	20,057 BTU/gal soy oil
Electricity	2,740 BTU/gal Biodiesel	3,320 BTU/gal soy oil
GHG emissions	1,593 g CO ₂ eq/gal Biodiesel	2,100 g CO ₂ eq/gal Biodiesel
GHG emissions	13,490g CO ₂ eq/mm BTU	17,645 g CO ₂ eq/mm BTU

Other than a low oil yield, the EPA is forecasting continuing improvement in the energy efficiency of soybean crushing facilities. It could also be that the energy requirements used are representative of newer plants.

4.1.2 Materials

There is a small amount of hexane that is consumed in the oil extraction process but there is no indication in the DRIA of what has been assumed for modelling.

4.2 BIODIESEL PRODUCTION

The biodiesel production energy requirements are also for the total process and have been estimated by the USDA. There is no mention of the co-product glycerine and unlike soybean meal glycerine is not included in FASOM. There should be a glycerine co-product credit that is calculated by the displacement method to be consistent with the approach used in FASOM and FAPRI.

4.2.1 Energy

The energy requirements used by EPA are compared to the results of a recent survey undertaken by the NBB. It can be seen that the industry is using considerably less energy than the EPA has allowed for in 2022. The GHG emissions have been calculated using the emission factors found in GREET.

Table 4-2 Comparison of Biodiesel Processing Energy

	EPA	NBB
Natural gas	5,559 BTU/gal Biodiesel	2,700 BTU/gal Biodiesel
Electricity	340 BTU/gal Biodiesel	410 BTU/gal Biodiesel
GHG emissions	458 g CO ₂ eq/gal Biodiesel	275 g CO ₂ eq/gal Biodiesel
GHG emissions	3,850 g CO ₂ eq/mm BTU	2,310 g CO ₂ eq/mm BTU

4.2.2 Materials

The DRIA provides the GHG emissions intensity for methanol, sodium hydroxide, sodium methoxide, and hydrochloric acid but does not specify the consumption rate of these chemicals. If we assume the consumption rates that included in GREET and the EPA emission intensity figures, then the GHG emissions related to the use of chemicals can be calculated. This is shown in the following table. The GHG emissions imbedded in the materials are 1,985 g CO₂eq/mm BTU.

Table 4-3 GHG Emissions From Biodiesel Chemicals

	Consumption	GHG Emission Intensity	GHG Emissions
	G/gal Biodiesel	g CO ₂ eq/g	g CO ₂ eq/gal Biodiesel
Methanol	336	0.465	156
Sodium Hydroxide	17	1.01	17
Sodium Methoxide	42	0.923	39
Hydrochloric acid	24	1.011	24
Total			236

4.2.3 Glycerine

There is no mention of the glycerine co-product in the DRIA. While the approach used by the EPA with the FASOM and FAPRI models should deal with the agricultural co-products as part of the new equilibrium the models are not capable of automatically compensating for non-agricultural co-products and these would have to be dealt with outside of the models.

The biodiesel process produces one pound of glycerine for every ten pounds of biodiesel produced. This means that 0.74 pounds are produced for every gallon of biodiesel or 6.2 pounds per mm BTU of biodiesel.

GREET calculates the GHG emissions associated with the materials that are embedded in the glycerine. These emissions are 2,735 g CO₂ eq/pound of glycerine. This amounts to 16,957 g CO₂ eq/mm BTU.

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There is more energy required to produce glycerine than the energy embedded in the raw materials. Agarwal (1990) reported that the processing energy required was 17,400 BTU/pound in addition to the energy embedded in the raw materials. He also reported that glycerol produced from crude glycerine from the soap making process required 13,000 BTU/pound of glycerine. The conservative approach would be to assume that the crude glycerine from a biodiesel plant has the same values as the ingredients used to make synthetic glycerine, this approach still results in a significant emission credit for biodiesel that is not accounted for in the EPA analysis.

4.3 RESULTS

The results presented in the Proposed Rule and the DRIA are compared with those calculated here and shown in the following table. The emissions calculated from the DRIA data correspond well with the value in the proposed Rule. The values calculated here from industry data are for the year 2008 and have not been reduced to an expected value in 2022. A case could be made for even lower emissions in 2022.

Table 4-4 Biodiesel Production GHG Emissions

	Proposed Rule	Calculated from DRIA	Calculated Here
	g CO ₂ eq/mm BTU		
Soybean Crushing		13,490	17,645
Biodiesel Energy		3,850	2,310
Biodiesel Materials		1,985	1,985
Glycerine		0	-16,960
Total	19,455	19,325	4,980

The difference between the value proposed by the EPA and that calculated here is 14,475 g CO₂eq/mm BTU of biodiesel, primarily resulting from the inclusion of the glycerine co-product credit. The difference could be even larger if the energy requirements for the crushing and biodiesel processing were extrapolated to the year 2022.

The 14,475 g CO₂eq/mm BTU is equivalent to 434,250 g CO₂eq/mm BTU in the 30 year undiscounted case and 622,000 g CO₂eq/mm BTU in the 100 year discounted case.

The combination of the farming N₂O emissions and the glycerine co-product credit are sufficient to move the GHG emission reductions past the 50% threshold outlined in EISA.

There could be some push back from the EPA on this issue due to a view that synthetic glycerine is not being displaced or that not all biodiesel producers are selling their glycerine for upgrading. Alternative glycerine utilization approaches could involve use as an energy source for animal feed or as a fuel for combustion.

On the animal feed issue if the glycerine displaced soy oil as an energy source then in the EPA modelling that should reduce the international land use change quantity. The reduction should be on the order of 10% of the reported emissions (5,000 to 8,000 g CO₂eq/mm BTU).

If the glycerine is combusted then the emission benefit will arise from producing the fuel. Most of the carbon in the glycerine is deemed to be fossil carbon (from the methanol) and this there is not a large GHG emission benefit from its use. This credit will be on the order of 1,500 to 2,000 BTU/mm BTU of biodiesel.

In practice the actual credit will probably be some combination of all different applications.

5. FEEDSTOCK AND FUEL TRANSPORTATION

The feedstock and fuel transportation emissions are reported as a separate category in the Proposed Rule Making. These emissions account for 3,463 g CO₂eq/mm BTU. In the discounted 100 year case they represent 4.6% of the lifecycle emissions. In the 30 year undiscounted case they represent 3.4% of the lifecycle emissions. The emissions are calculated using the default values in GREET although the EPA is suggesting that they are undertaking their own analysis of the transportation distances involved and may include those in the Final Rule.

5.1 FEEDSTOCK

The feedstock emissions are calculated based on the assumption that the soybeans move 10 miles by truck from the field to stacks and the 40 miles from the stack to the biodiesel plant. These GREET default values are combined with the GREET emission factors to arrive at the GHG emissions. Unlike in GREET, there is no allocation of these emissions between the oil and the meal as the FASOM and FAPRI models are assumed to take care of this. As a result the feedstock emissions total 2,615 g CO₂eq/mm BTU, or 75% of the transportation emissions.

While these emissions are real it is not clear that they have not already been included in the FASOM calculations as on farm combustion emissions. It was noted that the reported energy consumption for soybeans used in FASOM was significantly higher than reported by other sources. While both the FASOM data and the other data can be traced back to the USDA it is not clear what the system boundaries are for both data sets. One explanation of the high energy values in FASOM is that they include the energy used to move the crop from the farm to the processor or elevator. If this is the case, then these emissions are double counted in the EPA calculations.

5.2 BIODIESEL TRANSPORTATION

The biodiesel transportation assumptions in GREET are that 8% of the product is moved 520 miles by barge, 29% is moved 800 miles by rail and the remaining 63% is moved 50 miles by truck all to a distribution terminal. All product is then moved a further 30 miles by truck to the retail outlet. The emissions account for 701 g CO₂eq/mm BTU or 25% of the feedstock and fuel transportation emissions.

The EPA has stated that they are reviewing these assumptions and they may change in the Final Rule.

6. INDIRECT LAND USE

The indirect land use emissions for soybean biodiesel represent 76 to 82% of the lifecycle GHG emissions according to the EPA depending on the time horizon chosen and the discounting applied to future emission benefits. There is a lack of transparency in the information presented by the EPA with respect to the detailed calculations used to arrive at the emission values. Nevertheless it is possible to comment on the general methodology used and some gaps in the analysis.

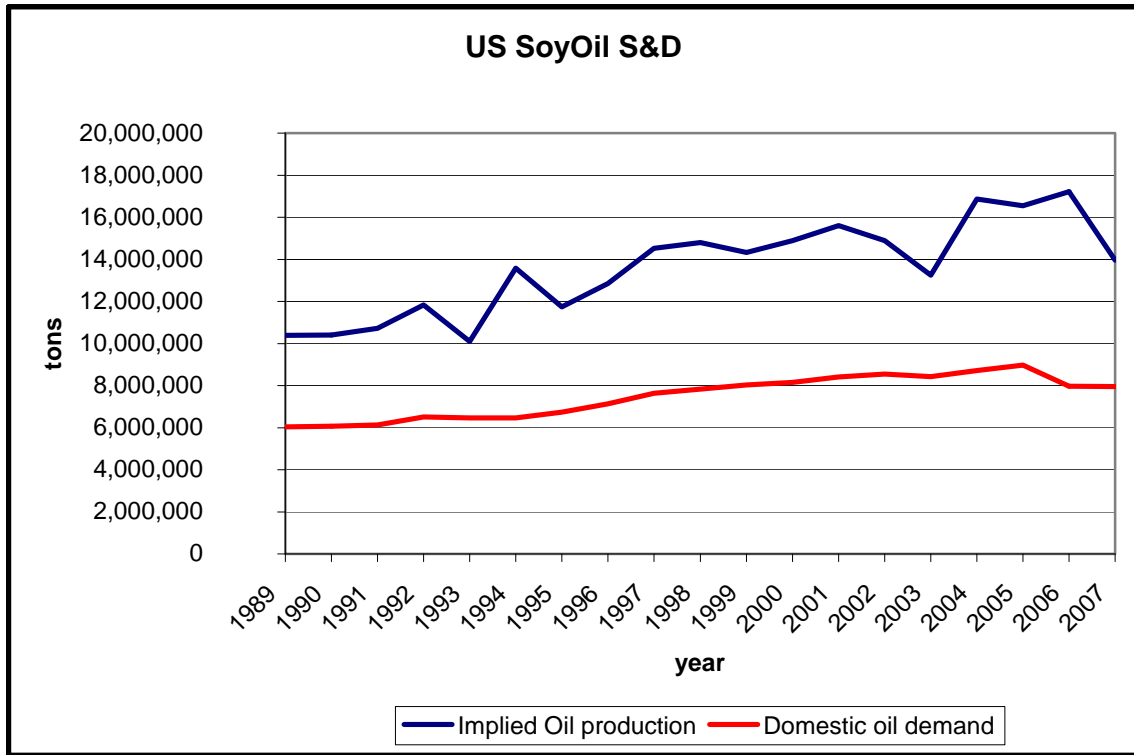
6.1 THE REFERENCE CASE

As noted in the introduction the GHG emissions for biodiesel in 2022 are being compared to the emissions from diesel fuel nominally in the year 2005. Very little of the data used in the petroleum calculations is actually from 2005, most of it is from an earlier period and thus the baseline underestimates the GHG emissions in 2005. Furthermore the diesel fuel emissions do not consider any land use emissions and there is some carbon lost from the environment through land clearing required for seismic activity, drilling and production platforms, service roads and pipeline right of ways.

Perhaps the more troubling issue with respect to the reference case is the indirect land use emission baseline. This is established as a 2022 business as usual scenario. So the combined reference system for biofuels is actually the direct emissions for a petroleum diesel fuel baseline with data from the 1990's and a projected 2022 land use scenario for calculating the indirect land use emissions. Improvements in agricultural productivity between 2005 and 2022 are essentially ignored (or credited to exports). The only role that agricultural productivity has in the 2022 land use calculations is the quantity of land required to meet the extra demand in 2022.

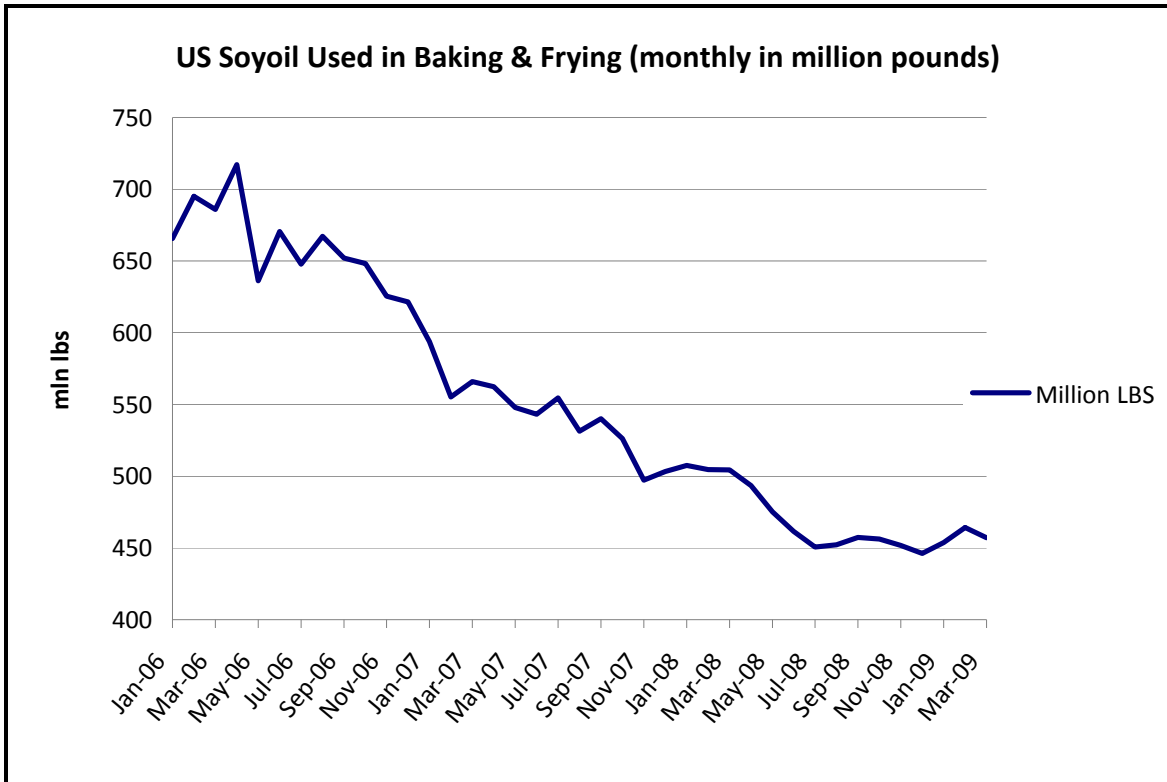
The 2022 business as usual baseline produces 19% more soybeans than were produced in 2005. There is no information presented in the documentation that shows what this increased production is used for. The domestic demand for soybean oil (and meal) has not been increasing at the same rate as production in the recent past as shown in the following figure. Since 1989 production is up about 50% but domestic oil demand is up only about 30%.

Figure 6-1 US Soyoil Production and Demand



The short term trend in soyoil demand for food purposes (US Census Bureau) is shown in the following figure. This more dramatically shows the impact of recent demand changes. This type of non-biofuel demand change cannot be accommodated in the land use modelling done by the EPA and this is a clear shortcoming in the approach.

Figure 6-2 Short Term Soyoil Demand



6.2 ABOVE GROUND BIOMASS LOSS

The FAPRI model calculates where new land would be brought into production when the system is shocked with new demand. FAPRI is not capable of projecting what kind of land (and how much biomass is on the land) is used in each country so the EPA has worked with Winrock International to estimate the type of land converted.

Winrock utilize satellite images over a period of time to locate changes in land use. The area deforested can be estimated and then if the area is not reforested the new use of the area can be identified. Winrock have developed a database of many (but not all) of the countries in the FAPRI model.

The problem with the Winrock approach is that it does not, and cannot, provide a causal link. The reason for the initial land use change cannot be linked to a demand for increased land for crops or grazing, just that after the land is deforested then the next use is pasture or crops. This is an important distinction and one that probably overestimates the amount of forest land that is converted to crops in the EPA analysis.

For example, the FAO reported that between 1990 and 2005 more than 28 million hectares of forest land was lost in Indonesia and 1.3 million hectares in Malaysia. In 2005, the total area devoted to palm in Malaysia and Indonesia was 3.5 million hectares. Clearly there are additional factors influencing deforestation beyond the growth in palm plantations.

Table 2.6-27 in the DRIA summarizes the types of land that have been assumed to be converted to meet the needs of biofuels. This is also shown in the following table. An

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estimate of the percentage of acres that come from each country/region for the biodiesel scenario are provided based on Figure 1.6-17 in the DRIA.

Table 6-1 Types of Land Converted

Country	% acres	Forest	Grassland	Savanna	Shrub
Argentina	7.4	8%	40%	45%	8%
Brazil	18.3	4%	18%	74%	4%
China	5.6	17%	38%	23%	21%
EU	0	27%	16%	36%	21%
India	11.1	7%	7%	33%	53%
Indonesia	5.6	34%	5%	58%	4%
Malaysia	Inc in Indonesia	74%	3%	19%	3%
Nigeria	7.4	4%	56%	36%	4%
Philippines	-	49%	5%	44%	3%
South Africa	-	10%	22%	53%	15%

The forest land will have a much larger impact on the results than the other land types, as the carbon stocks on this land are much higher. Brazil and Paraguay combined represent 40% of the increased acres in the soybean biodiesel scenario. While relatively little land is converted in Southeast Asia, the land that is converted is heavily weighted to forests. No data is presented in the DRIA on the above ground carbon loss for forests although some of the figures indicate that as much as 400 tons of live biomass/acre is possible. It is not clear if the conversion from live biomass to carbon has been properly corrected for moisture content.

The EPA has also not made any allowance for the possibility that some of the wood is converted to wood products. They conclude that including this would have an immaterial impact on the results. This is based on an assumption that only about 10 m³ of timber/ha (one tonne of carbon/acre) could be harvested. Considering that the forest land could contain several hundred tonnes of carbon/acre, according to some of the other tables in the report, this seems like an incredibly low rate and is probably an error. This could be a very important variable in the calculation of carbon lost and needs to be thoroughly investigated.

The basic approach taken by the EPA (and California) is that carbon stored in the forests is there permanently and unfortunately this is not true. Some of these issues are raised in a recent paper by Reijnders (2009). He argues that forestation is not an ideal means of offsetting carbon emissions. While this is a slightly different perspective than removing a forest the core issue is essentially the same. Reijnders identifies the issues of permanence in that trees don't live forever and that unforeseen events such as fire, disease, and extreme weather events can further shorten the projected life of carbon storage in forests.

Trees are living organisms and like all living things they have a life cycle and at the end they die. The end of the lifecycle could be caused by natural fires, by disease or pests, or simply by old age. At the end of the lifecycle the carbon in the above ground biomass starts to decompose and is returned to the atmosphere. Thus if the forest land use was changed to produce crops and the carbon stored in the trees is released to the environment, then it may not change the total amount of carbon that is released but *when* that carbon is released. In a system that discounts future carbon changes this will have an impact on the net present value of the carbon emissions but in a system that does not discount future changes the premature release of carbon would not impact the overall emissions.

The rather simplistic approach taken so far towards changes in carbon inventory in forests overestimates carbon emissions by ignoring the carbon emissions that would be present in

the natural cycle of the forests. Much more work on this aspect of indirect land use change is required before reasonable estimates of indirect GHG emissions can be made.

Data on carbon stocks for the other land types is presented and it varies from 2.7 tonnes of carbon/acre to 42 tonnes of carbon/acre. This is one to two orders of magnitude less than the forests and demonstrates the importance of the forest carbon in the overall calculation.

6.3 SOIL CARBON LOSS

To calculate soil carbon losses the IPCC soil carbon tool is used. It has been assumed that the new management practice is full tillage and medium inputs. This typically results in the loss of about 30% of the soil carbon over a period of 20 years.

There are two issues here; the first is that the IPCC soil carbon tool is not universally accepted and there are many agronomists who believe that it overestimates changes in soil carbon, good and bad, the second is that the assumption of full tillage is not appropriate for many countries. The use of zero tillage management practices could reduce soil carbon losses to half that estimated by the EPA even with the use of minimum inputs. Producers who use no tillage, manure and high inputs can increase soil carbon even on native ecosystem land according to the IPCC soil carbon tool.

No till cultivation is widely practiced throughout the world and many countries including Paraguay, Argentina, and Brazil have a higher utilization of no-till than the United States (Rolf Derpsch). These countries are some of the primary beneficiaries of expanded land use in the biodiesel scenario. Some data on no till management practices by country are shown in the following table.

Table 6-2 No Till Cultivation Practices

Country	Area under No-tillage	Arable land	No Till Portion of Arable Land
	1,000 ha		
USA	25,304	174,244	14.5%
Brazil	23,600	59,000	40.0%
Argentina	18,269	28,500	64.1%
Canada	12,522	45,660	27.4%
Australia	9,000	48,743	18.5%
Paraguay	1,700	4,200	40.5%
Indo-Gangetic-Plains	1,900	159,670	1.2%
Bolivia	550	3,050	18.0%
South Africa	300	14,753	2.0%
Spain	300	13,711	2.2%
Venezuela	300	2,650	11.3%
Uruguay	263	1,370	19.2%
France	150	18,461	0.8%
Chile	120	1,980	6.1%
Colombia	102	2,216	4.6%
China	100	141,664	0.1%
Others (Estimate)	1,000		
Total	95,480		

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Based on the data in the table above the soil carbon losses projected by the EPA overestimate the actual loss. The soil carbon loss is probably in the range of 20 to 25% rather than the 30% range that the EPA approach would produce. This difference overestimates emissions by 30 to 50%. No breakdown of the indirect land use emissions are provided by the EPA so it is difficult to determine how much of a difference a more appropriate methodology would produce.

6.4 FOREGONE SEQUESTRATION

The EPA has estimate a lost carbon sequestration potential of forest lands that have been converted to cropland. The theory being that if the forest hadn't been cut down it would have continued to grow and accumulate carbon so a charge for this foregone capacity to store carbon is made.

Even if this is accepted there has been no attempt made by the EPA to correlate the age of the forest (and therefore the initial store of carbon lost) with the length of time that the forest could continue to collect and store carbon. In all cases this was assumed to be 80 years. Older, high carbon intensity forests, may not be able to continue to grow and store carbon for this length of time, whereas younger forests may be able to do this for longer than 80 years. Some analysis should have been done to correlate the age of the lost forests and the length of time that sequestration would occur.

7. OTHER ISSUES

The EPA has chosen to use the 1995 IPCC global warming potentials for methane and nitrous oxides. The IPCC has updated these values twice since these values were produced. The new values put a greater weighting on methane and a lower weighting on nitrous oxide. In the comparison of biofuels to petroleum fuels we see that the importance of each gas is different. Methane is a more important gas for the petroleum fuels and nitrous oxide is more important to the biofuel pathways.

The choice of the 2007 IPCC GWPs could be expected to increase the emissions related to gasoline and diesel fuel and reduce the emissions associated with biofuels. In the interest of using the best science available these GWPs should be used instead of the older 1995 values.

8. DISCUSSION AND SUMMARY

It has been a difficult task to evaluate the EPA work on GHG emissions of soy biodiesel as the documentation in the DRIA and the Preamble is not fully transparent and in some cases it is contradictory. This report has been essentially completed before all of the supporting documentation was released through the official docket. This docket material will be reviewed prior to finalizing this report.

Nevertheless two major quantifiable issues have been identified that have a large impact on the results. Numerous other issues have been identified that are difficult to quantify but nevertheless introduce errors and biases in the results presented by the EPA. These errors and issues are summarized below.

8.1 THE REFERENCE CASE

The EPA is estimating the GHG emissions from the production and use of biofuels in the year 2022. The land use emissions in 2022 are estimated based on the difference in a business as usual scenario and an expanded biofuels scenario. These emissions are then compared to petroleum GHG emissions purportedly for the year 2005. The data used for estimating the petroleum emissions is actually older than 2005. No estimate of land use emissions is included for the petroleum emissions.

The comparison in GHG emissions is therefore based on a different time period and uses different system boundaries. The models used to calculate the petroleum emissions and biofuel emissions are different in both structure and concept. These factors all introduce great uncertainty into the analysis and make meaningful comparisons almost impossible.

The methodology employed by the EPA almost totally negates any impact of agricultural productivity and ignores fundamental shifts in product demand from conventional markets. The probability of the 2022 scenarios realistically representing actual conditions in 2022 is extremely low.

8.2 PETROLEUM BASELINE

The petroleum baseline emissions rely on the GREET model developed for the DOE by Argonne National Laboratory. While GREET has many positive features it is poorly documented and much of the data is old and in need of an update. As a result the model will tend to underestimate emissions from processes that are in decline, such as crude oil production, and overestimate emissions from technologies that are still developing such as biofuels.

The review has estimated that GREET underestimates the emissions for the production and use of diesel fuel by about 3%. Furthermore the data presented shows that these emissions are increasing and can be expected to be significantly higher in the year 2022.

The petroleum baseline emissions do not include any emissions associated with land use change. This source of emissions has not been seriously researched and some estimates developed here suggest that for some regions of the world they may not be as low as many have suggested.

The EPA also has baseline information developed by NETL. Some aspects of this baseline are better than the GREET data but the NETL information has deficiencies as well. A combination of the data and data sources from NETL and the use of the GREET model would provide the best baseline data (this would still not include land use emissions).

8.3 DOMESTIC AGRICULTURE EMISSIONS

There is a large and serious error in the estimate of the domestic agricultural emissions for the production of soybeans. The FASOM model is calculating N₂O emissions from the production of nitrogen fixing crops in addition to N₂O emissions from the application of nitrogen fertilizer and the decomposition of crop residues. It is now widely accepted by most soil scientists and the IPCC that these emissions do not exist. The EPA has not calculated these emissions for soybeans grown internationally and they should not be calculated for domestic soybean production. These emissions account for about 20,000 g CO₂ eq/mm BTU, more than 20% of the lifecycle emissions of diesel fuel.

The domestic agricultural emissions are also based on very high energy consumption rates, 50% higher than those used in the GREET model and 300% higher than a recent survey of Iowa soybean producers. Because of the structure of the FASOM model it is difficult to quantify the impact of high energy consumption on the soybean biodiesel scenario. It appears that the impact will be relatively small, perhaps under 2,000 g CO₂ eq/mm BTU.

8.4 INTERNATIONAL AGRICULTURAL EMISSIONS

The data used to estimate international agricultural emissions is very weak. Fertilizer use looks to be similar to that in the United States, after adjustment for yield, but the use of herbicides and pesticides is very low. This indicates an obvious potential to increase agricultural productivity internationally without bringing new land into production. These opportunities are not addressed in the EPA work.

The estimates of energy used for crop production internationally are extremely weak. Even though the US data shows different energy requirements for different crops the assumptions used for international production are that within a given country all crop land requires the same amount of energy. This approach will clearly overestimate emissions attributable to soybean production.

8.5 DOMESTIC LAND USE CHANGE

The FASOM model is projecting a small reduction in GHG emissions for domestic land use from changing management practices. This is consistent with data that the EPA reports to the UN climate change program annually.

8.6 BIODIESEL PRODUCTION

There is another methodology error in the biodiesel production emission calculations and the process data used for the biodiesel production is higher than current industry performance and thus far above the expected performance in the year 2022.

There is no mention of the glycerine co-product and allocation of any of the emissions to that product. The use of the economic models FASOM and FAPRI, in theory, should eliminate the need for allocation of the emissions between the feed products and the biofuels. The models do not appear to have the capacity to do the same for the glycerine co-product. Using the displacement approach to allocating emissions (the same approach used by FASOM and FAPRI), there should be an emissions credit for the glycerine. On the basis that the crude glycerine from biodiesel displaces the emissions embedded in the feedstock for synthetic glycerine these emissions amount to 16,957 g CO₂ eq/mm BTU.

8.7 TRANSPORTATION EMISSIONS

The transportation emissions for feedstock and fuel are calculated from the GREET model using the model defaults. The concern here is that the feedstock transportation emissions may also be included in the FASOM emission estimates because this energy is included in farm energy. These emissions would amount to 2,615 g CO₂ eq/mm BTU and could be double counted.

8.8 INTERNATIONAL LAND USE CHANGE

The EPA estimates that the largest contributor to the biodiesel lifecycle emissions is produced by international land use changes. The calculation of these emissions for the biodiesel scenario is not very transparent and it is not possible to determine if there have been any errors in the calculations. There are several issues with the methodology used.

The fundamental issue, as mentioned previously is that the scenario modelled by the EPA does not really factor in improvements in agricultural productivity. The basic assumption of the economic models is that the world is always in equilibrium and the underlying assumption is essentially that demand will increase at the same rate as productivity. It has been shown that this has not been the case for soybeans in the short and medium terms recently. The opportunity to use biodiesel to balance supply and demand and thus support the farm price of soybeans is lost in the analysis.

With respect to the calculations of emissions from bringing new land into production there are some fundamental assumptions made by the EPA that may not be supportable. These include:

5. The calculation of the type of land being converted is based on the loss of land to crops in the recent past. This loss of forest land may not have been caused by increased demand for crops but rather after land had been deforested the lowest cost option was to plant crops rather than reforest. This lack of causation is a major concern and the calculations may not reflect land use change patterns resulting from an increase in demand. Since loss of forest land drives the emission calculation small changes here can create large differences in the results.
6. The statement that harvested wood products would not significantly impact the results is a concern. The numbers presented for the quantity of harvested wood products that could be recovered compared to the biomass present are shockingly low compared to recovery rates in North America.
7. The lack of discussion about the ultimate fate of carbon stored in a forest and how it is cycled through the atmosphere naturally is a large gap in the logic. Some of the forests of the world are lost each year to fire, pests, disease and old age. This carbon is released back to the environment and thus carbon can only be considered to be stored in forests temporarily yet a permanent charge is made against biofuels without recognition that what is really happening might just be a difference in the timing of the carbon emissions.
8. Soil carbon changes assume that new agricultural production uses full tillage. Many of the countries that are projected to see increased agricultural land use have very high rates of penetration of no till management. Soil carbon emissions will be significant lower with no till management.

8.9 SUMMARY

The EPA projected that soybean biodiesel would have a 22% reduction in GHG emissions using a 100 year time frame and a 2% discount rate. The impacts of the two largest issues with the EPA analysis are shown in the following table using the same format as Table VI.C.1-10 in the Preamble.

Table 8-1 Summary Of Biodiesel GHG Emissions

Lifecycle Stage	Petroleum Diesel	EPA Reported Soy Biodiesel	Soy Biodiesel w/o domestic N ₂ O emissions	Soy Biodiesel w/o domestic N ₂ O emissions and glycerine co-product credit
	g CO ₂ eq/mm BTU			
Net Domestic Agriculture (w/o land use change)		-423,206	-1,295,306	-1,295,306
Net International Agriculture (w/o land use change)		195,304	195,304	195,304
Domestic Land Use Change		-8,980	-8,980	-8,980
International Land Use Change		2,474,074	2,474,074	2,474,074
Fuel Production	749,132	838,490	838,490	107,677
Fuel and Feedstock Transport		149,258	149,258	149,258
Tailpipe Emissions	3,424,635	30,169	30,169	30,169
Net Total Emissions:	4,173,768	3,255,109	2,383,009	1,652,196
% Change		-22.0	-42.9	-60.4

Correcting these issues will increase the GHG emission reduction for biodiesel to over 60% even without making any changes to the indirect land use emission calculations.

This report has identified issues with the petroleum baseline that if addressed would increase those emissions. There are other issues raised with energy use in the soybean production cycle domestically and internationally that could increase the GHG emission reduction potential of soy biodiesel. Finally the approach and methodology of the international land use emission estimates is questionable. Compared to the current soybean supply and demand situation and the projected increase in ag productivity the methodology overestimates the demand for new land. The assumptions used to estimate the carbon loss from this new land are not well supported and the effect is to overestimate these losses.

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