EFFECTS OF

THE PROPOSED RENEWABLE FUELS STANDARD (RFS)

ON

U.S. FOSSIL FUEL CONSUMPTION

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September 25, 2002

1. Introduction

The energy bill being considered by Congress includes a set of provisions bearing on the use of oxygenates in gasoline production:

- A national phase-down of MTBE blending, effective by 2006;
- Repeal of the oxygen content requirement for federal reformulated gasoline (RFG), effective in 2003; and
- A Renewable Fuels Standard (RFS), mandating use of progressively increasing volumes of renewable fuels (primarily ethanol) in gasoline consumed in the U.S., starting in 2004.

  The mandate volume would increase on an annual schedule, reaching 5 billion gallons per year (bgy) in 2012. Thereafter, annual mandate volumes would be set to maintain the percentage share of the U.S. gasoline pool that ethanol held in 2012.

This memorandum addresses two questions:

- How would a 5 bgy ethanol mandate affect U.S. fossil fuel consumption?
- What would be the cost of the fossil fuel savings associated with a 5 bgy ethanol mandate?

Section 2 of this memorandum gives an overview of the analysis that we conducted regarding these two questions. Section 3 presents our findings. Section 4 briefly discusses these findings. Section 5 provides some information on our technical approach for the analysis.

2. Overview of the Analysis

Adding additional volumes of ethanol to the U.S. gasoline pool (e.g., as the result of an ethanol mandate) changes total U.S. energy use and fossil fuel consumption. The magnitude and the cost of these changes are determined by a complex energy balance comprising:

- The energy content of ethanol used in gasoline
- The energy inputs to the ethanol supply cycle, including
  - corn production
  - ethanol production
  - ethanol transportation (from plants to end-use sites)
- Refinery inputs (crude oil and purchased blendstocks, ex ethanol)
- Refinery outputs (gasoline and other products)

- Refinery consumption of natural gas, electricity, and fuel

Our analysis addresses these elements using rigorous, multi-regional refinery LP modeling.[1, 2] Refinery LP modeling is essential in analyzing the effects of increased ethanol use because ethanol use affects (1) the composition, fuel economy, and cost of gasoline (both ethanol-blended and clear) and (2) refinery operations, including product out-turns and energy consumption.

The analysis examines two scenarios:

- A Reference case, representing the 2012 baseline for the analysis (including projected ethanol consumption without an RFS); and

- An RFS case, representing all elements of the Reference case and, in addition, an ethanol mandate of 5 bgy in 2012.

Both scenarios incorporate *a national ban on MTBE blending* and *repeal of the federal oxygen requirement in reformulated gasoline*.

Both scenarios incorporate a sub-set of the existing incentives for ethanol blending, including (1) the federal excise tax credit for ethanol blending (scheduled to expire 2007), at the 2007 level of 51¢/gal of ethanol, (2) the 1 psi RVP waiver for ethanol-blended conventional gasoline, (3) existing state tax subsidy programs for ethanol blending (e.g., Illinois), (4) existing state ethanol mandates (e.g., Minnesota), and (5) existing state ethanol production credits (on existing ethanol capacity only).

In addition, both scenarios incorporate the likely effects on gasoline demand, quality, and production costs of new regulatory programs taking effect before 2012, including:

- The 8-hour ozone standard (which will increase calls for low-RVP gasolines and RFG);

- The Tier 2 sulfur control program (which will increase refining costs and octane values); and

- The Mobile Sources Air Toxics (MSAT) program (which will increase refining costs).

[1] The analysis covered six U.S. refining regions: PADD 1, PADD 2, PADD 3, PADDs 4 & 5 (ex California), California, and an "off-shore" region denoting sources of U.S. gasoline imports.

[2] "LP" stands for linear programming, a standard mathematical modeling technique. Refinery LP models are routinely used by refining companies, government agencies, and other organizations to analyze refining operations and economics.

In the RFS case, the ethanol mandate applies to each gasoline season, making ethanol use uniform over the seasons.

The RFS case includes representation of an ethanol credit trading program that would allow refiners and blenders to comply with the RFS through some combination of physical ethanol blending and the use of ethanol credits.

Finally, the analysis measures changes in energy flows in consistent units: crude oil equivalent barrels (**coeb**). One coeb = 5.8 million BTU, the average energy content of a barrel of crude oil.[3]

3. KEY FINDINGS

3.1 How Would a 5 bgy Ethanol Mandate Affect U.S. Fossil Fuel Consumption?

We estimate that a 5 bgy ethanol mandate would reduce U.S. consumption of fossil fuel energy by about **40–50 thousand coeb/day** (corresponding to about 0.5% of U.S. oil imports).

> U.S. oil imports averaged about 9 million barrels/day in 2001 and DOE projects them to increase to about 11 million barrels/day in 2012 [DOE AEO].

This estimate is the sum of the various energy effects induced by the 5 bgy ethanol mandate:

- Increase in energy use to produce additional ethanol;
- Increase in total gasoline out-turn, to compensate for the fuel efficiency loss caused by ethanol's low energy content relative to gasoline;
- Reduction in refinery inputs (imported crude oil and purchased blendstocks, ex ethanol);
- Reduction in refinery outputs of products other than gasoline;
- Reduction in refinery energy use, reflecting reduced refinery through-puts and operating severity; and
- Increase in energy inputs to ethanol logistics

The estimated reduction in fossil fuel energy use resulting from a 5 bgy ethanol mandate stems from two factors. First, corn ethanol has a positive net energy value (NEV). That is, the amount of energy that ethanol contributes to the gasoline pool exceeds the energy input required to produce it.[4] Second, increasing ethanol's volume share of the U.S. gasoline pool reduces

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[3] In terms of energy content, one barrel of ethanol corresponds to 0.61 coeb.

[4] Section 5 includes a brief discussion of the estimated ethanol NEV used in this analysis.

average refinery operating severity and product volumes. These reductions, in turn, reduce refinery inputs and refinery energy use.

3.2 What Is the Cost of the Fossil Fuel Savings Associated With the Ethanol Mandate?

We estimate that the national cost of the savings in fossil fuel energy consumption generated by a 5 bgy ethanol mandate would be **$80–$100/coeb**.

This cost is *over and above* the marginal cost of the energy source displaced by the ethanol. (In other words, the indicated national cost is $80–$100/coeb higher than the average price of crude oil projected by DOE for 2012).

> "National cost" is the dollar value of the net additional resources that society consumes to implement a given regulatory program or mandate. The indicated national cost for an ethanol mandate, which incorporates the federal tax subsidy (likely to be 51¢/gal in 2012), measures the net resource losses that the U.S. economy would incur on ethanol production above the baseline volume. In other words, national cost is the amount by which the full cost of meeting U.S. gasoline demand with a 5 bgy ethanol mandate would exceed the corresponding cost without the mandate.

An ethanol mandate would incur a significant national cost for one over-riding reason: ethanol's value as a gasoline blendstock is less than the full cost of producing and delivering it (including all federal and state subsidies).[5] In the scenarios that we analyzed, ethanol's full cost of supply is about **50–60¢/gal** higher than its value in gasoline. The various subsidies for ethanol do not reduce its cost; they merely shift a substantial portion of it from gasoline consumers to taxpayers. Ethanol's value as a gasoline blendstock decreases – and its production cost increases – with increasing ethanol volume. Hence, the more ethanol is used, the higher its national cost – in aggregate, per gallon of additional ethanol use, and per coeb of fossil fuel energy saved.

4. DISCUSSION

Our analysis focuses on total U.S. fossil fuel energy use – not on oil imports, which are but one constituent of the total energy balance associated with ethanol use. Increased ethanol use leads to "direct" reductions in oil import volumes (as a consequence of decreased refinery out-turns of gasoline). In the total energy balance, these reductions are partially offset by increases in energy inputs needed to support increased ethanol production.

[5] The excess of ethanol's cost over its value in gasoline explains why ethanol blending is practiced in the U.S. only in response to preferences, subsidies, and mandates.

The increases in energy inputs to ethanol production would require some combination of (1) increased domestic energy supply (primarily coal), (2) increased imports of fossil fuels (natural gas and oil), or (3) the bidding away of natural gas and oil by the ethanol industry from other sectors of the U.S. economy.

In this connection, we estimated (using information in [DOA] and [DOE AER]) the approximate percentage shares of the primary energy inputs to the ethanol supply cycle, as follows:

	Estimated Share of Total Energy Input	Source of Incremental Supplies
➢ Natural Gas:	65–70%	Imports from Canada[6]
➢ Oil (including LPG):	15–20%	Imports from various sources
➢ Coal:	10–15%	Domestic production
➢ Other (nuclear, hydro, etc.):	2– 4%	Domestic production

As these figures indicate, 80%–90% of the energy input to the ethanol supply cycle comes from natural gas and oil – the marginal supplies of which are imported. Consequently, more than 50% of the direct reductions in oil imports that would result from additional volumes of ethanol in the U.S. gasoline pool would be offset by increases in oil and natural gas imports required to support production of the additional ethanol.

In summary, a 5 bgy ethanol mandate would reduce U.S. fossil fuel energy use; but the reduction would be small (about 40–50 thousand coeb/day) and would come at a high unit cost (about $80–$100/coeb). These findings suggest that other approaches to increasing domestic energy supply or to reducing domestic energy consumption would offer greater volume potential and entail lower costs than an ethanol mandate.

5. Key Elements of the Technical Approach

We used the estimate of corn ethanol's *net energy value*[7] given in the Department of Agriculture's most recent report on this subject [DOA]. This net energy value – 21,105 BTU/gal (after allowing for the energy embodied in ethanol by-products) – is about 25% of the total energy content of ethanol.

[6] In 2000, net U.S. imports of natural gas amounted to 3.5 trillion cubic feed (TCF) of natural gas, about 15% of U.S. natural gas consumption and equivalent to about 1.7 million barrels day [DOE AER].

[7] The net energy value of a fuel – ethanol, in this instance – is the amount by which the energy released in burning the fuel exceeds the energy input to producing it.

Our estimate of the ethanol production cost corresponds to the projected marginal cost of production, incorporating (1) corn and ethanol by-product prices and (2) production costs and capital investments for new dry-milling ethanol plants of advanced design. We drew these and other cost elements from the Department of Energy's National Energy Modeling System [DOE NEMS]. We estimated ethanol logistics costs using information from a recent report on the subject [DAI] and from independent analysis.

To represent existing ethanol capacity as of the end of 2001, we used information provided on the web site of the Renewable Fuels Association.[8]

Finally, projections of U.S. gasoline consumption and oil import volumes and prices in 2012 were drawn from the Department of Energy's *Annual Energy Outlook 2002* (Reference Case) [DOE AEO].

6. References

- **DAI**: *Infrastructure Requirements for an Expanded Fuel Ethanol Industry*; Downstream Alternatives, Inc.; December 2001

- **DOA:** *The Energy Balance of Corn Ethanol: An Update*; Shapouri, Duffield, and Wang; Agricultural Economic Report No. 814; Office of the Chief Economist; Department of Agriculture; July 2002

- **DOE AEO**: *Annual Energy Outlook 2002, With Projections to 2020*; DOE/EIA 0383 (2002); U.S. Department of Energy/Energy Information Administration; December 2001

- **DOE AER:** Annual Energy Review 2000; DOE/EIA 0384(2000); U.S. Department of Energy/Energy Information Administration; August 2001

- **DOE NEMS:** *National Energy Modeling System: An Overview 2000*; DOE/EIA-0581(2000); Department of Energy, Energy Information Administration; March 2000

[8] Since the end of 2001, additional ethanol capacity has come on-stream. Accounting for that additional capacity in the Reference case of the analysis would (1) *reduce* the estimated savings in fossil fuel energy use and (2) *increase* somewhat the estimated national cost per coeb of fossil fuel energy saved as a consequence of a 5 bgy ethanol mandate.