MathPro

NATIONAL COSTS

OF

INCREASED NATIONAL ETHANOL MANDATE VOLUMES

Prepared for

American Petroleum Institute

By

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August 8, 2007

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SUMMARY

The U.S. Congress is considering energy legislation requiring (in part) large increases in ethanol production and use, with mandated "renewable fuel" volumes ramping up to 30–35 billion gallons per year (bgy) over the next 10 to 15 years. Because corn ethanol production appears unlikely to exceed about 14–16 bgy, the legislative proposals call for achieving the mandated volumes by large-scale commercial production of "advanced biofuels," particularly cellulosic ethanol. At present, no cellulosic ethanol plants are in commercial operation in the U.S.

Exhibit 1 shows estimated national costs and energy savings resulting from national ethanol mandates that would increase ethanol use by 2020 to 17 bgy and to 34 bgy, corresponding to 10% and 20%, respectively, of projected gasoline consumption in 2020.[1] With a 17 bgy mandate in 2020, all U. S. gasoline would be E10 (*National E10*); with a 34 bgy mandate, all U.S. gasoline would be either E20 (*National E20*)[2] or a mix of E10 and E85 (*National E10/E85*).

Exhibit 1: Estimated National Cost of Proposed Ethanol Mandates (2020)

	Units	Ethanol Mandate Scenario		
		National E10	National E20	National E10/E85
Additional Ethanol Volume (over Baseline)	bgy	4.3	22.4	22.4
Total Ethanol Volume	bgy	**17**	**34**	**34**
Corn ethanol		17	17	17
Cellulosic ethanol		0	17	17
Ethanol Volume in E85	bgy	0	0	20
Net Change in National Fossil Energy Use				
Total	K Coeb / day	**-30**	**-610**	**-540**
Per Bbl of Additional Ethanol	Coeb / Bbl	**-0.12**	**-0.42**	**-0.37**
National Cost	Bil. $ / year			
Low estimate		**4**	**49**	**52**
High estimate		**4**	**58**	**62**
National Cost per Coeb of Energy Savings	$ / Coeb			
Low estimate		**290**	**220**	**260**
High estimate		**340**	**260**	**310**

Coeb stands for "crude oil equivalent barrel," a unit of energy equal to the average energy content of a barrel of crude oil.

- **National Cost.** The national cost of gasoline supply would increase by about **$4 billion/year** with a National E10 mandate, **$49–58 billion/year** with a National E20 mandate, and **$52–62 billion/year** with a National E10/E85 mandate. These costs would be borne in some combination by the refining sector (through lower margins), consumers (through higher

[1] The Reference case in DOE's *Annual Energy Outlook 2007* projects U.S. ethanol use (under current law) of 12.5 bgy in 2020 and U.S. gasoline consumption of 168 bgy (10.93 Mil Bbl/day) in 2020. (*AEO2007*)

[2] A National E20 mandate would require EPA certification of E20 for use as a motor fuel.

gasoline prices), and taxpayers (through subsidies and other payments for ethanol production).

- **Fossil Energy Savings**. U.S. fossil energy use would decrease by about **30 K coeb/day** with National E10, **610 K coeb/day** with National E20, and **540 K coeb/day with National E10/E85**. The reductions in fossil energy use would be reflected in corresponding reductions in U.S. imports of fossil fuels, primarily gasoline. The largest reduction in energy use, achieved with National E20, would amount to about 3½% of projected net U.S. imports of crude oil, petroleum products, and natural gas in 2020.[3]

- **Cost of Fossil Energy and Import Savings**. The fossil energy savings would cost about **\$290–\$340/coeb** for National E10, **\$220–\$260/coeb** for National E20, and **\$260–\$310/coeb** for National E10/E85, *over and above the price of crude oil*.[4]

  Fossil energy savings from increased ethanol use are expensive because (1) ethanol is costly to produce, (2) a gallon of ethanol has only 2/3 the energy content of a gallon of gasoline, and (3) ethanol production uses a significant amount of energy obtained from fossil fuels.

- **E20 Mandates.** A national E20 mandate would require an essentially complete turnover of the car and LDT fleets, so that essentially all cars and LDTs on the road would be FFVs. It would also require that all off-road engines be capable of using E20. During the period of transition, the U.S. refining and distribution system would have to supply both E10 and E20 nation-wide, which could cause operating problems and impose significant costs.

- **E85 Mandates**. Implementing an E85 mandate would require large numbers of E85-capable flexible fuel vehicles (FFVs), with essentially all new vehicles sold in the U.S. being FFVs by 2020; large numbers of service stations nationwide retrofitted to handle E85; and complex regulatory mechanisms to induce consumers to use E85 because E85 has lower fuel economy, and hence lower value to consumers, than E10.

- **Cellulosic Ethanol Production.** The economic and technical feasibility of large-scale cellulosic ethanol production has not been established. No cellulosic ethanol has been produced in sustained, commercial-scale operations. No commercial-scale (≈ 50–60 MM gal/yr) cellulosic ethanol plants are in operation or under construction. No established markets or infrastructure exist for acquiring, assembling, transporting, and handling the required volumes of biomass feedstock. Cellulosic ethanol production is inherently more difficult, more complex, and more capital intensive than corn ethanol production. Hence, even after its feasibility is established, cellulosic ethanol – regardless of the biomass feed material of choice – likely will be more costly than corn ethanol.

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3 *AEO 2007* projects net imports of crude oil, petroleum products, and natural gas of about 17 million coeb/day in 2020. (Reference case)

4 The estimated cost of energy savings, in \$/coeb, is lower for National E20 and National E10/E85 than for National E10 because cellulosic ethanol, although more costly, yields greater energy savings than corn ethanol.

The estimated costs of ethanol mandates shown in Exhibit 1 and below reflect projected average prices ($2006) in 2020 of $47/Bbl for crude oil (*AEO 2007*) and $2.35/bu for corn (consistent with USDA projections).

The national costs of ethanol mandates would decline with increasing crude prices. But, the National E20 and National E10/E85 mandates would incur large national costs even at historically high crude oil prices. For example, if the average crude oil price in 2020 were $100/Bbl ($2006), more than double the *AEO 2007* projected price, the estimated cost of the ethanol mandates would be near zero for National E10, about **$25–35 billion/year** for National E20 and **$35–45 billion/year** for National E10/E85. These costs translate to over $100/coeb of fossil energy savings, over and above the price of crude oil.

These estimates apply solely to long-term national costs incurred in the supply and use of fuel ethanol. They do not include (1) the costs of the environmental consequences of increased production of corn and other biomass for ethanol production; (2) the effects of increasing ethanol production on the costs of corn and biomass production and on the economics of the rest of the agricultural sector; (3) the costs incurred in the transition to National E20 or National E10/E85; or (4) the long-term costs of implementing, enforcing, and complying with ethanol mandates.

The findings reported here come from a detailed technical and economic analysis, conducted by MathPro Inc., of the effects of large ethanol mandates.

NATIONAL COSTS OF ETHANOL MANDATES

The national cost of gasoline supply would increase by about **$4 billion/year** with a National E10 mandate, **$49–58 billion/year** with a National E20 mandate, and **$52–62 billion/year** with a National E10/E85 mandate.

The total *national cost* of an ethanol mandate is the amount by which the dollar value of the economic resources used to produce, distribute, and use the mandated volumes of ethanol-blended gasolines (E10, E20, or E85) exceeds the dollar value of the resources used to produce, supply, and use the (energy-)equivalent amount of gasoline without the mandate. Adding ethanol to the national gasoline pool incurs a national cost because ethanol's value as a gasoline blendstock – adjusted for its low energy density and hence its adverse effect on fuel economy – is less than its full cost of supply (without subsidy) at projected crude oil prices.

The costs of federal and state blender subsidies, production subsidies, financial guarantees, and other economic incentives are not part of a national cost accounting framework. Such subsidies are "transfer payments" that shift part of the national cost of ethanol to taxpayers.

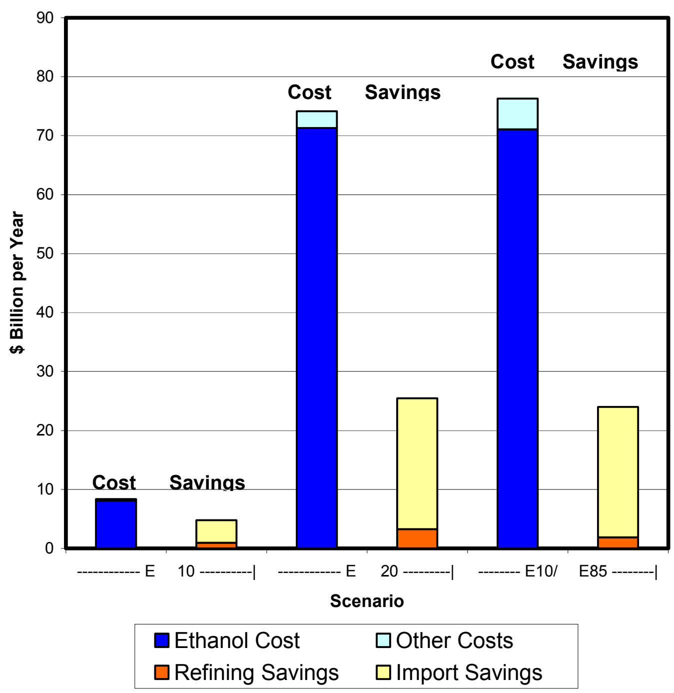
Exhibits 2 and 3 shows the elements of the national costs estimated in this analysis.

The full cost of ethanol supply (production and distribution) is by far the largest contributor to the national cost of ethanol mandates. The Low and High estimates shown in Exhibit 2 differ only in this cost element. (Exhibit 3 shows only the Low estimate.)

Exhibit 2: Elements of National Cost in 2020

	Annual Cost (Billion $/year) ($2006)					
	National E10		National E20		National E10/E85	
Cost Components Considered	**Low**	**High**	**Low**	**High**	**Low**	**High**
Change in refining cost (ex ethanol)	-0.9	-0.9	-3.2	-3.2	-1.9	-1.9
Change in gasoline and blendstock imports	-3.8	-3.8	-22.2	-22.2	-22.1	-22.1
Ethanol supply (full cost)	8.1	8.6	71.3	80.8	71.1	80.6
Time lost in extra fueling	0.3	0.3	1.4	1.4	1.4	1.4
FFV production (incremental cost)			1.4	1.4	1.4	1.4
E85 dispensing facilities					2.4	2.4
Total National Cost	**4**	**4**	**49**	**58**	**52**	**62**

Exhibit 3: Costs and Savings in the Low Estimate, 2020



The line items in Exhibit 2 are as follows.

- *Change in refining cost (ex ethanol)* is the amount by which refining costs (not including the cost of ethanol purchases) and charges related to refinery investment increase or decrease in response to the change in the ethanol mandate volume.

    Increasing ethanol use tends to reduce U.S. refining costs – even at constant refinery production of gasoline components (ex ethanol) – mainly because ethanol's high octane reduces the octane that must be generated in refining operations. The reduction in refinery octane requirement allows a reduction in refining severity, which reduces refinery energy consumption and increases the yield of gasoline material per barrel of crude oil.

- *Change in gasoline and blendstock imports* is the dollar value of the reduction in gasoline and blendstock import volumes resulting from the specified ethanol mandates.

    This estimated cost savings reflects the U.S. refining sector essentially maintaining its baseline 2020 output of the hydrocarbon components of gasoline in *volumetric* terms and accounts for the additional gasoline volumes required to off-set ethanol's fuel economy deficit. Additional ethanol volumes called out by mandates would displace an *energy-equivalent* volume of imported gasoline blendstocks. For this analysis, the average cost of imported blendstocks was set at the estimated cost of gasoline blendstock production in U.S. refineries in 2020 (derived from refinery modeling) plus the cost of gasoline distribution.

- *Full cost of ethanol supply* denotes the estimated full cost of supply (without reference to subsidies) of the additional ethanol called for by the ethanol mandate.

    In the National E10 scenario, this cost is the corn ethanol volume in excess of the baseline volume times the estimated full cost of supply from new dry mill ethanol plants.

    In the National E20 and National E10/E85 scenarios, this cost is the cost of the additional corn ethanol in the National E10 scenario plus the estimated average full cost of supply of cellulosic ethanol produced in pioneering plants.

- *Time lost in extra fueling* is the estimated cost of the time lost in additional vehicle fueling due to the loss in fuel economy resulting from additional ethanol use.[5]

- *FFV production (incremental cost)* denotes the additional annual production cost of ramping FFV production up to 100% of U.S. new vehicle sales by 2020.

    This cost, estimated to be about $1.4 billion in 2020, reflects the *AEO 2007* projections of annual sales of cars and light-duty trucks (LDTs), excluding projected sales of FFVs in

[5] The national cost of the additional volumes of gasoline that consumers must use as a consequence of ethanol's low energy content is incorporated in the line item *Change in gasoline and blendstock imports*.

the Reference case. In this analysis, this cost applies to the National E20 and National E10/E85 scenarios.[6]

- *E85 dispensing facilities* denotes the amortized share, allocated to 2020, of the estimated total cost of $12 billion of installing E85 facilities in retail stations (only).

  The estimated annual capital charge is about $2.4 billion, assuming that all of the facilities were installed in 2020 and their cost amortized over fifteen years. This cost applies only to the National E10/E85 scenario.

These cost elements do not include (1) costs arising from the environmental consequences (e.g., soil, water, and air degradation) of increased production of corn and other biomass for ethanol production; (2) the effects of increasing ethanol production on the costs of corn and biomass production and on the economics of the rest of the agricultural sector; (3) the costs occurred in the transition to National E20 (for both on-road vehicles and off-road vehicles and equipment) or to National E10/E85; or (4) the costs of implementing, enforcing, and complying with ethanol mandates. These costs could be significant in their own right, but estimating them was beyond the scope of the analysis.

THE FULL COST OF ETHANOL SUPPLY

Exhibit 4 shows the full cost of supply and the investment requirements of corn ethanol and cellulosic ethanol estimated in this analysis.

Exhibit 4: Cost of Ethanol Supply in 2020 ($2006)

		Corn Ethanol		Cellulosic Ethanol	
	Units	Low	High	Low	High
Full Cost of Ethanol	$/gal	**1.7**	**1.8**	**3.5**	**4.0**
Operating cost		1.15	1.15	2.10	2.10
Capital recovery and return		0.28	0.40	1.20	1.70
Logistics costs		0.23	0.23	0.23	0.23
Full Cost of Ethanol at Gasoline Energy Parity	$/gal	**2.5**	**2.6**	**5.2**	**6.0**
Ethanol Plant Investment	$/gal-year	**1.4**	**2.0**	**6.0**	**8.5**

The costs of *corn ethanol* apply to dry mill plants in 2020. They were developed using data from USDA publications and surveys. The costs of *cellulosic ethanol* were developed from data in recent USDA and DOE publications.

[6] In fact, a National E20 mandate would entail a higher FFV production cost a National E10/E85 mandate, because National E20 would require that *all* U.S. cars and LDTs (new and used) fleet be FFVs.

DOE's February 28, 2007 announcement[7] states that DOE will provide investment grants to six cellulosic ethanol demonstration plants, whose stated capacities and investment requirements indicate an investment requirement of $6–$8½ per gallon-year for a 60 MM gal/year plant. A USDA presentation in March 2007[8] includes operating cost elements representative of the best current technology that indicate a full cost of cellulosic ethanol production (including capital charges) of $3½–$4/gal.

The indicated capital investment requirements are estimated for a plant with capacity of 60 MM gal/year of fuel ethanol. (The average capacity of future cellulosic ethanol plants may be less than 60 MM gal/yr., due to practical limitations and costs associated with accumulating, transporting, and handling the required volumes of biomass feed material. Per gallon capital costs and hence full costs of supply tend to increase with decreasing plant size (all else equal)).

The Low and High estimates differ only in the assumed capital investment, and the resulting per-gallon *Capital recovery and return* for new plants. The Low estimates embody estimates of capital investment based on the current DOE publications indicated above. The High estimates embody 40% higher capital investments, reflecting a prospective increase in ethanol plant construction costs, due to bottlenecks and shortages of key equipment and services likely to be induced by the rapid pace of ethanol capacity addition needed to meet the proposed mandates. Such inflation appears to have occurred in corn ethanol projects since 2004. The ethanol mandate volumes considered in this analysis would require continued expansion of ethanol capacity at higher annual rates of capacity addition than the ethanol industry has experienced since 2004.

The *Logistics cost* line item does not include any transport or storage costs that might be incurred by terminals in handling additional volumes of light, volatile hydrocarbon fractions needed to meet winter vapor pressure (RVP) standards for E85.

The cost estimates shown in Exhibit 4 indicate that on an energy-parity basis (1) the cost of corn ethanol is higher than the estimated refining and distribution cost of gasoline, which is about $1.50/gal at the projected crude oil price, and (2) the projected cost of cellulosic ethanol is more than double that of corn ethanol. These ethanol supply costs account for the high national costs of ethanol mandates.

REDUCTIONS IN FOSSIL ENERGY USE AND GASOLINE IMPORTS

Exhibit 5 summarizes the effects of additional ethanol use on U.S. fossil energy use and imports of gasoline blendstocks.

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7 *DOE Selects Six Cellulosic Ethanol Plants for Up to $385 Million in Federal Funding*, 28 February 2007, www.doe.gov/print/4827.htm.

8 *The New World of Biofuels: Implications for Agriculture and Energy*; K. Collins, Chief Economist, USDA; EIA Energy Outlook, Modeling, and Data Conference; 28 March 2007

Exhibit 5: Changes in U.S. Fossil Energy Use With Ethanol Mandates (2020)

	Changes In Energy Flows		
	Nat'l E10	Nat'l E20	Nat'l E10/E85
Additional Ethanol Volume (over Baseline)			
Billion gal per year (bgy)	4.3	22.4	22.4
Thousand ethanol barrels per day (K bbl/day)	280	1460	1460
Thousand Coeb per day (K coeb/day)	175	911	911
National Energy Use Component (K Coeb/day)	**-34**	**-607**	**-543**
Refinery net energy use	-18	-102	-39
Gasoline blendstock imports	-161	-882	-880
Ethanol supply	145	377	376

All values are year-round averages, reflecting summer and winter refining operations.

Net U.S. fossil energy use would decrease by about 30 K coeb/day with National E10, 610 K coeb/day with National E20, and 540 K coeb/day with National E10/E85. The largest of these reductions (achieved with National E20) would be about 3½% of projected net U.S. imports of crude oil, petroleum products, and natural gas in 2020 and less than 2% of projected U.S. consumption of petroleum and natural gas in 2020.

Net imports of gasoline and blendstocks would decrease by about 160 K coeb/day with National E10, and about 880 K coeb/day with National E20 and National E10/E85. On the other hand, imports of natural gas would increase somewhat to supply the natural gas required for additional ethanol production.

The savings in fossil fuel use and the corresponding import displacements due to additional ethanol use result from a complex set of interactions among the various energy effects of additional ethanol use.

- The total energy input to *corn ethanol* supply – corn production, corn transport, ethanol production (in new dry mill plants), and ethanol transport to the blending site – is 80%– 85% of ethanol's energy content. That is, corn ethanol's *Net Energy Value* (NEV) is 15%–20%.
- The total energy input to cellulosic ethanol supply (defined in the same way) – though difficult to estimate in the absence of any commercial experience – could be approximately 30% of ethanol's energy content, corresponding to an NEV of about 70%.
- Ethanol's energy content – and hence fuel economy – is about 2/3 that of clear gasoline.
- U.S. refineries would accommodate additional ethanol volumes in U.S. gasoline by
  - Maintaining baseline production volume of gasoline blendstocks,

- Reducing the average octane of the gasoline blendstocks produced (to take advantage of ethanol's high octane), and
- Reducing refinery energy use (because of the reduced requirements for octane).

These changes in refining operations would lead to a slight decrease in the average energy content of the gasoline blendstocks produced.

- Overseas refineries that export gasoline and blendstocks to the U.S. would reduce their exports to the U.S. by a volume equivalent to the energy content of the additional ethanol volume (adjusted for small decreases in the energy content of gasoline blendstocks).

- The natural gas needed for additional ethanol production would be imported from sources outside North America, which are now the marginal sources of supply for natural gas.

COST OF ENERGY SAVINGS: $/COEB

As indicated in Exhibit 1, the fossil energy savings resulting from the ethanol mandates would cost about $290–$340/coeb for National E10, $220–$260/coeb for National E20, and $260–$310/coeb for National E10/E85. For each ethanol mandate, the per-coeb costs are the estimated national cost (Exhibit 3) divided by the estimated change in energy use (Exhibit 5). The Low and High estimates reflect the low and high estimates of the cost of ethanol supply shown in Exhibit 4.

The estimated costs of energy savings are *over and above the price of crude oil*. For example, if the average crude oil price is $50/Bbl, then a national cost of $210/coeb means that $260 worth of economic resources would be expended to reduce national energy use by the equivalent of one barrel of crude oil, worth $50.

The fossil energy and import savings resulting from increased ethanol use are expensive because

- The full cost of producing ethanol substantially exceeds the cost of producing gasoline;

- Ethanol has only about 2/3 the energy content of a gallon of gasoline; and

- Ethanol production itself consumes a significant amount of energy (mostly from fossil fuels).

E20 MANDATE

A national E20 mandate would entail a long, complex, and costly nation-wide transition from clear gasoline and E10, under the current RFS, to exclusive use of E20. At present:

- E20 is not certified for use as a vehicle fuel in the U.S. Federal regulations require that EPA certify E20 as "substantially similar" to gasoline before it could be used in commerce.

- The vehicles (other than FFVs) in the U.S. car and LDT fleets are not designed to use E20 and may not be capable of doing so in sustained operation.

- The manufacturers of cars and LDTs sold in the U.S. have indicated that their existing vehicle warranties would not cover adverse effects of fueling with gasoline/ethanol blends containing more than 10 vol% ethanol (E10).

- E20 may not be suitable or safe for use in small, two-stroke gasoline engines, commonly used in off-road vehicles and equipment.

- No E20 is produced or transported in the U.S. refining and production distribution sectors.

A national E20 mandate would require that essentially all cars and LDTs on the road be FFVs and that all off-road engines be capable of using E20. The historical average turnover rate of the U.S. car and LDT fleets suggest that the transition to an FFV vehicle fleets would extend well beyond 2020, absent special programs or incentives. During the period of transition, the U.S. refining and distribution system would have to supply both E10 and E20 nation-wide, which could cause operating problems and impose significant costs.

This analysis did not consider the technical issues or costs of the transition to a national E20 mandate. The estimated costs of National E20 shown in Exhibits 1 and 2 are long-term annual costs, post-transition.

E85 Mandate

A national E85 mandate would entail a less difficult transition than an E20 mandate. But certain attributes of E85 would complicate the long-term implementation of an E85 mandate and raise its long-term cost (relative to an E20 mandate for the same ethanol volume).

First, E85 is corrosive to components of vehicle fuel systems and the fuel distribution system. Hence, as with E20 mandates, an E85 mandate would require a national mandate for FFV production. In addition, an E85 mandate would require retrofitting service stations nationwide with special fueling facilities dedicated to E85. The estimated annualized costs of the FFV production and of the fueling facilities needed to support a national E85 use (the National E10/E85 scenario) are about $1½ and $2½ billion/year, respectively. An E85 mandate also might cause terminals to incur some transport or storage costs for handling additional volumes of light, volatile hydrocarbon fractions needed to meet winter vapor pressure standards for E85.

Second, E85 has excess (greater than 87) octane due to ethanol's high blending octane (≈ 113), ethanol's most valuable attribute as a gasoline blendstock. Excess octane has no value to consumers, because FFVs are designed to run on 87 octane fuel. Octane-barrels "given away" in E85 are not available for the rest of the gasoline pool and must be replaced by refinery production of a like quantity of additional octane-barrels. Production of the additional octane-barrels would (1) increase national refining costs by amount equal to about 7–8¢/gal of ethanol used in E85 and (2) would increase refinery energy use by an amount equal to about 7–8% of the energy content of the ethanol used in E85.

Third, E85's energy density is low – about 24% less than that of E10, on an average year-round basis. Hence E85's fuel economy is about 24% less than that of E10.[9]

Consumers would perceive this fuel economy deficit and, given a choice, most likely would value E85 at no more than energy-parity with E10, i.e., about 24% less than E10.[10] At the same time, E85's cost of production would be higher than E10's (especially so in light of the projected cost of cellulosic ethanol). Consequently, if Congress were to impose an ethanol requirement equivalent to an E10/E85 mandate, additional market interventions (e.g., mandatory use by fleets or other FFV owners, no cross-fueling, etc.), government credits and/or subsidies, and other measures might be needed to induce demand for E85 sufficient to meet the mandate.

PROSPECTIVE ECONOMICS OF CELLULOSIC ETHANOL PRODUCTION

The national costs of large ethanol mandates would depend in large measure on the economics of commercial-scale cellulosic ethanol production. Cellulosic ethanol production is inherently more difficult, more complex, and more capital intensive than corn ethanol production. Hence, cellulosic ethanol – if it proves feasible and regardless of the biomass feed material of choice – likely will be more costly than corn ethanol. The question is how much more.

Little information is available on the economics of prospective cellulosic ethanol production. Numerous research and development efforts bearing on cellulosic ethanol production are in progress in the public sector, the private sector, and academia. These efforts have produced a substantial body of literature, but almost none of that literature spells out in detail the prospective economics – investment requirements and operating costs – of future commercial cellulosic ethanol production.

The economic estimates used in this analysis, estimated from recent U.S. government publications, indicate that the assumed 17 bgy of cellulosic ethanol production would require \$100–\$150 billion in capital investment and that the full cost of cellulosic ethanol supply would be about \$3½–\$4/gal – about twice the current cost of corn ethanol.

From a public policy standpoint, cellulosic ethanol is intrinsically different from corn ethanol. When EPAct2005 established the current RFS (intended for corn ethanol), commercial-scale corn ethanol production had been practiced for more than thirty years. Corn ethanol's

[9] The annual DOE/EPA fuel economy ratings of current FFV models confirm the relationship between E85's energy content and fuel economy.

[10] Reduced fuel economy means less vehicle range and hence more frequent refueling. If E85 consumers placed a value on the inconvenience and the time lost in these additional tank fills, E85's value would be subject to a further discount to offset the value of the time lost. This leads to a *time-discounted energy parity* value of E85 that is ≈ 10¢/gal less than energy parity value.

production technology, costs, and overall economics were well established, and the primarily feedstock (corn) was in commerce and readily available.

By contrast, neither the technology nor the economics of large-scale commercial cellulosic ethanol production, assuming it proves feasible, are yet established. No cellulosic ethanol has been produced in sustained, commercial-scale operations. No commercial-scale (≈ 50–60 MM gal/yr) cellulosic ethanol plants are in operation or under construction, and the proposed biomass feedstocks for such plants are not now in commerce.

The extent to which research and development activities might improve the economics of cellulosic ethanol production is unclear. Moreover, the rapid surge in cellulosic ethanol capacity that would be required to achieve the proposed mandate volume by 2020 – construction of ≈ 270–350 plants (each 50–60 MM gal/year) in less than a decade – would limit the economic benefits that normally accrue from accumulated experience in designing and operating new facilities. And, the surge would likely trigger bottlenecks in engineering, procurement, and production, with resulting inflation in plant design and construction costs.

Basis for The Findings Reported Here

The findings reported here come from a detailed technical and economic analysis conducted by MathPro Inc., of the effects of an RFS on the refining economics of U.S. gasoline supply. The analysis:

- Reflected baseline ethanol use of 12.5 bgy, the AEO 2007 projection of ethanol use in 2020, under current law;
- Used (1) Department of Agriculture and other estimates of the net energy inputs to ethanol production (net of by-product credits); (2) Department of Energy forecasts of crude oil and natural gas prices, U.S. gasoline demand, and domestic gasoline production; and (3) a forecast by Global Insight, Inc. of the corn price in 2020 with 17 bgy of corn ethanol production;
- Assumed continuation of the 1 psi RVP waiver for ethanol-blended conventional gasoline and (in the Midwest) low-RVP gasoline;
- Assumed that all legislation, regulatory programs, market conditions and/or incentives needed to implement the proposed volumes of ethanol use would be in place prior to 2020, including
    - Establishment of the ethanol mandates themselves, including an overall ethanol mandate and a mandate specific to cellulosic ethanol or advanced biofuels in general
    - EPA and auto industry certification of E20 as a vehicle fuel (as called for in the *National E20* scenario)
    - Production each year of a sufficient number of flexible fuel vehicles to support the introduction of E20 or E85

- Installation of special E85 facilities and equipment in a sufficient number of service stations and in the logistics system to support the introduction of E85
- Market conditions, special incentives, and/or regulatory mechanisms specifically for E85 production (if E85 were included in the proposed ethanol mandate program, as in the *National E10/E85* scenario);

- Considered only domestic production of ethanol and not ethanol imports as a means of meeting the assumed ethanol mandates; and

- Considered only long-term national costs incurred in the production and consumption of fuel ethanol, and therefore did not consider

  - Costs arising from the environmental consequences (e.g., soil, water, and air degradation) of increased production of corn and other biomass for ethanol production
  - Effects of increasing ethanol production on the economics of the agricultural sector
  - Costs of the transition to National E20 or National E10/E85
  - Costs of implementing, enforcing, and complying with ethanol mandates.

All prices are in 2006 US$. All ethanol volumes are annual averages.