EFFECTS OF THE 1 PSI RVP WAIVER ON THE REFINING VALUE OF ETHANOL

AS

GASOLINE BLENDSTOCK AND ETHERIFICATION FEEDSTOCK

Prepared by

Math*Pro Inc.*
Dave Hirshfeld
Jeff Kolb

Under Subcontract to

Information Resources, Inc.

for

The National Renewable Energy Laboratory

Under Contract No. ACG-5-15356-01

revised
November 14, 1995

Effects of the 1 psi RVP Waiver on the Refining Value of Ethanol as Gasoline Blendstock and Etherification Feedstock

Background

This report describes an analysis of the effects on ethanol's long-term refining value of the 1 psi RVP waiver granted for ethanol-blended conventional gasoline. The work described in this report was carried out as part of Task 1 of NREL Subcontract No. ACG-5-15356-01 (21 September 1995).

This work is a sensitivity analysis extending prior work performed for NREL to analyze ethanol's value in the U.S. petroleum refining sector. The prior work was performed under Subcontract No. AAW-4-14125-01 and documented in that subcontract's Report 5, *The Refining Value of Ethanol as Gasoline Blendstock and Etherification Feedstock* (18 July 1995). This report should be considered a supplement to the 18 July report. In general, the work described here embodies the same methodology, data, and assumptions as did the prior work. The reader interested in these matters should refer to the 18 July report.

The prior work (1) explored the technical determinants of ethanol's refining value as a gasoline blendstock and as an etherification feedstock and (2) developed aggregate demand functions for fuel-grade ethanol in the U.S. refining sector, for the year 2010.[1] The estimated demand functions correspond to various crude oil and natural gas prices projected for 2010 in DoE's *1995 Annual Energy Outlook* and reflect assumptions regarding future refining technology, refining economics, and public policies bearing on gasoline quality and composition. In particular, it reflected the assumption that no public policies, including the 1 psi waiver, would be in place in 2010 to promote the use of ethanol by the U.S. refining sector.

The analysis described in this report reflects the assumption that the current 1 psi RVP waiver for ethanol-blended conventional gasoline remains in place through 2010 and beyond. The analysis focuses on two issues.

- The effect of the 1 psi RVP waiver on the refining value of ethanol under alternative oil price scenarios (high, mid-range, and low as defined in the *1995 Annual Energy Outlook*).
- The effect of the 1 psi RVP waiver on the refining value of ethanol under alternative scenarios regarding investments in DIPE process capacity.

---

[1] We use the term "demand function" to refer to the relationship between the refining value of ethanol and the volume of ethanol used by refineries, either as an ether feedstock or as a direct gasoline blendstock. Refer to the previous report for a discussion of the distinction between the market value and the refining value of ethanol.

Ethanol raises the RVP of the finished gasoline or gasoline blendstocks to which it is blended by about 1 psi. Thus, in the absence of a summer RVP waiver for ethanol blends, refiners must reduce the RVP of the base gasoline by about 1 psi to compensate for the RVP effect of ethanol. In general, the least costly option for reducing RVP is to reduce the butane concentration of their gasoline by debutanizing various gasoline blendstocks. Butanes (normal butane and isobutane) have very high RVPs and high octanes; their removal reduces both the RVP and the octane of the base gasoline. (Refiners also may blend more blendstocks with low RVP or low octane to offset increases in RVP and octane due to ethanol blending.) Consequently, in the absence of the 1 psi RVP waiver, increased ethanol blending generally will lead to an increase in the volume of butanes sold (or a reduction in the volume purchased) by refiners. This change in butane demand may depress somewhat market prices for butanes and reduce the refining value of ethanol.

Effect of RVP Waiver -- Alternative Oil Price Scenarios

Methodology

As in the previous study, we employed a generalized refinery modeling system (ARMS) to assess the effects of the 1 psi RVP waiver on the refining value of ethanol. Our analysis consists of the following steps.

- Baseline refining capacity. Use the ARMS configuration and modeling results developed in the previous study for the scenario in which refining capacity is optimized to produce 50% RFG (without using ethanol either as a feedstock for ethers or as a direct gasoline blendstock) and 50% conventional gasoline (using 100,000 bbls/day of ethanol as direct blendstock).

- Refining value of ethanol with no RVP waiver. Use ARMS to regenerate the "demand functions " for ethanol reported in the previous study for each of the oil price scenarios.

- Refining value of ethanol with a 1 psi RVP waiver. Represent in ARMS the 1 psi waiver for conventional gasoline during the summer season and then use ARMS to generate revised baseline refining capacity and "demand functions" for ethanol under each of the oil price scenarios.

Results

The results of this analysis are portrayed in Charts 1 through 3. (Tables 1-A&B provide the data used to generate the charts and Tables 2-A&B provide a breakdown of oxygenate use for each of the oil price scenarios.) The primary findings are:

- In most cases examined, the 1 psi RVP waiver increases the value of ethanol blended into *conventional gasoline* by about $1.00 per barrel, or about 2½ ¢/gallon of ethanol.

  On the premise that reducing gasoline RVP by 1 psi costs about 0.5 to 1 ¢/gallon of gasoline, most analysts peg the value of the 1 psi RVP waiver at about 5 to 10 ¢/gal of ethanol, assuming a 10% ethanol blend. Our estimate of the waiver's value is lower, for two reasons.

  (1) Our estimate applies to the entire year, not just to the summer (RVP control) season. (The value of the RVP waiver for the summer is divided by two to calculate the average annual value of the waiver.)

  (2) Our estimate reflects elements of the methodology that tend to reduce the estimated (as opposed to the actual) value of the RVP waiver:

  -- the cost of adding more debutanization capacity in some refineries may be greater than the estimate of average industry costs incorporated in ARMS;

  -- we use an annual capital recovery factor for all investments in process capacity, but the capital recovery factor would be higher for investments in RVP control capacity used only in the summer months; and

  -- we maintain a constant butane price across all ethanol use and RVP scenarios, rather than reducing the price in scenarios in which butane sales increase because of the introduction of ethanol into summer gasoline blends (ARMS optimizes butane sales subject to a specified market price).[2]

  These elements of methodology tend to *increase* ethanol's indicated refining value in the absence of the RVP waiver (as analyzed in the previous study). The first two elements tend to understate the cost to refiners of using ethanol and increase its refining value. The third element tends to overstate the market value of butane removed from gasoline blendstocks (to meet the RVP requirements), and understate the cost of RVP control. However, these elements of methodology do not increase ethanol's value with the RVP waiver in place (as analyzed in the current study), because the RVP waiver obviates the need for additional RVP controls.

- The 1 psi waiver has little effect on the value of ethanol as a feedstock for ethers.

  This result is reflected in the Charts whenever the demand functions coincide. In the high- and mid- price scenarios, the refining value of ethanol as a direct blendstock in

[2] Sensitivity runs indicate that variations in butane sales or use (at constant prices) have negligible effect on the refining value of ethanol and the value of the 1 psi RVP waiver.

conventional gasoline is higher than its value as an ether feedstock. Hence, the demand functions reflect the upward shift in refining value for ethanol used for direct blending in conventional gasoline. At sufficient ethanol volume to exhaust this use (more than 400 M bbls/d), the demand functions coincide because ethanol is then used as a feedstock for ether production. The order is reversed for the low price scenario, because ethanol initially has a higher value as feedstock for ether production.

As discussed in the previous report, in the absence of the 1 psi RVP waiver ethanol blenders would incur distribution costs not now incurred. "Sub-grade" gasoline blends destined for ethanol blending would have to be segregated from conventional gasoline (1) because their RVP would have to be 1 psi lower than the summer RVP standard and (2) to enable marketing of the full complement of gasoline grades while still taking advantage of ethanol's high octane.

With the RVP waiver in place, the situation is somewhat different. Absorbing the ethanol volumes contemplated by NREL would require the production and marketing of ethanol-blended, regular gasoline (in addition to midgrade and premium gasolines). Marketing ethanol-blended, regular gasoline would entail the production and segregation in the distribution system of a "sub-grade" regular gasoline blend with lower octane but the same RVP as regular grade gasoline. This could increase the logistics costs associated with using ethanol and reduce its rack value.

Effect of RVP Waiver -- Alternative Investments in DIPE Process Capacity

Our previous study found that significant investments likely would be made in DIPE process capacity to meet the oxygenate demands associated with a gasoline pool that is 50% RFG. In a companion paper[3], we estimate the aggregate investment in DIPE process capacity under various scenarios in which (1) the investment cost for DIPE capacity varies between 75% and 150% of current estimates and (2) petrochemical demands for propylene (the refinery-based feedstock to the DIPE process) varies between 75% and 125% of the previous study's projected demand for the year 2010. We found that DIPE capacity varied across these scenarios from zero to about 350 M bbls/day for the mid-range oil price scenario, with 50% of the gasoline pool as RFG and no RVP waiver.

Here we estimate (1) the effects of the 1 psi RVP waiver on investment in DIPE process capacity under three alternative assumptions regarding the investment cost of DIPE (75%, 100%, and 150% of current estimates) and (2) the effects on ethanol demand of the RVP waiver, given alternative levels of investment in DIPE process capacity.

[3] "The Effects of DIPE Economics on the Refinery Value of Ethanol as Gasoline Blendstock and Etherification Feedstock."

Methodology

For this sensitivity analysis, we use essentially the same approach as outlined above .

- Baseline refining capacity. Use the modeling results described in the companion paper for the scenarios in which investment costs for DIPE are 75% and 150% of current estimates.

- Refining value of ethanol with no RVP waiver. Use the "demand functions " for ethanol reported in the companion paper.

- Refining value of ethanol with a 1 psi RVP waiver. Alter the RVP specification for conventional gasoline to reflect a 1 psi waiver for gasohol during the summer season and use ARMS to generate revised baseline refining capacity and "demand functions" for ethanol under each of the scenarios for DIPE investment costs.

Results

The results of this analysis are portrayed in Charts 4 and 5. The primary findings are:

- The 1 psi RVP waiver has little effect on investment in DIPE process capacity.

- As in the analysis discussed above, the 1 psi RVP waiver increases the value of ethanol blended to conventional gasoline by about 2½ ¢/gal and does not affect the value of ethanol used as a feedstock for ether production. This probably understates the increase in value of ethanol that derives from the RVP waiver (for the same reasons as outlined above).

Actual DIPE economics, as it may evolve, will have little or no effect on the value of the 1 psi RVP waiver (i.e., it affects the demand for ethanol but not the value of the RVP waiver). More broadly, changes in the profile of refinery process capacity (the mix of refining processes) will have little or no effect on the value of the 1 psi RVP waiver. The value of the waiver depends on the marginal cost of RVP reduction. Although gasoline RVP is influenced by the types of blendstocks produced by refineries, RVP control primarily involves fractionating lighter ends (butanes) from gasoline blendstocks. Typically this is accomplished through investments in debutanization capacity targeted to meet specific RVP requirements. Thus, the marginal cost of RVP control is not a strong function of the profile of refinery capacity.

11/13/95

Table 1-A: Estimated Refining Value of Ethanol, by Oil Price and RVP Waiver Scenario

Oil Price Scenario	Ethanol Volume (M bbls/d)			Refining Value ($/bbl)		Refining Cost of Conventional Gasoline
	Conventional Gasoline	Ether Feed	Total	No RVP Waiver	1 psi RVP Waiver	
High	100		100	37.00	38.10	38.00
	200		200	35.50	36.50	34.00
	400		400	34.40	35.60	33.00
	400	120	520	28.90	28.90	33.00
	400	145	545	28.10	28.10	33.00
Mid Range	100		100	32.90	34.00	33.00
	200		200	31.20	32.30	29.00
	400		400	29.40	30.00	27.00
	400	120	520	26.90	26.90	27.00
	400	145	545	22.10	22.10	27.00
Low	100		100	29.90	29.90	23.00
	100	100	200	24.10	24.10	20.00
	280	120	400	18.30	19.10	17.00
	390	120	510	18.00	18.80	17.00
	390	140	530	17.20	17.20	17.00

11/13/95

Table 1-B: Estimated Refinery Value of Ethanol, by DIPE Capacity Senario

Initial DIPE Capacity	Ethanol Volume (M bbls/d)			Refining Value ($/bbl)		Refining Cost of Conventional Gasoline
	Conventional Gasoline	Ether Feed	Total	No RVP Waiver	1 psi RVP Waiver	
350 M bbls/d	100		100	31.60	32.50	33.00
	200		200	29.90	30.80	28.00
	400		400	29.30	30.10	27.00
	400	100	500	27.00	26.90	27.00
	400	120	520	20.00	20.00	27.00
No DIPE; Low MTBE Imports	100	0	100	31.70	32.50	33.00
	200	0	200	30.00	30.80	28.00
	400	0	400	29.40	30.20	28.00
	400	120	520	28.00	28.00	27.00
	400	200	600	26.90	26.50	27.00
	400	230	630	20.00	20.00	27.00

Table 2-A: Oxygenate Volumes, byType and Oil Price Scenario
(M bbls/day)

Oil Price/ RVP Scenarios	Total Ethanol	Type of Oxygenate						
		MTBE						
		Captive	Merchant	ETBE	TAME	TAEE	DIPE	Ethanol
High Price:								
No Waiver	102	157	129	2	12	0	207	101
	202	159	80	0	10	3	243	201
	401	158	80	0	10	3	244	400
	520	0	14	258	4	9	246	400
	545	0	0	313	4	9	207	400
1 psi Waiver	102	156	130	2	12	0	202	101
	202	156	127	2	0	0	201	201
	401	156	127	2	0	0	201	400
	520	0	56	265	0	0	201	400
	545	0	50	310	0	13	201	400
Mid Range Price:								
No Waiver	102	154	130	2	12	0	188	101
	202	157	80	0	10	3	245	201
	401	156	80	0	9	3	247	400
	520	0	11	258	4	9	249	400
	545	0	0	313	4	9	207	400
1 psi Waiver	102	154	130	2	12	0	189	101
	202	156	80	0	10	3	247	201
	401	156	80	0	9	3	247	400
	520	0	11	258	4	9	249	400
	545	0	0	313	4	9	207	400
Low Price:								
No Waiver	102	141	130	2	25	0	183	101
	201	0	49	205	8	19	237	101
	402	0	5	249	8	19	243	282
	514	0	5	249	8	19	243	394
	534	0	0	285	0	29	214	394
1 psi Waiver	102	141	130	2	18	0	189	101
	201	0	46	209	6	14	243	101
	402	0	1	254	6	13	251	282
	514	0	2	254	6	14	250	394
	534	0	0	293	0	19	214	394

Table 2-B: Oxygenate Volumes, byType and DIPE Scenario
(M bbls/day)

DIPE/ RVP Scenarios	Total Ethanol	Type of Oxygenate						
		MTBE		ETBE	TAME	TAEE	DIPE	Ethanol
		Captive	Merchant					
High DIPE								
No Waiver	102	163	80	2	12	0	297	101
	202	160	41	2	0	0	296	201
	401	160	40	1	1	2	296	400
	500	0	12	221	0	0	296	400
	520	0	0	265	0	1	296	400
1 psi Waiver	102	163	77	2	12	0	296	101
	202	163	39	2	0	0	296	201
	401	163	39	2	0	0	296	400
	500	0	11	219	1	2	296	400
	520	0	0	255	0	12	296	400
Low DIPE								
No Waiver	102	227	130	2	116	0	0	101
	202	277	80	2	116	0	0	201
	401	279	80	0	113	3	0	400
	520	116	80	191	38	87	0	400
	600	0	44	368	38	87	0	400
	630	0	0	418	21	105	0	400
1 psi Waiver	102	232	125	2	116	0	0	101
	202	279	80	0	113	3	0	201
	401	279	80	0	113	3	0	400
	520	116	80	191	38	87	0	400
	600	0	44	368	38	87	0	400
	630	0	0	426	21	96	0	400

Chart 1: Estimated Refining Value of Ethanol - High Price Scenario

With and Without RVP Waiver

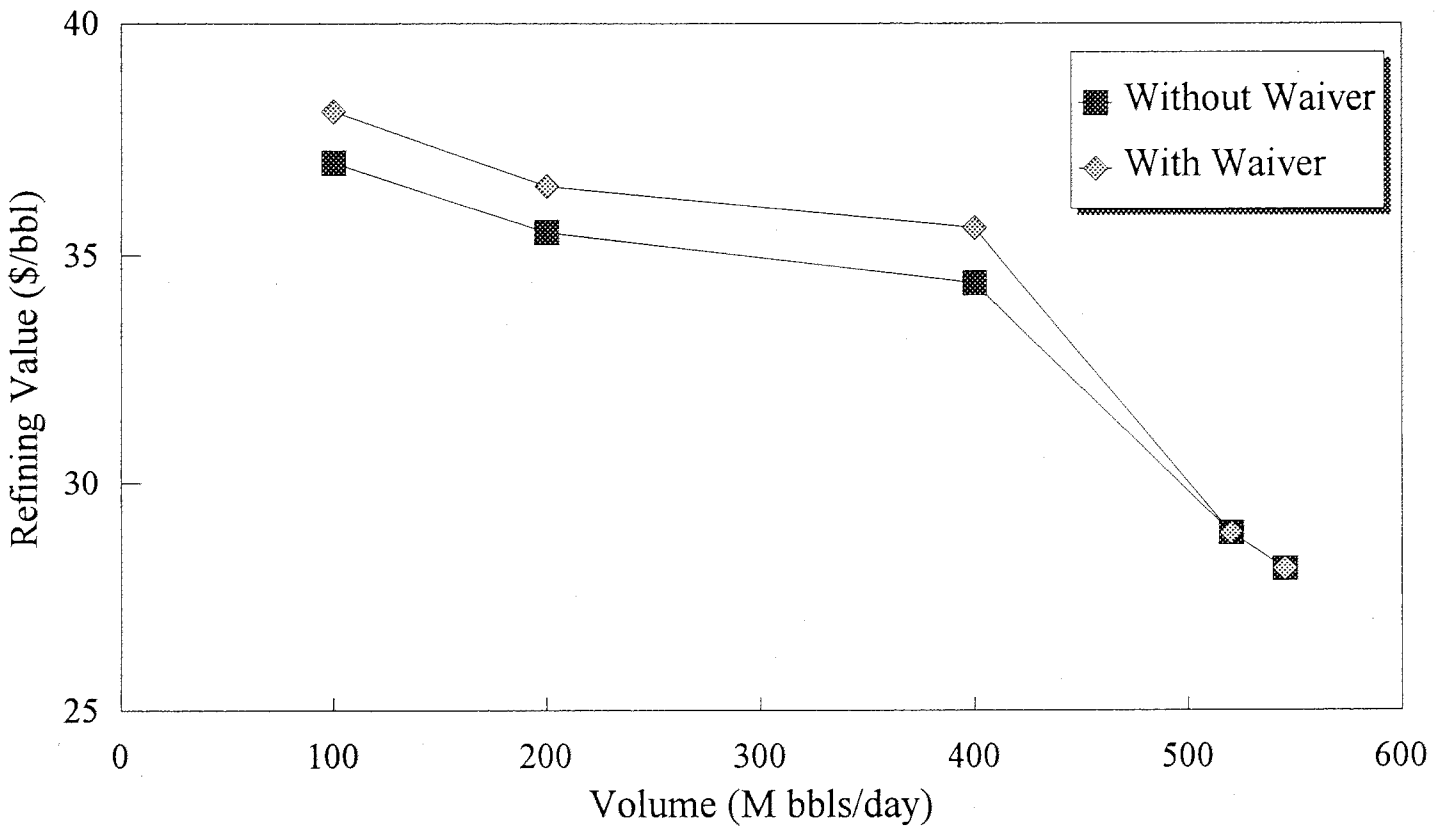

Chart 2: Estimated Refining Value of Ethanol - Mid Price Scenario

With and Without RVP Waiver

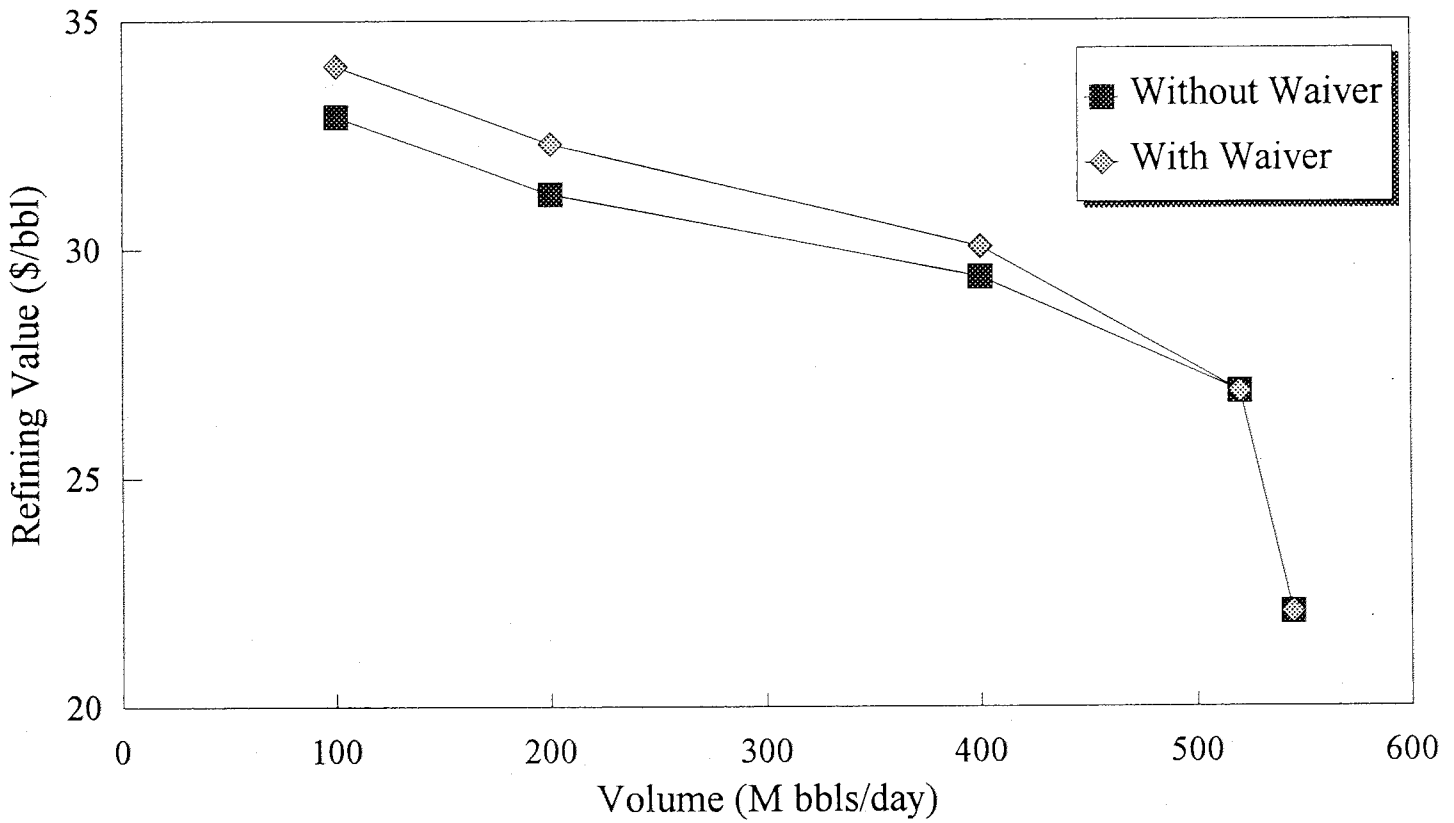

Chart 3: Estimated Refining Value of Ethanol - Low Price Scenario

With and Without RVP Waiver

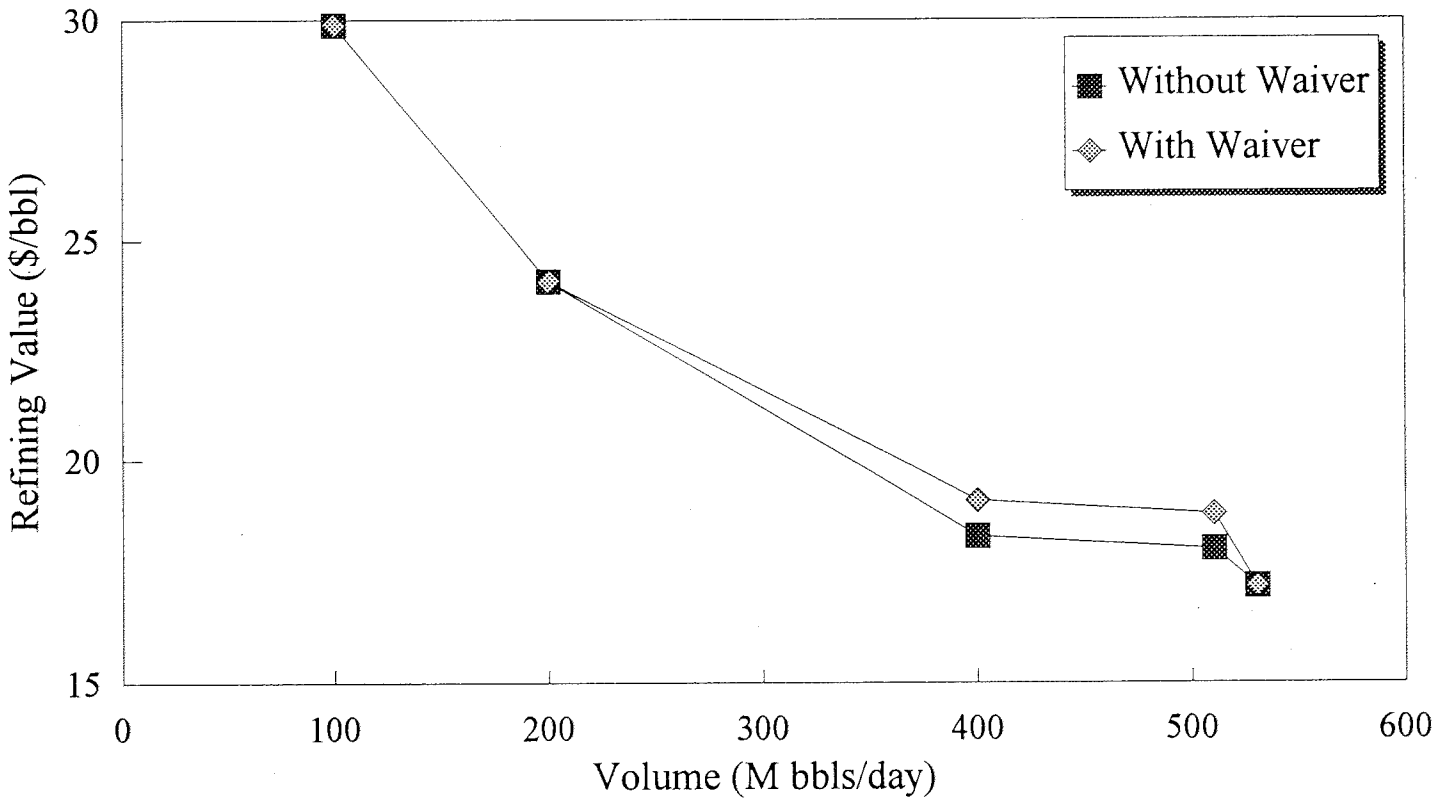

Chart 4: Estimated Refining Value of Ethanol - High DIPE Capacity

With and Without RVP Waiver

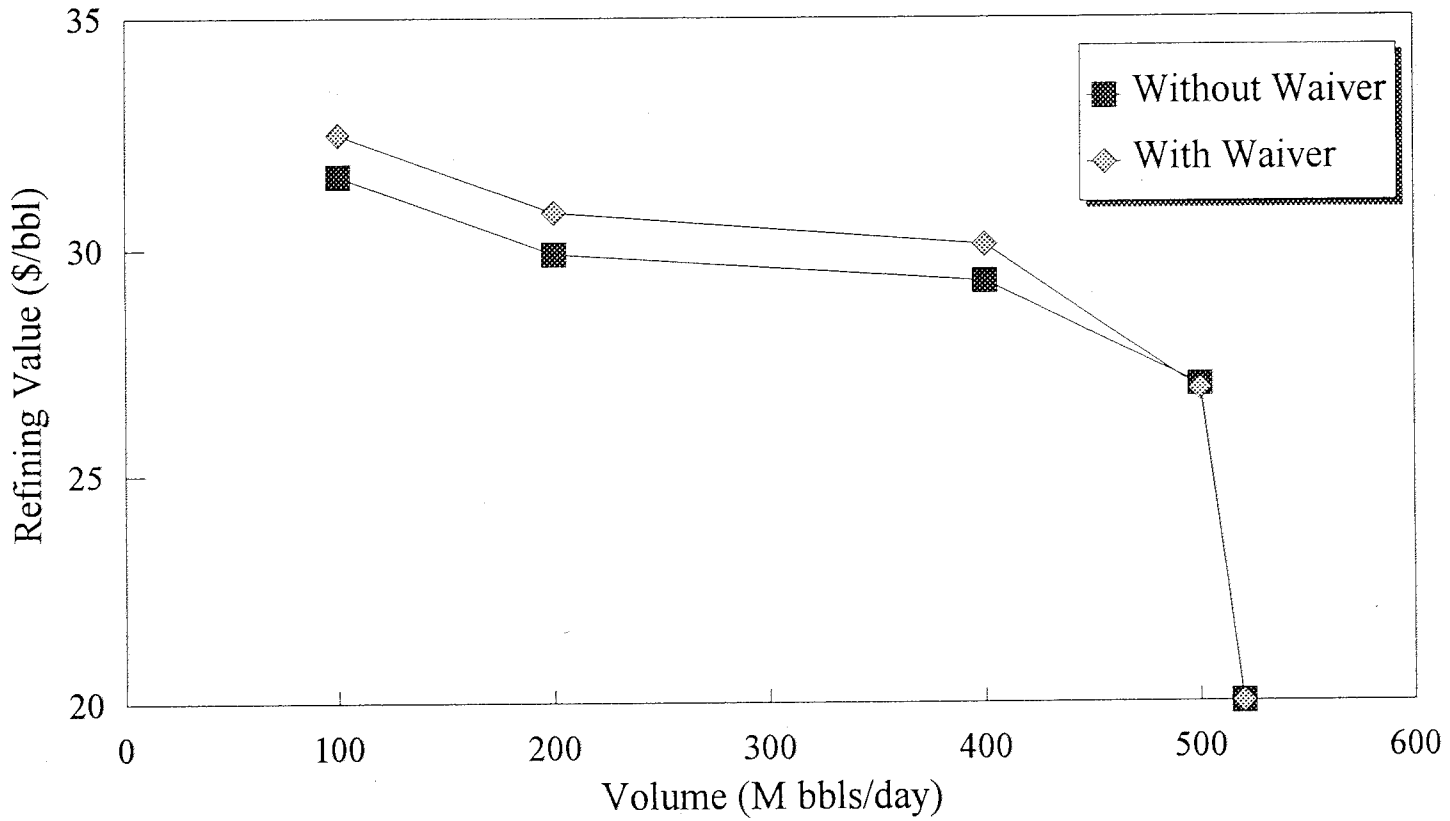

Chart 5: Estimated Refining Value of Ethanol - Zero DIPE Capacity

With and Without RVP Waiver