MTBE Production Economics

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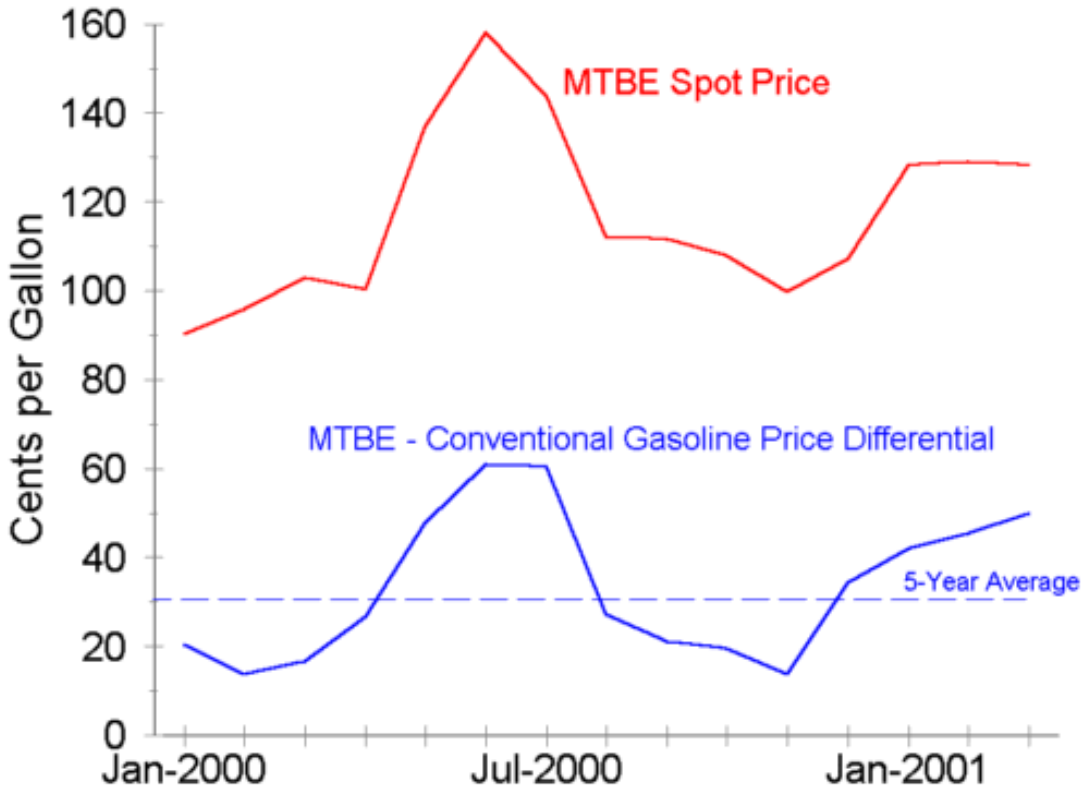
1. Summary

Last year the price of MTBE (methyl tertiary butyl ether) increased dramatically on two occasions (Figure 1) (see *Data Sources* at end of article.):

1. Between April and June 2000, the price (U.S. Gulf Coast waterborne market) of MTBE rose from $1.00 per gallon to over $1.60 per gallon. This represented an increase in the price premium for MTBE over the wholesale price of conventional gasoline from its normal (1995 though 2000 average) $0.26 per gallon to $0.60 per gallon. The MTBE price fell back to an average $1.12 per gallon by August and the price premium to conventional gasoline to $0.27 per gallon.
2. The MTBE price hit a low point in November 2000 (under $1.00 per gallon and $0.14 per gallon over conventional gasoline) but quickly rebounded to $1.35 per gallon at the end of March 2001 ($0.52 per gallon over conventional gasoline).

Figure 1. MTBE Spot Price and Price Premium over Conventional Gasoline, January 2000 - March 2001



The purpose of this analysis is to evaluate the causes of these MTBE price increases. Our focus is on the supply side, in particular the cost of producing MTBE.[(1)] For example, during the fourth quarter of 2000, the price of natural gas almost doubled. This natural gas price run-up raised the price of normal butane and methanol, which are feedstocks in the production of MTBE. In fact, the price of normal butane rose above the price of conventional gasoline for the first time in at least 15 years. The summer prise rise, on the other hand, cannot be explained by the costs of MTBE production.

The price of MTBE has an impact on gasoline markets because of its use as an oxygenate blendstock in reformulated gasoline. Reformulated gasoline (RFG), which makes up about 1/3 of total domestic gasoline demand, requires the blending of an oxygenate such as ethanol or MTBE. MTBE generally represents the marginal source of oxygenate for RFG blending, particularly during the summer months. The price premium for RFG over conventional gasoline, which does not require oxygenates, is directly related to the price premium for MTBE over conventional gasoline. For example, since RFG contains about 11.5 volume percent MTBE, each 10-cent per gallon increase in the price of MTBE relative to the price of conventional gasoline should raise the price of RFG by about 1.2 cents per gallon.

The availability of MTBE can also influence gasoline prices if MTBE shortages were to create a gasoline supply constraint. During the first MTBE price spike in the second quarter of 2000, production of MTBE remained at high levels. But during the second price surge in the fourth quarter 2000, MTBE production declined from 210,000 barrels per day in October 2000, to 142,000 barrels per day in January 2001, the lowest level of output since March 1995.[(2)]

An analysis of the relationships between the prices of the different products reveals the following:

- The Spring 2000 MTBE price increase cannot be explained by increases in the cost of producing MTBE. The winter 2000/2001 MTBE price increase can, however, be fully explained by increases in the cost of production, brought on by the rise in the price of natural gas.
- The cost of producing MTBE rose faster than the spot market price in the winter 2000/2001, which led to significant cutbacks in production, primarily by the large merchant producers.
- The price of RFG relative to conventional gasoline has maintained a relatively steady relationship to the price premium for MTBE over conventional gasoline. During the Spring 2000, however, there was a surge in the price premium for RFG, most likely caused by the additional cost of complying with the new Phase 2 RFG requirements.

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2. MTBE Production Costs

There are three types of MTBE production plants:

- **Refinery/Petrochemical plants**: Isobutylene, produced as a byproduct in refinery catalytic crackers and in petrochemical ethylene plants, is reacted with methanol to produce MTBE. These are the smallest and the least expensive MTBE plants to build at $6,000 to $10,000 per daily barrel of capacity.[(3)]
- **Merchant plants:** Merchant plants isomerize normal butane to isobutane, dehydrogenate isobutane to isobutylene, and then react the isobutylene with methanol to produce MTBE. The merchant plants are the most expensive to build at $20,000 to $28,000 per daily barrel of capacity.[(3)]
- **TBA plants:** Tertiary butyl alcohol (TBA) is a byproduct of the propylene oxide production process. TBA is reacted with methanol to produce MTBE. Only 2 plants in the United States use this process

The marginal source of MTBE supply comes from the large merchant plants. The merchant plants have the highest production costs and generally are the first to cut back production when MTBE prices fall.

This production cost analysis looks at the relationship between the spot market prices for the raw materials normal butane and methanol with the MTBE spot market price. A simple regression

analysis indicates a price relationship very close to the expected yield (Table 1). In summary (refer to *Regression Results* for full results and *Data Sources* for data definitions and sources):

- A $0.10 per gallon increase in the price of normal butane (Month Belvieu spot market) increases the price of MTBE (U.S. Gulf Coast waterborne market) by $0.10 per gallon.
- A $0.10 per gallon increase in the price of methanol (U.S. Gulf Coast spot market) increases the price of MTBE (U.S. Gulf Coast waterborne market) by $0.04 per gallon.

Table 1. MTBE Production Yields
Gallons raw material per 1 gallon MTBE

	Normal Butane	Methanol
Theoretical Yield (1)	0.839	0.339
Published Yield (2)	0.92 to 0.99	0.340
Regression Estimate (3)	0.989	0.387

Normal Butane —> Isobutane —> Isobutylene + Hydrogen

C_4H_{10} —> C_4H_{10} —> C_4H_8 + H_2

Isobutylene + Methanol —> MTBE

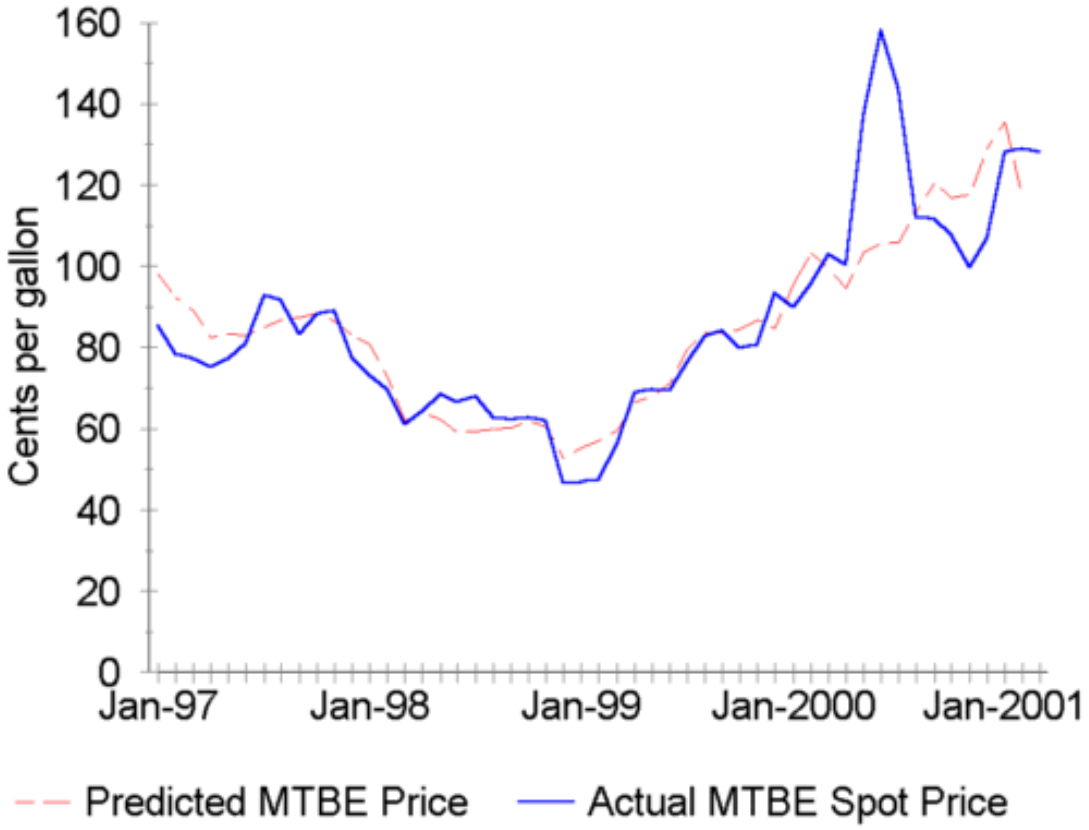
C_4H_8 + CH_3OH —> $C_5H_{12}O$

Notes:

1. 58.12 pounds normal butane (at 4.865 pounds per gallon) + 32.04 pounds methanol (at 6.63 pounds per gallon) = 88.14 pounds MTBE (at 6.19 pounds per gallon) + 2.02 pounds hydrogen.
2. Gulf Publishing Co., *Hydrocarbon Processing*, Refining Processes annual issue, Houston, TX.
3. Refer to Regression Results

A graph of the actual MTBE spot price and the price estimated using the regression equation and butane and methanol spot prices (Figure 2) provides a convenient method of comparing the MTBE spot market price with the estimated cost of production.

Figure 2. MTBE Actual and Predicted Spot Price, January 1997 - February 2001



The comparison in Figure 2 shows:

- The Spring 2000 MTBE price increase cannot be explained by increases in the cost of producing MTBE. The winter 2000/2001 MTBE price increase can, however, be fully explained by increases in the cost of production, brought on by the rise in the price of natural gas.
- The MTBE spot market price fell below the cost of producing MTBE during the winter 2000/2001, which led to significant cutbacks in production, primarily by the large merchant producers.[(1)]

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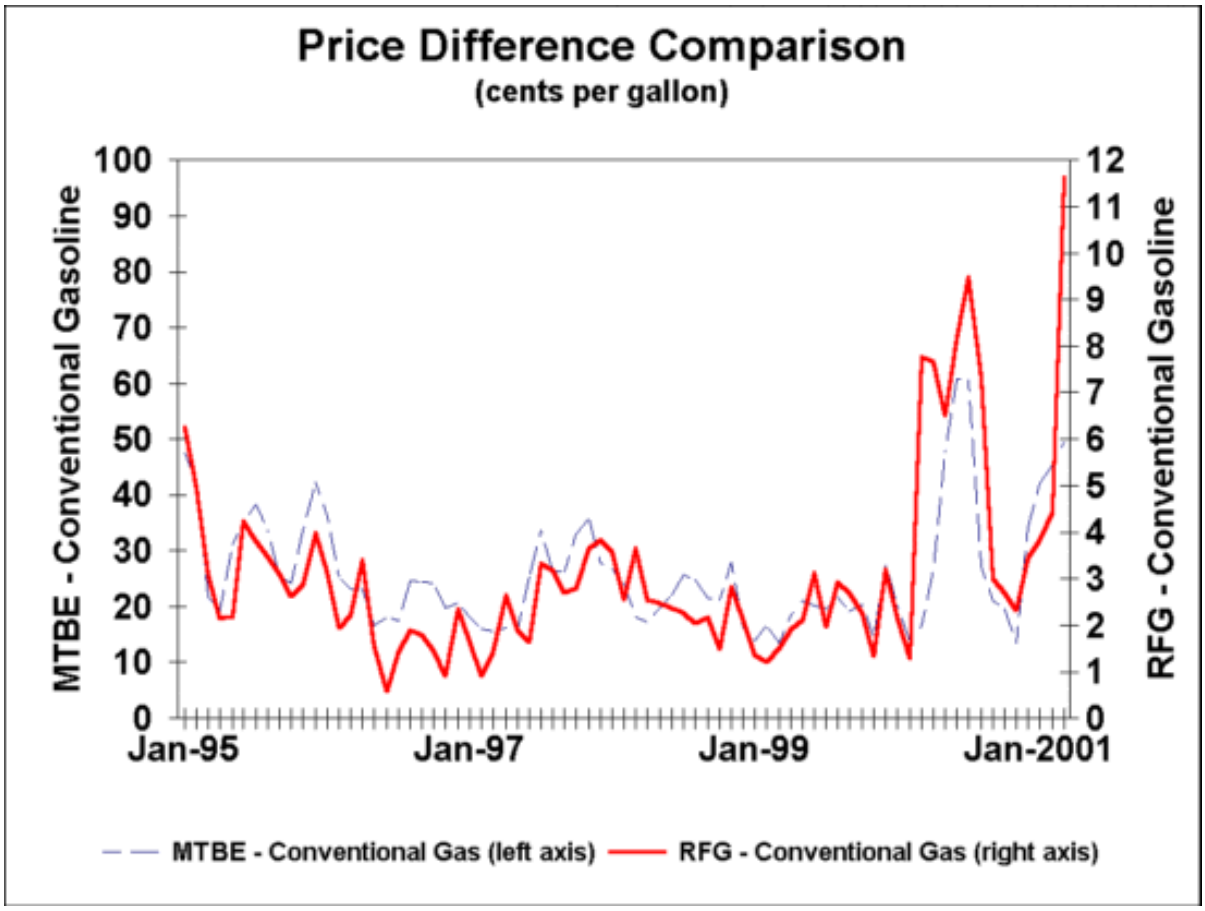
3. Relationship between price of MTBE and Reformulated Gasoline

RFG, which makes up about 1/3 of total domestic gasoline demand, requires the blending of an oxygenate such as ethanol (about 5.7 percent by volume) or MTBE (about 11.5 percent by volume). MTBE generally represents the marginal source of oxygenate for RFG blending, particularly during the summer months. The price premium for RFG over conventional gasoline, which does not require oxygenates, is directly related to the price premium for MTBE over conventional gasoline (in the U.S. Gulf Coast waterborne market).

Regression analysis indicates the observed price premium for RFG over conventional gasoline is consistent with that expected from the price difference between MTBE and conventional gasoline. A $0.10 per gallon increase in the price of MTBE is estimated to raise the price for RFG over conventional unleaded gasoline by $0.012 per gallon (refer to *Regression Results* for full results, and *Data Sources* for data definitions and sources). This relationship is illustrated in Figure 3. The actual price premium for RFG was higher than predicted during the summer of 2000 because of the additional costs of producing Phase 2 RFG.[(4)]

Figure 3. MTBE and RFG Price Premiums Over Conventional Gasoline, January 1995 - March 2001



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4. Influence of Natural Gas Prices on the Gasoline Market

One of the issues in the most recent MTBE price increase is the contribution made by the rise in the natural gas price this past winter. The price of natural gas to electric utilities increased from an average $5.60 per million Btu in November 2000, to $8.93 per million Btu in January 2001, while the price of MTBE rose from $1.00 to $1.28 per gallon over that period. The analysis below investigates the relationship between the natural gas price and normal butane and methanol prices.

Normal Butane

The relationship between natural gas and normal butane prices is not easily determined. The price of normal butane is most influenced by demand-side rather than supply-side factors. Normal butane is a naturally occurring hydrocarbon present in both crude oil and wet natural gas and supply is relatively price inelastic. The marginal sources of demand for normal butane are motor gasoline blending and as feedstock to ethylene production plants.

As the price of motor gasoline increases then the price of normal butane rises. As the prices of alternative feedstocks to ethylene production (e.g., ethane and propane) increase then the price of normal butane rises. When the price of motor gasoline is high relative to the price of natural gas, the value of normal butane for gasoline blending dominates. When the price of natural gas is high relative to motor gasoline, then the value of normal butane for ethylene production may dominate.

A simple regression analysis indicates that a $1 per million Btu increase in the price of natural gas to electric utilities is associated with a $0.052 per gallon increase in the price of normal butane (refer to *Regression Results* for full results, and *Data Sources* for data definitions and sources):

Normal Butane Price = - 1.324
(cents per gallon)
+ 0.546 * Conventional Gasoline Price (cents per gallon)
+ 5.157 * Natural Gas Price (dollars per million Btu)
+ monthly dummy variables

This estimated relationship between the normal butane price and the natural gas price is less than would be expected if butane was consistently priced at its heating value. Normal butane has a net heating value of 93,201 Btu per gallon. Consequently, a $1 per million Btu increase in heating fuel costs would be equivalent to a 9.3 cents per gallon increase in the price of normal butane.

Methanol

Methanol is produced from natural gas. A $1 per million Btu increase in the price of natural gas to electric utilities is estimated to increase the price of methanol by $0.099 per gallon (Table 2) (refer to *Regression Results* for full results, and *Data Sources* for data definitions and sources).

Table 2. Methanol Production Yields
Btu per 1 gallon Methanol

	Natural Gas
Theoretical Yield (1)	64,000 - 71,000
Published Yield (2)	84,000
Regression Estimate (3)	99,000

Methane + Water —> Methanol + Hydrogen

$2\ CH_4 + H_2O \longrightarrow 2\ CH_3OH + H_2$

Ethane + Water —> Methanol + Hydrogen

$C_2H_6 + 2\ H_2O \longrightarrow 2\ CH_3OH + H_2$

Notes:

1. Range is for methane (71,000) to ethane (64,000)
2. Includes gas used for process heat. Gulf Publishing Co., *Hydrocarbon Processing*, Petrochemical Processes annual issue, Houston, TX.
3. Regression of Methanol price (cents per gallon) against price of Natural Gas ($ per million Btu) over the period Jan. 1997 through Dec. 2000: Methanol Price = 15.79 + 0.099 * Natural Gas Price

The price of methanol can be significantly affected by constraints in production capacity. There are 18 methanol production plants in the United States. The unplanned shutdown of one of the larger plants can reduce available domestic production capacity by as much as 16%.[(5)]

Reformulated Gasoline

Given the above estimated relationships, a $1 per million Btu increase in the price of natural gas increases the cost of producing MTBE by 9.4 cents per gallon, and raises the price premium for RFG over conventional gasoline by 1.2 cents per gallon.

Change in Price of Natural Gas	->	Change in Price of Methanol	->	Change in Price of MTBE
$ 1 / million Btu		$ 0.10 / gallon		$ 0.039 / gallon

Change in Price of MTBE	->	Change in Price of RFG
$ 0.094 / gallon		$ 0.012 / gallon

Change in Price of Natural Gas	->	Change in Price of Normal Butane	->	Change in Price of MTBE
$ 1 / million Btu		$ 0.052 / gallon		$ 0.055 / gallon

Regression Results

Table 3. MTBE Spot Price (cents per gallon)

Independent Variable	Estimated Coefficient	't' Statistic	Units
Intercept	20.17	1.54	
Normal Butane Price	0.989	6.05	Cents per gallon
Methanol Price	0.387	2.65	Cents per gallon
Method of estimation: Ordinary Least Squares R-Square = 0.696 Estimation period: January 1997 through January 2001 (monthly average prices)			

Table 4. RFG Price Premium (cents per gallon)

Independent Variable	Estimated Coefficient	't' Statistic	Units
Intercept	- 0.19	- 0.15	
MTBE Price Premium	0.124	8.43	Cents per gallon
Method of estimation: Ordinary Least Squares R-Square = 0.500 Estimation period: January 1995 through January 2001 (monthly average prices) Price premiums relative to conventional regular gasoline			

Table 5. Normal Butane Price (cents per gallon)

Independent Variable	Estimated Coefficient	't' Statistic	Units
Intercept	- 1.324	- 0.26	
Conventional Gasoline Price	0.546	12.6	Cents per gallon
Natural Gas Price	5.157	3.71	Dollars per million Btu
Jan	- 0.635	- 0.32	=1 if January, 0 otherwise
Feb	- 1.02	- 0.51	=1 if February, 0 otherwise
Mar	- 3.40	- 1.62	=1 if March, 0 otherwise
Apr	- 6.95	- 3.22	=1 if April, 0 otherwise
May	- 7.95	- 3.65	=1 if May, 0 otherwise
Jun	- 6.16	- 2.86	=1 if June, 0 otherwise
Jul	- 5.39	- 2.51	=1 if July, 0 otherwise
Aug	- 4.08	- 1.89	=1 if August, 0 otherwise
Sep	- 1.69	- 0.79	=1 if September, 0 otherwise
Oct	- 1.37	- 0.65	=1 if October, 0 otherwise
Nov	- 0.54	- 0.26	=1 if November, 0 otherwise

Method of estimation: Ordinary Least Squares
R-Square = 0.618
Estimation period: January 1986 through January 2001 (monthly average prices)

Table 6. Methanol Price (cents per gallon)

Independent Variable	Estimated Coefficient	't' Statistic	Units
Intercept	15.79	1.22	
Natural Gas Price	0.099	5.68	Dollars per million Btu

Method of estimation: Ordinary Least Squares
R-Square = 0.412
Estimation period: January 1997 through January 2001 (monthly average prices)

Data Sources

Product	Description	Source
Reformulated Gasoline Price	U.S. Gulf Coast Spot Waterborne	McGraw-Hill, *Platts Oilgram Price Report*, Price Average Supplement
Conventional Gasoline Price	U.S. Gulf Coast Spot Waterborne	McGraw-Hill, *Platts Oilgram Price Report*, Price Average Supplement
MTBE Price	U.S. Gulf Coast Spot Waterborne	McGraw-Hill, *Platts Oilgram Price Report*, Price Average Supplement
Normal Butane Price	Spot Gas Liquids, Month Belvieu	McGraw-Hill, *Platts Oilgram Price Report*, Price Average Supplement
Methanol Price	U.S. Gulf Coast Spot	Hart *Oxy-Fuel News*
Natural Gas Price	U.S. Average to Electric Utilities	EIA, *Electric Power Monthly*, Table 26 (DOE/EIA-0226) http://www.eia.gov/cneaf/electricity/epm/epm_sum.html

End Notes

1. For an analysis of MTBE economics through 1999 refer to: U.S. International Trade Commission, "Methyl Tertiary-Butyl Ether (MTBE): Conditions Affecting the Domestic Industry," (Publication 3231) Washington, DC, September 1999, http://www.usitc.gov/publications/docs/pubs/332/pub3231.pdf.

2. MTBE production rates: Energy Information Administration, *Weekly Petroleum Status Report* (DOE/EIA-0208) Washington, DC,

http://www.eia.gov/oil_gas/petroleum/data_publications/monthly_oxygenate_telephone_report/motr.html.

3. California Energy Commission, "Supply and Cost Alternatives to MTBE in Gasoline," (P300-98-013) Sacramento, CA, February 1999, http://www.arb.ca.gov/regact/carfg3/appp.pdf.

4. For an analysis of the cost of producing Phase 2 RFG refer to: Tancred Lidderdale and Aileen Bohn, "Demand and Price Outlook for Phase 2 Reformulated Gasoline, 2000," Washington, DC, August 1999, http://www.eia.gov/forecasts/steo/special/pdfl/rfg4.pdf.

5. American Methanol Institute, *World Methanol Plants*, December 1999, http://www.methanol.org/methanol/fact/wmethplants.html

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