

Bio-ETBE

- Highest Refinery LP Value
- Most Effective Biofuel Carrier
- Leading Alternative Energy Provider
- Maximizes Gasoline Production + Refinery Yield
- Lowest Carbon Footprint + Advanced Biofuel Benefits
- Extends Crude Oil Supplies
- Improves Environment - Lowering Emissions
- Leverages Renewable Ethanol Attributes
- Fully compatible with Petroleum Infrastructure
- Adds more Value than MTBE
- High Commercial Use in Europe + Japan
- Available Today!

California Energy Commission

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11-ALT-1

TN # 66889

AUG 17 2012

Bio-ETBE: The Right Road to High Quality 21st Century Motor Fuels



A supplement to

FUEL

Unique in Delivering Maximum Energy + Environmental Benefits

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Testimonials: Bio-ETBE Providing Quality and Value Worldwide

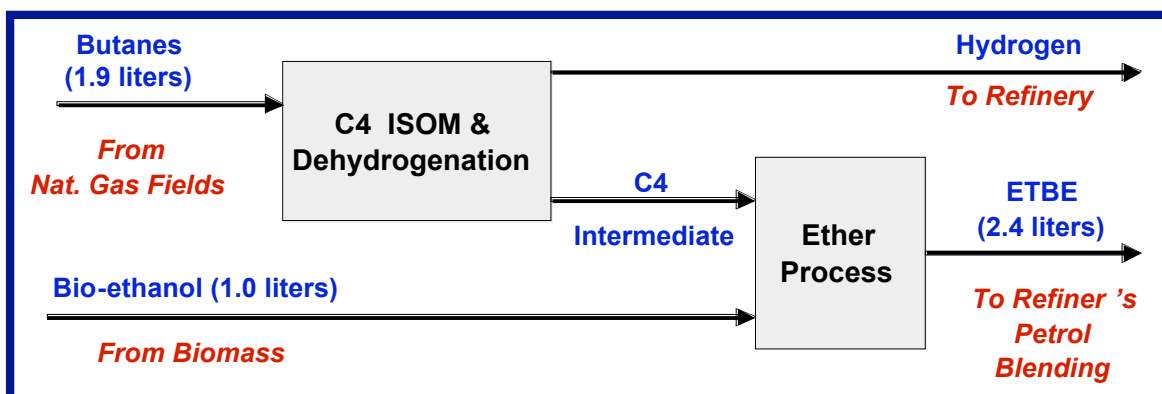
Bio-ETBE: The Right Road to High Quality 21st Century Motor Fuels
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Understanding How Bio-ETBE is Made



Raw Material Building Blocks: Bio-Ethanol and NGL's

Modern Ether Process Combines Renewable Ethanol and Butanes
To Make More Valuable Motor Fuel Products



Source: CDTECH Process Technology - Houston, Texas USA

Modern ether process facilities combine Bio-Ethanol and butane to make a high value, fungible (easy to use) product that can be blended into bulk petrol at the refinery without any additional refinery processing or capital investment. A side benefit of the dehydrogenation ETBE process is the production of high value hydrogen for use in refinery processing. Hydrogen aids in supporting refinery processing requirements such as gasoline and diesel sulfur reduction to reduce emissions.

Bio-ETBE Extends Motor Fuel Supplies, and Enhances Gasoline Properties



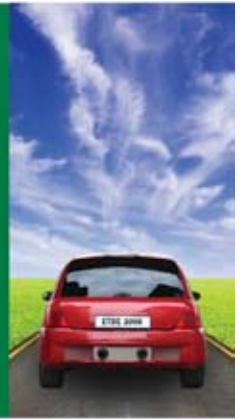
Bio-ETBE: Gasoline Supply Extender that Enhances Gasoline Properties

Performance Properties of High Octane Components for Petrol

		N-Butane	Ethanol	MTBE	ETBE	M-Xylene	EU Petrol Premium	
<i>Raw Energy Source</i>		<i>Nat. Gas</i>	<i>Biomass</i>	<i>Nat. Gas</i>	<i>Biomass & Nat. Gas</i>	<i>Petroleum</i>	<i>Petroleum</i>	
Octane	RON	94	130	119	120	117	95	min
	MON	91	96	101	102	101	85	min
	(R+M)/2	92.5	113	110	111	109	90	
RVP	kPa	379	138	54	28	3	60	Summer max
	psi	55	20	7.8	4	0.4	8.7	
Boiling Point	°C	0	78	55	72	139	70	min @ 48 V% max
	°F	31	173	131	161	282	158	
Oxygen	Wt. %	0	34.8	18.2	15.7	0	2.7	max
Specific Gravity	SG	0.5836	0.7937	0.7433	0.7445	0.8686	0.7445	typical

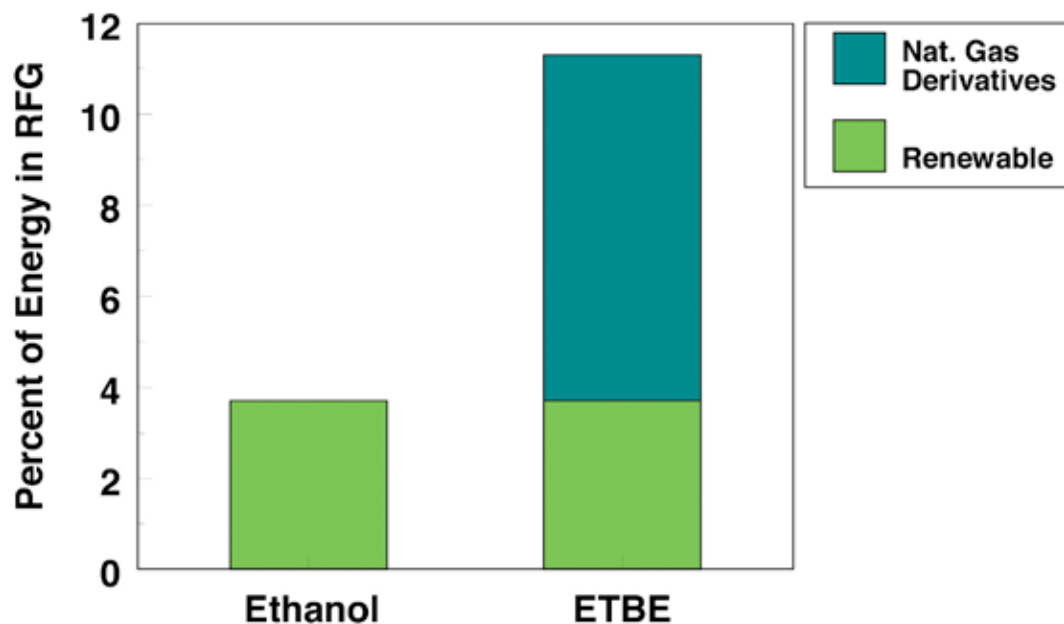
The above Table shows the key blending properties of the fuel components for the refiner to add octane to European petrol, and global gasoline supplies. Of all the non-petroleum options, Bio-ETBE provides the lowest RVP (vapor pressure) and the highest motor octane. When comparing all the clean burning fuel oxygenates, ETBE has the lowest oxygen content, and highest BTU value. These key properties allow the Refiner to blend the greatest amount of oxygenate volume before reaching the oxygen limit in European petrol, or global gasoline supplies. Therefore, Bio-ETBE displaces the greatest amount of crude oil energy processed to manufacture global gasoline supplies.

Improved Energy Security by Reducing Crude Oil Use



Bio-ETBE Uniquely Uses Clean Bio-Energy and NGL Energy Sources

ETBE Enhances Ethanol's Alternative Energy Contribution
for 5 Volume Percent Ethanol in European Petrol, and Global Gasoline



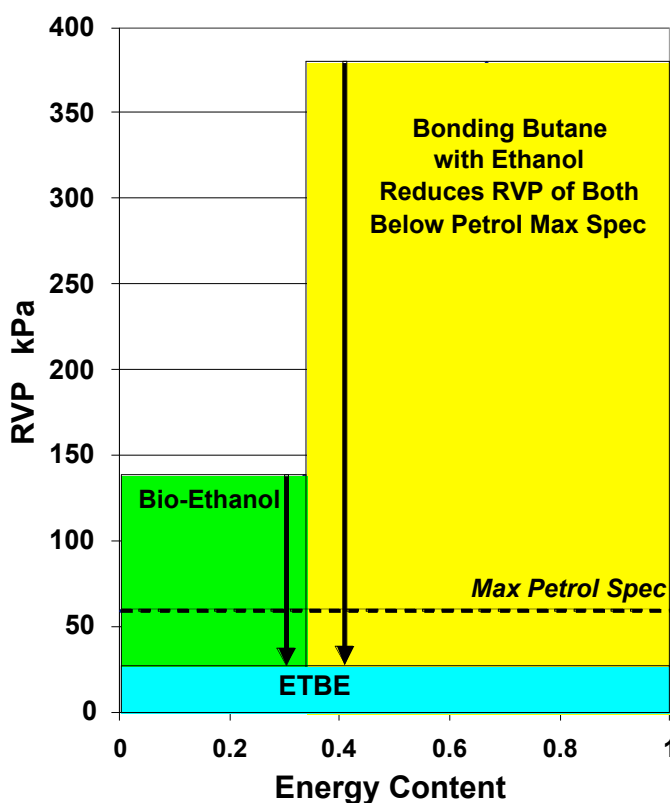
By combining clean burning butane feedstocks derived from natural gas supplies (NGL's) with Bio-Ethanol, ETBE provides nearly triple the alternative energy production than directly blending 5 percent ethanol into petrol blends. Therefore, Bio-ETBE can not only supply the same amount of bio-energy as ethanol, but will diversify transportation fuel energy supplies even further by including more clean burning butane feedstock -- and low greenhouse gas (GHG) energy from abundant natural gas resources.

Lowers Cost of Fuel Production and Expands Refinery Flexibility



Bio-ETBE Maximizes Low Cost Butanes (NGLs) & Renewable Ethanol in Petrol

ETBE's Low RVP and High Octane Provides Highest Value in Gasoline



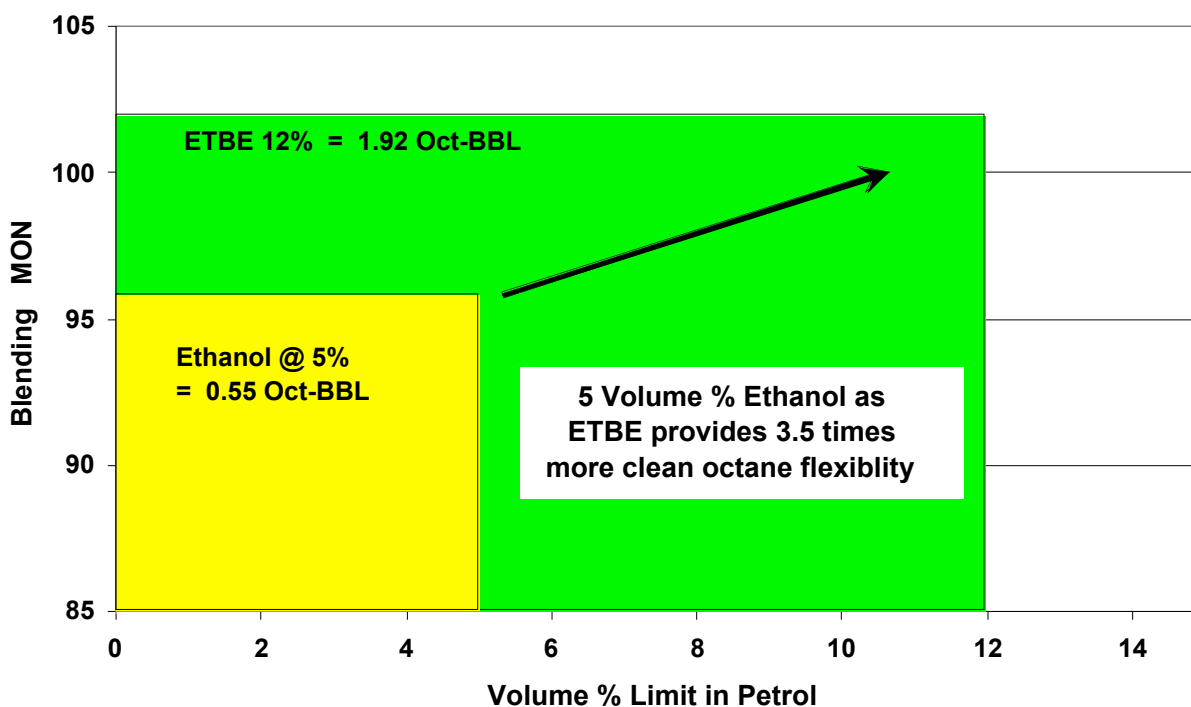
As illustrated in the above chart, chemically bonding renewable ethanol to low cost butane to make Bio-ETBE provides a significant benefit in reducing the relative high blending RVP's of both motor fuel components. Bio-ETBE is a clean product whose low RVP is much less than the RVP specification for summer grade petrol. In addition, the Bio-ETBE supplies about two-thirds of its energy from clean burning, low GHG butanes.

Lowest Cost of Fuel Production and Expands Refinery Flexibility



Bio-ETBE's Low RVP and High Octane Provides Highest Value in Gasoline

Potential Octane Contribution to Petrol Pool Under 5% Bio-Ethanol Options



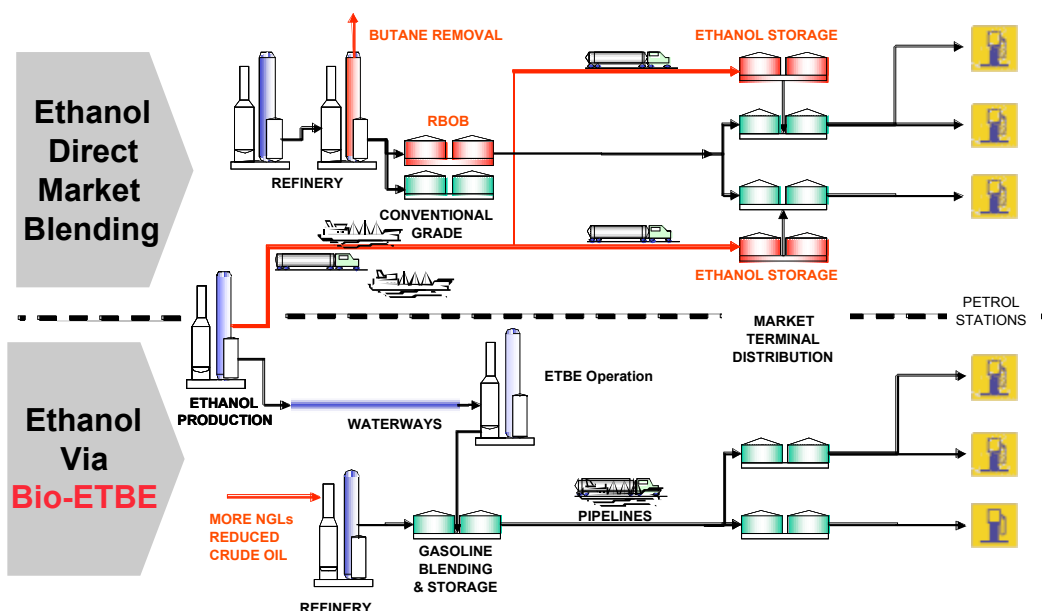
As illustrated in the above chart, Bio-ETBE increases both the volume and the octane contribution in the Petrol product. Bio-ETBE provides the Refiner with more flexibility to reduce processing energy consumption in the refinery -- which otherwise would be necessary to produce higher octane, and requires the further processing of crude oil feedstocks.

Lowers Cost of Fuel Production and Expands Refinery Flexibility



Fungible Properties Reduce Logistical Costs of Supplying Alternative Energy

Bio-ETBE Utilizes Existing Bulk Distribution Infrastructure for Petrol
Ethanol Blending in Market Requires Segregated Distribution & Storage



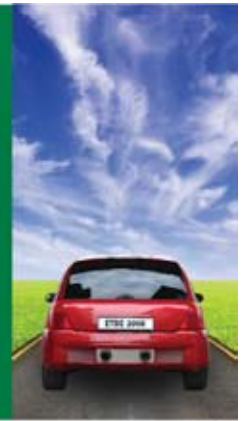
Bio-ETBE's easy and fungible handling properties allow this form of renewable ethanol to be shipped efficiently in large volumes over the water directly to the refinery where it can be easily blended into bulk batches of petrol. Just like gasoline, Bio-ETBE petrol blends are then easily transported in the highly efficient petrol product distribution system to the individual petrol terminals and petrol stations.

Using the Bio-ETBE pathway allows the renewable ethanol to be blended in 400,000 liter increments (approximately 110,000 gallons) into petrol at a relatively small number of Refineries. The alternative option of direct ethanol blending requires that ethanol be first shipped to many product terminals in relatively small truck volumes, and stored in separate tanks where the ethanol is then blended in small 2000 liter increments into each truck which is delivering petrol to the retail petrol stations.

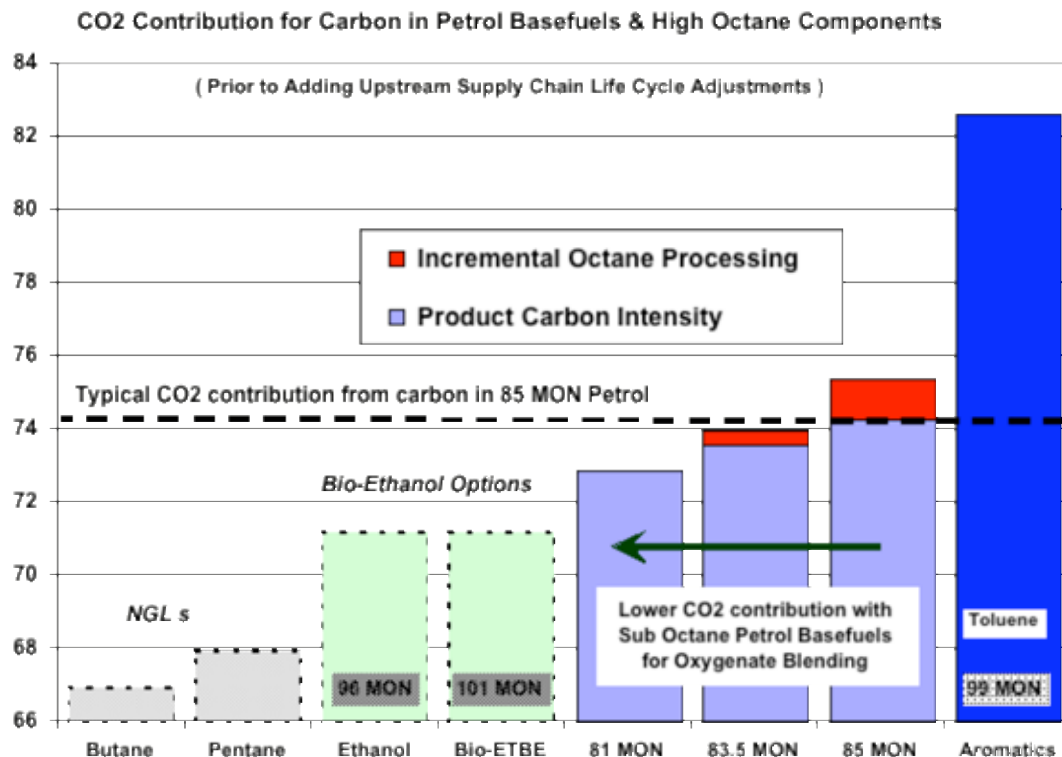
Bio-ETBE offers a broad element of logistical efficiency for renewable ethanol use in motor fuels.

Bio-ETBE: The Right Road to High Quality 21st Century Motor Fuels
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Bio-ETBE Provides More Greenhouse Gas Reductions

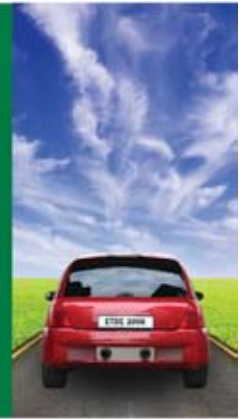


Enhances Carbon Footprint of Ethanol & Offers *Advanced Biofuel* Benefits



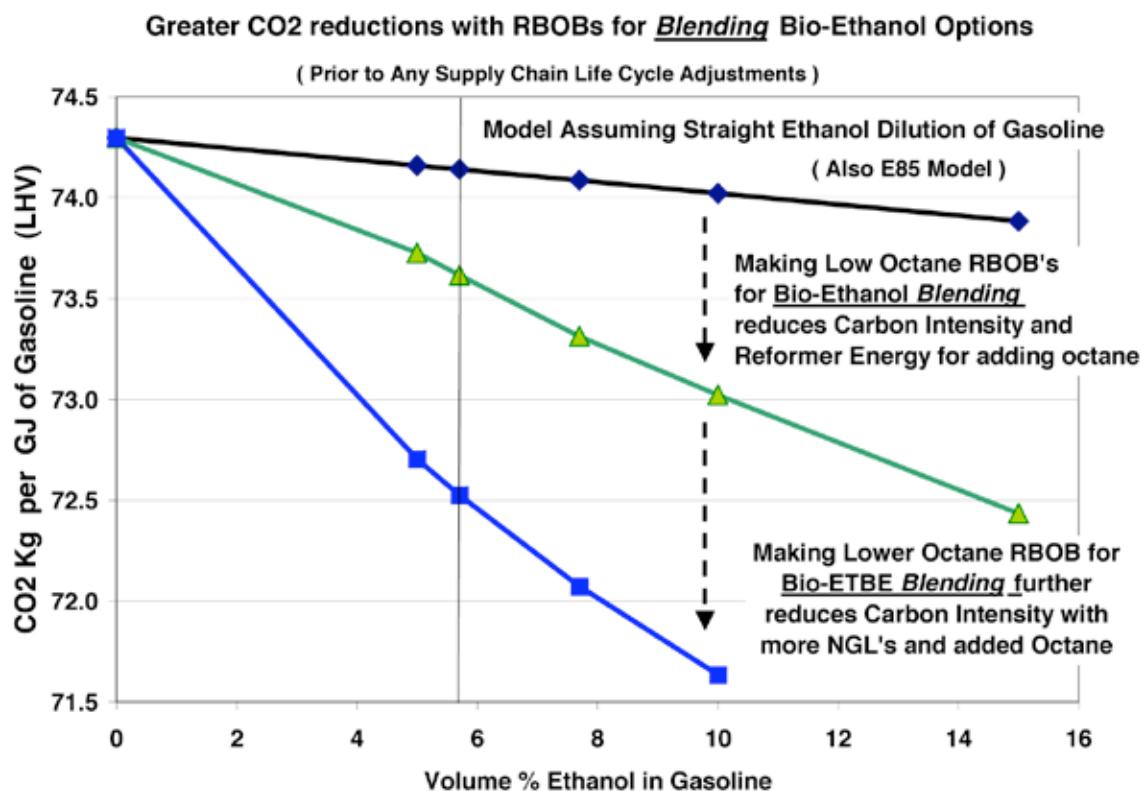
On an equal Bio-Ethanol content basis, Bio-ETBE delivers three times as much clean octane for replacing aromatics (high carbon intensity), and two and 1/2 times more low carbon energy as direct ethanol blending. Bio-ETBE allows the refinery to substantially reduce the carbon intensity of the hydrocarbon energy in the petrol. The higher contribution of the carbon-efficient energy from Bio-ETBE further reduces CO₂ emissions in the refinery supply chain, by decreasing crude oil use, and lowering refinery energy consumption for crude oil processing and octane production.

Bio-ETBE Provides More Greenhouse Gas Reductions



Fungible High Octane Provides More Refinery Energy Reductions

By using Bio-ETBE, a refiner uses less refinery fuel when producing finished petrol than when directly blending ethanol instead. This improved energy resulting from Bio-ETBE efficiency naturally means less CO₂ emissions. Bio-ETBE typically offers an additional savings of 24kg of CO₂-equivalent/GJ of ethanol. Bio-ETBE is the most environmentally friendly GHG route to blend ethanol in European petrol and global motor gasoline supplies.

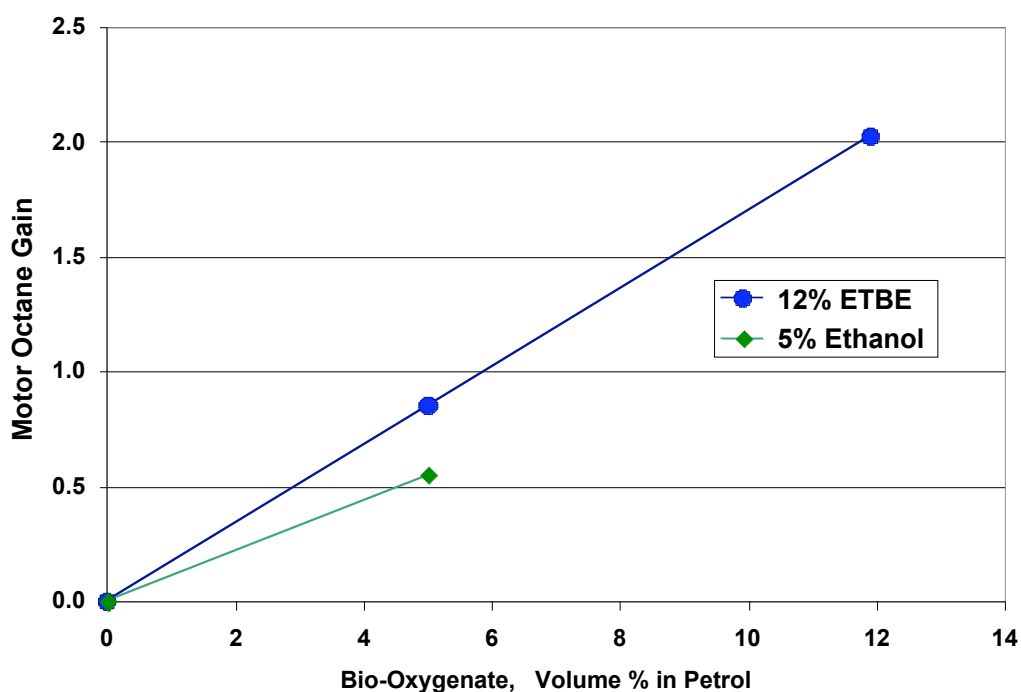


Bio-ETBE Enhances Environmental Performance of Gasoline



Bio-ETBE Decreases Aromatic Content of Motor Gasoline

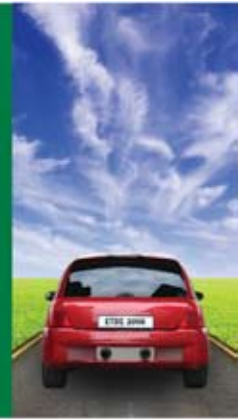
Octane Gain for 5 Volume % Ethanol Equivalent in Petrol



On a renewable ethanol volume equivalent basis, Bio-ETBE provides at least three times more clean-burning octane than the alternative option of directly blending ethanol. Therefore, using Bio-ETBE for meeting global government biofuel requirements should replace about three times more aromatics in the European petrol and global gasoline pool.

Reducing aromatic content reduces exhaust emissions of VOC, CO, NO_x and air toxics. Additionally, Bio-ETBE also contributes to reducing particulate matter (PM) and secondary aerosols. Bio-ETBE also lowers the carbon energy intensity of the hydrocarbon base fuel of the petrol -- as Lower octane is needed from crude oil processing at the Refinery manufacturing source.

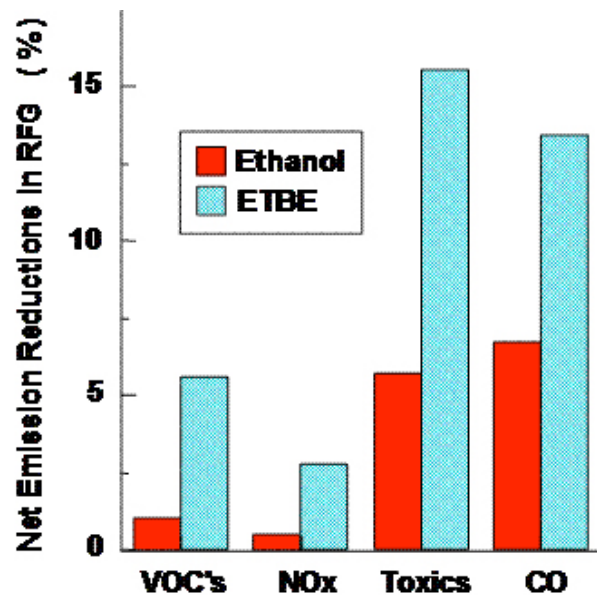
Bio-ETBE Enhances Environmental Performance of Gasoline



Bio-ETBE Provides Large Contribution to Lowering Emissions

Carbon Monoxide, Hydrocarbons and Air Toxics

Exhaust Emission Reductions Greater with Bio-ETBE
For 5 volume percent Ethanol Fuel Blends



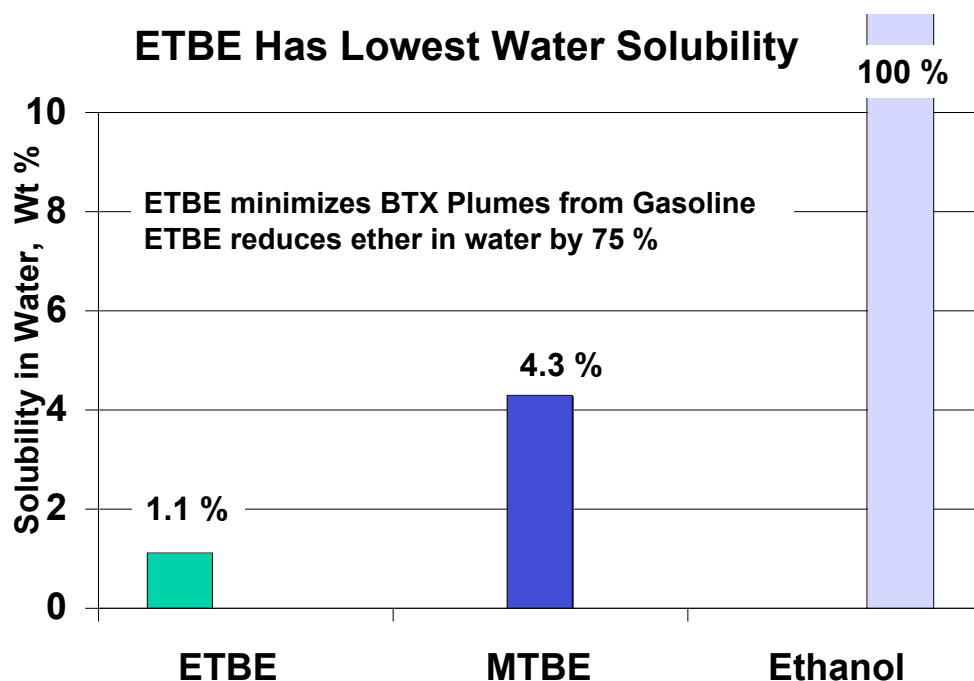
Petrol and gasoline fuel blends made with the Bio-ETBE equivalent of 5 volume percent renewable ethanol provide more than twice the exhaust emission reductions than direct ethanol blending - as predicted by the U.S. EPA's Complex Model for Estimated Emissions from Reformulated Gasoline (RFG) Fuel Blends.

Emissions offered by blending 12-13 volume percent Bio-ETBE in motor gasoline reduce VOCs by 6%, NOx by 2%, Air Toxics by 17% and Carbon Monoxide by 13%. (See above.)

Bio-ETBE Lowers Environmental Risks from Hydrocarbons



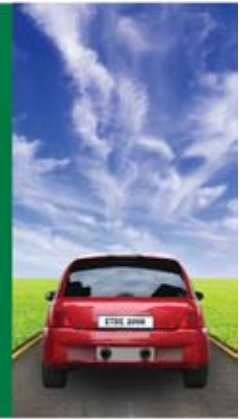
Low RVP and Water Solubility Reduces Releases to Environment



The RVP's on the previous properties chart (See page 6) show Bio-ETBE's blending RVP to be about 1/5 that of ethanol's RVP in petrol, and lower than MTBE's RVP. The comparatively low RVP of Bio-ETBE suggests that it has a lower tendency to volatilize, or escape from the fuel blend, into the atmosphere.

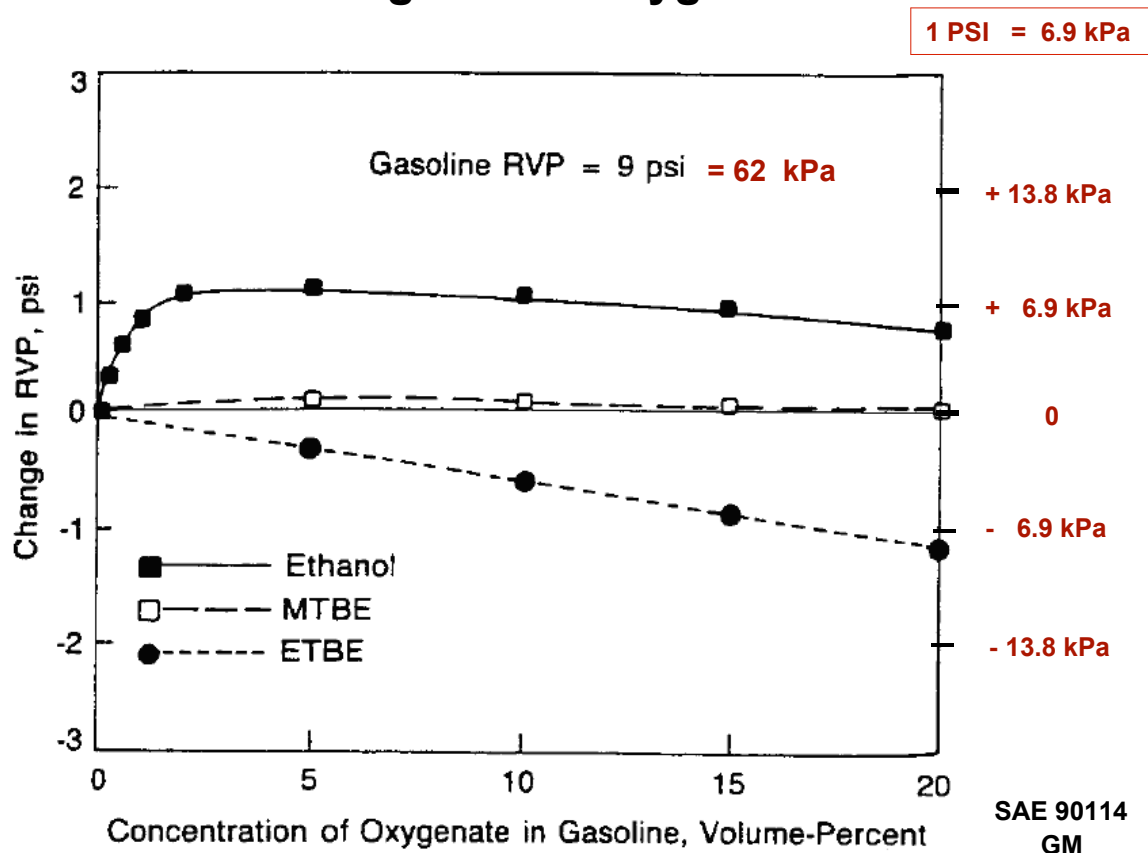
As illustrated in the above chart, Bio-ETBE also has a much lower water solubility than either MTBE or ethanol. This means that Bio-ETBE is less likely to solubilize into groundwater from a potential leak from a damaged underground petrol storage tank. Therefore, Bio-ETBE has favorable environmental properties that can minimize its release into the environment, as compared to MTBE and renewable ethanol. Bio-ETBE is also a non-benzene, non-aromatic octane enhancer.

Vehicle Performance and Lower Emissions Benefits



1. Lower Gasoline RVP Benefits Provided with Bio-ETBE

RVP Changes with Oxygenates



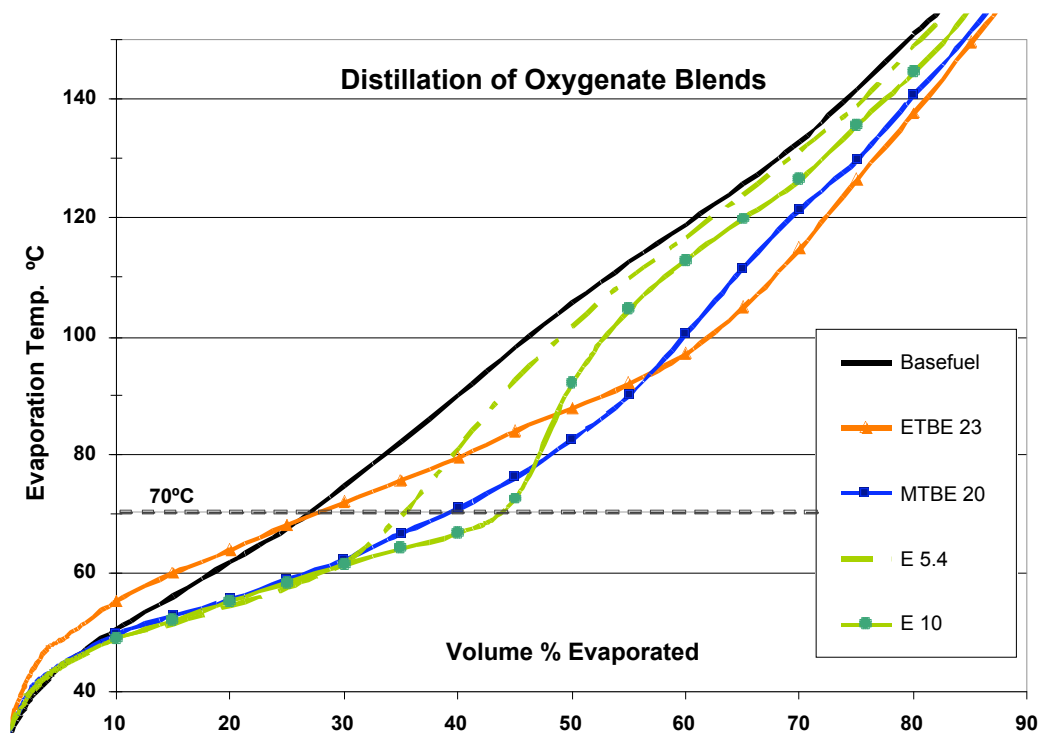
Unlike direct ethanol blending which can increase the RVP of petrol, Bio-ETBE has a lower RVP that will decrease the petrol's RVP. The lower RVP of Bio-ETBE blends will help reduce evaporative VOC emissions from the vehicles' fuel system, and as well as reduce the potential probability of drivability performance difficulties during some hot summer days.

Vehicle Performance and Lower Emissions Benefits



2. Bio-ETBE Improves Petrol Distillation Profile

Bio-ETBE Enhances Drivability Performance Properties



Unlike the direct blending of ethanol, the blending of Bio-ETBE produces no azeotropic effects on the distillation curve of petrol - which would unfavorably increase volatility. Therefore, Bio-ETBE blends into petrol in a smooth, predictable fashion - much like any other hydrocarbon that boils in the same temperature range.

Vehicle Performance and Lower Emissions Benefits



2. Bio-ETBE Improves Petrol Distillation Profile *(continued)*

The effects of Bio-ETBE and other clean burning oxygenates on the petrol distillation curve are illustrated in the above chart. The chart displays the distillation impact for three oxygenates blended at 3.7 wt.% oxygen (23 vol.% Bio-ETBE, 20 vol.% MTBE and 10 vol.% ethanol or E 10) as well as a 5.4 vol.% ethanol blend or E 5.4 (2wt.% oxygen). Of all the distillation specifications for petrol, the volume percent evaporative at 70°C (Evap @ 70°C) is probably the most significant since it has such a large impact on a number of factors such as:

- Vehicle Operating Performance (hot vapor locking)
- Evaporative emission performance

Bio-ETBE adds to the refiner petrol blending flexibility to utilize other non-petroleum components such as light naphthas from natural gas condensates which also contain large amounts of hydrocarbons that boil below 70°C.

As illustrated in the previous chart, the various oxygenates differ significantly in their impact on the volume percent evaporated at 70°C. Because of the proximity of its boiling point temperature (72°C) to 70°C, blending large amounts of Bio-ETBE has little or no impact on the Evap @ 70°C. Most of Bio-ETBE's temperature decrease for petrol occurs near the mid-range portion of the distillation curve. Bio-ETBE should improve vehicle warm-up during cold engine operation -- without any other corresponding unfavorable impact on hot drivability performance of the gasoline.

Vehicle Performance and Lower Emissions Benefits



3. Lower Vapor Generation from Petrol Components

Bio-ETBE Provides Low Vapor Volume
for Better Hot Vapor Locking Performance

	Ethanol	Butane	MTBE	ETBE	C7 Isomer
Boiling Point (C)	78	0	55	72	79
Blending RVP kPa	138	379	54	28	24
M wt	46	58	88	102	100
Vapor/Liquid @ 70C	485	283	237	205	190
Vapor Ratio to C7	2.55	1.48	1.25	1.08	1.00

← Increasing Vapor Volume During Volatization in Fuel Lines

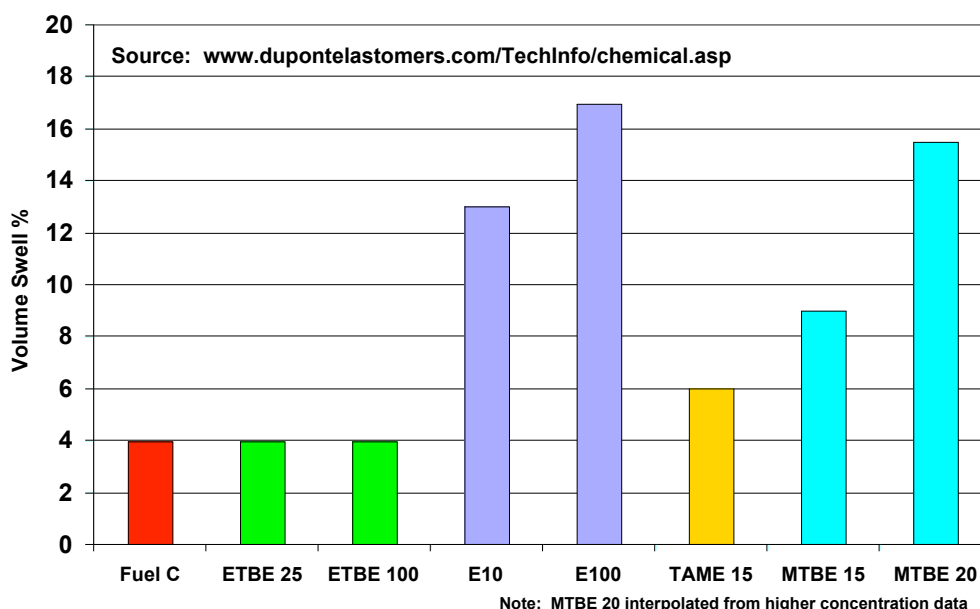
Vapor locking occurs when vapor formation in the vehicle's hot fuel lines impedes the flow of liquid fuel to the engine. The amount of vapor volume generated during vaporization can make the vapor locking situation worse. The table above shows that amount of vapor volume for vaporizing Bio-ETBE is similar to C7 hydrocarbons found in petrol. Bio-ETBE has much lower tendency than that for direct ethanol blending, by a more than a factor of two.

Vehicle Performance and Lower Emissions Benefits



4. Bio-ETBE Offers Fuel System Compatibility

VITONTM A Fluoroelastomer in Gasoline Blends and Neat Oxygenates
Volume Swell after 168 Hours @ 23°C



Sealants are a vital part of a vehicle fuel system. OEM's (Original Equipment Manufacturers) take great care to select the most appropriate elastomers. Factors such as temperature, pressure and required service life are taken into consideration, along with the nature of the fuel they will be in contact with, and the degree of that contact. Compatibility is often assessed by volume swell in long term immersion tests as the swell is related to the mechanical strength of the elastomer. In general, the greater the increase in volume swell for an elastomer, then the greater will be the loss of the elastomer properties for service in liquid sealing and permeation. While OEM's may have different criteria for different elastomers, a good rule of thumb appears to be that swells of less than 20% in the fuel solution will provide acceptable service and life.

The most recent swell data for oxygenated fuel blends are reported on DuPont's elastomer website for fluoroelastomers. The bars in the chart above illustrate elastomer swells for fuels that include MTBE, TAME, Ethanol and Bio-ETBE. In general, Bio-ETBE blends produced the lowest elastomer swell. Based on these favorable results for Bio-ETBE, DuPont recommends the use of all fluorinated elastomers for all Bio-ETBE concentrations up to 100%.

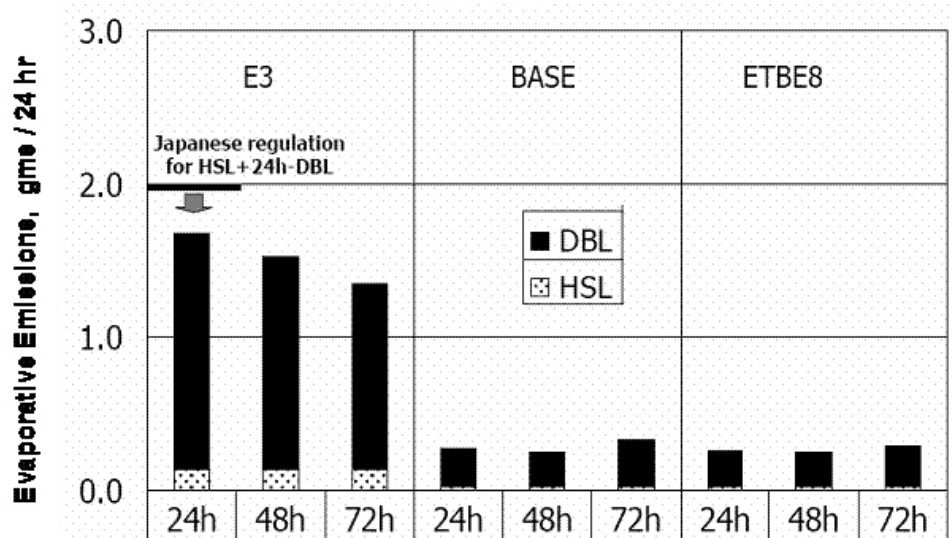
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Vehicle Performance and Lower Emissions Benefits



5. Fuel System Permeation Losses Reduced with Bio-ETBE

Lower Permeation Emissions with Bio-ETBE

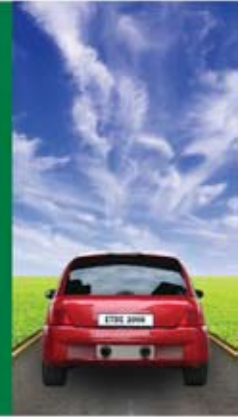


The ability of a fuel to permeate through elastomers is a strong function of its ability to swell the elastomer. Since prior data sets show that Bio-ETBE blends at all Bio-ETBE concentrations generate low or little additional elastomer swell as compared to oxygenate-free petrol base fuel, then Bio-ETBE blends would not be expected to increase fuel permeation emissions as compared to the petrol base fuel.

A Japanese research team conducted various evaporative emission tests on two Japanese vehicles using both E3 (3% ethanol in petrol) and Bio-ETBE 8% blends with matched RVPs. The study found much higher DBL (diurnal breathing losses) with the E3 blend which the authors attributed to increased fuel permeation in the elastomers after conducting a number of additional emission tests. The above chart shows that the HSL (hot soak losses) and DBL emissions for the Bio-ETBE blends compare favorably to the petrol base fuel.

Source: *Effects of Ethanol or ETBE Blending in Gasoline on Evaporative Emissions for Japanese In-Use Passenger Vehicles*, SAE 2007-01-4005, by H. Tanaka, et.al., Oct 2007

Understanding Global Bio-ETBE Use



History of Bio-ETBE Use in the United States and Other Global Markets

Beginning in 1992, Bio-ETBE was used as an avenue to provide renewable ethanol blending benefits and lower emissions in United States gasoline markets. Companies such as BP, Marathon, ARCO and AMOCO all used Bio-ETBE as an option to reduce emissions, particularly carbon monoxide and hydrocarbons during winter time oxygenated fuels programs.

After 1995, issues regarding the ability to fully utilize the Federal Tax Credit for renewable ethanol, as well as concerns about potential liability from lawsuits brought by trial lawyers in the United States served to curtail Bio-ETBE use in United States gasoline.

Nonetheless, Bio-ETBE technically remains a commercial blending option in the United States today, and offers lower greenhouse gas emissions, reduce tailpipe exhaust and efficiently delivers renewable ethanol supplies to the US motor gasoline pool.

Understanding Global Bio-ETBE Use



- Bio-ETBE Use is Increasing in Europe and Japan -

High Commercial Use in Europe Today

As one strategic option to meet the European Renewable Fuels Directive, many refiners in Europe are using volumes of Bio-ETBE to meet government requirements of increasing renewable fuel use.

In the process, European refiners are also reducing greenhouse gases, while offering the public clean motor fuel supplies to reduce tail pipe emissions of carbon monoxide, hydrocarbons and airborne toxics.

Japan Ready for Bio-ETBE Market Expansion

After several years of extensive and detailed testing, the country of Japan has now begun to utilize Bio-ETBE in certain markets as an overall effort to expand renewable ethanol supplies -- and lower greenhouse gas emissions as part of its commitment to the Kyoto Protocol.

Bio-ETBE blends are extremely compatible with refinery systems in Japan and offer lower emissions than traditional hydrocarbon gasoline supplies used in Japanese motor vehicles.

Further Bio-ETBE expansion is expected in Japan during 2009 and 2010.



Even your classic can be biofuel ready



CDTECH has the most advanced technology - CDEtbe® - to combine bio-ethanol with butenes to make ETBE, an ideal gasoline blending component.

- Gasoline blended with ETBE is compatible with all gasoline engines, including your classic car
- It's fungible with gasoline, making transportation and storage much simpler
- It can be blended at the refinery
- It lowers gasoline volatility and emissions
- And it helps refiners utilize excess C₄ olefins

*Ethanol blending made easy ...
Using ETBE process technology
from CDTECH!*

Bio-ETBE: Unique in Delivering Maximum Energy + Environmental Benefits



TESTIMONIALS

“After blending, ETBE is much more stable than ethanol, is easily fungible in gasoline, it can therefore be transported via pipeline, and needs no modification to be used in an engine. In addition, ETBE increases the octane index like ethanol and has a better calorific value whereas ethanol is more volatile and fungible in water.”

Jacques Blondy, Total, Europe

“In summary, ETBE greatly increases the base product, which allows its blending at high proportions e.g. up to 15% in gasoline, and such is the level we always use.”

Jacques Blondy, Total, Europe

“Europe is the leader in blending Bio-ETBE. The automotive manufacturers clearly prefer the ETBE route over direct blending of ethanol. ETBE behaves basically like a regular hydrocarbon. As long as the ETBE blending levels are within legal and standardized limits, there are no concerns with regard to its compatibility with the gasoline distribution infrastructure or the vehicle fuelling systems. ETBE can also offer significant emissions benefits, particularly for the older vehicle park.”

Anders Roj, Volvo Technology, and Chairman of ACEA Working Group Fuels & Lubricants

“We at Nippon Oil Research Institute recognize the positive blending characteristics of Bio-ETBE, enhancing gasoline octane while helping to satisfy the Kyoto protocol. Bio-ETBE is also fully compatible with the existing Japanese fuel distribution system.”

Michirou Matsubara, Executive Director, Nippon Oil Research Institute Co. Ltd, Japan

For all Category I, II, III, IV motor fuels in the World Wide Fuel Charter, Global Automakers say:
“When Oxygenates are Used, Ethers are Preferred.”

Official Publication, Number IV, September, 2006

“When all global refiners looked at the most efficient option to product MTBE for low emissions, more than half also licensed the Bio-ETBE option.”

John Adams, Managing Director CDTECH, 1992-2007

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