CO_2 VALUE OF BIO ETHERS

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LyondellBasell Industries

Central and Eastern European Refining and Petrochemicals 13th Annual Meeting

Budapest, Hungary
12th October 2010

World Refining Association
CLARION EVENTS

EFOA

European Fuel Oxygenates Association

WWW EFOA ORG

- **Non-profit Technical Organisation**
- **Founded in 1985**
- **~ 2/3rd of Total EU Etherification Capacity**

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CO_2: High Profile in the EU

Overall EU GHGs Emission Reduction Targets

Climate and Energy Package

2020 = 20% *(if EU Unilaterally)*

2020 = 30% *(if Global Agreement)*

Biofuels & Bioliquids' GHGs LC Emission Saving Thresholds

Directive 2009/28/EC "Renewable Energy"

2011 ≥ 35 %

2017 ≥ 50 %

2018 ≥ 60 % *(Plants ≥ 1/2/2017)*

Fuels GHGs Emission Reduction Targets *(per unit of energy)*

Directive 2009/30/EC "Fuel Quality"

2020 = 10 % *(Indicative)*

2020 ≥ 6 % *(Mandatory)*

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GHGs Emissions Reduction & Refining:
- 6% a big Challenge !

100%

Crude Production	Fuel Refining	Distribution Retail	Engine Combustion
4%	10%	1%	85%
			

15% — **Oil Ind.**

85% — **Automotive Ind.**

- 6%

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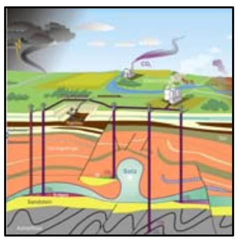
Only Few Options Available to Refiners:
Bio-fuels key !

Operations Energy Efficiency



Carbon Capturing and Storage

Bio-Fuels

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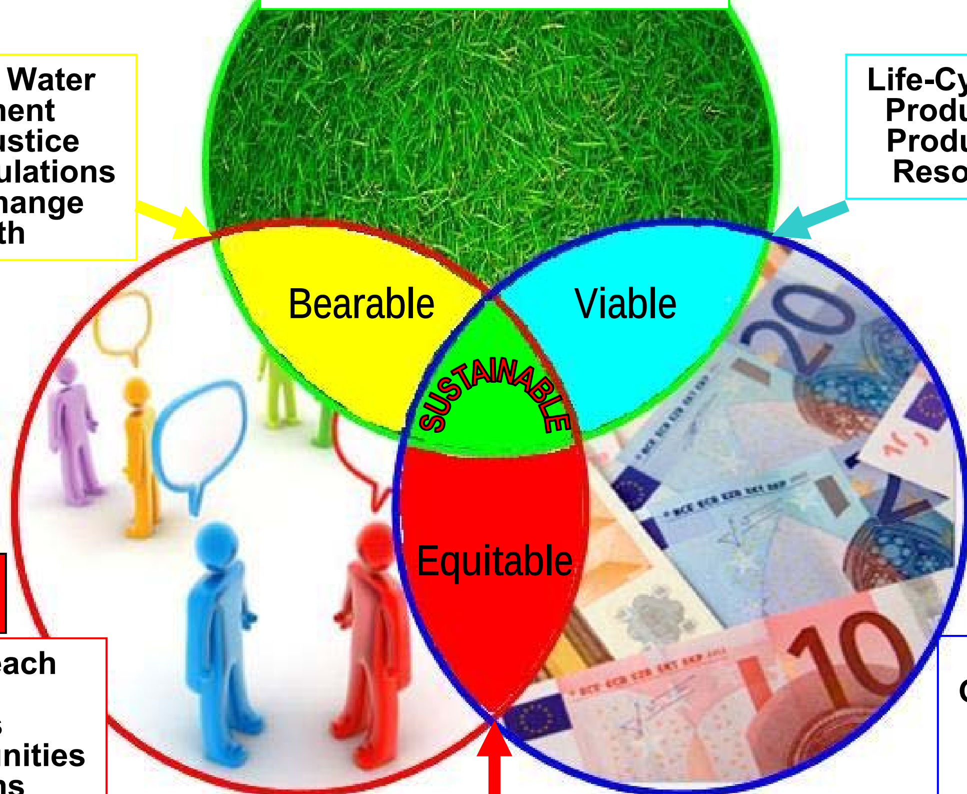
Bio-component to Address ≠ Sustainability Objectives

ENVIRONMENTAL

Clean Air, Water & Land
Emissions Reductions
No Waste, Releases & Spills
Biodiversity

Access to Potable Water
Crisis Management
Environmental Justice
Environmental Regulations
Global Climate Change
Safety & Health

Life-Cycle Management
Product Stewardship
Products to Services
Resource Efficiency



SOCIAL

Community Outreach
Diversity
Human Rights
Indigenous Communities
Labour Relations

ECONOMIC

Capital Efficiency
Growth Enhancement
Innovation
Margin Improvement
Risk Management
Shareholders Return

Business Ethics
Job Creation
Local Economic Impacts
Security
Skills Enhancement
Social Investments

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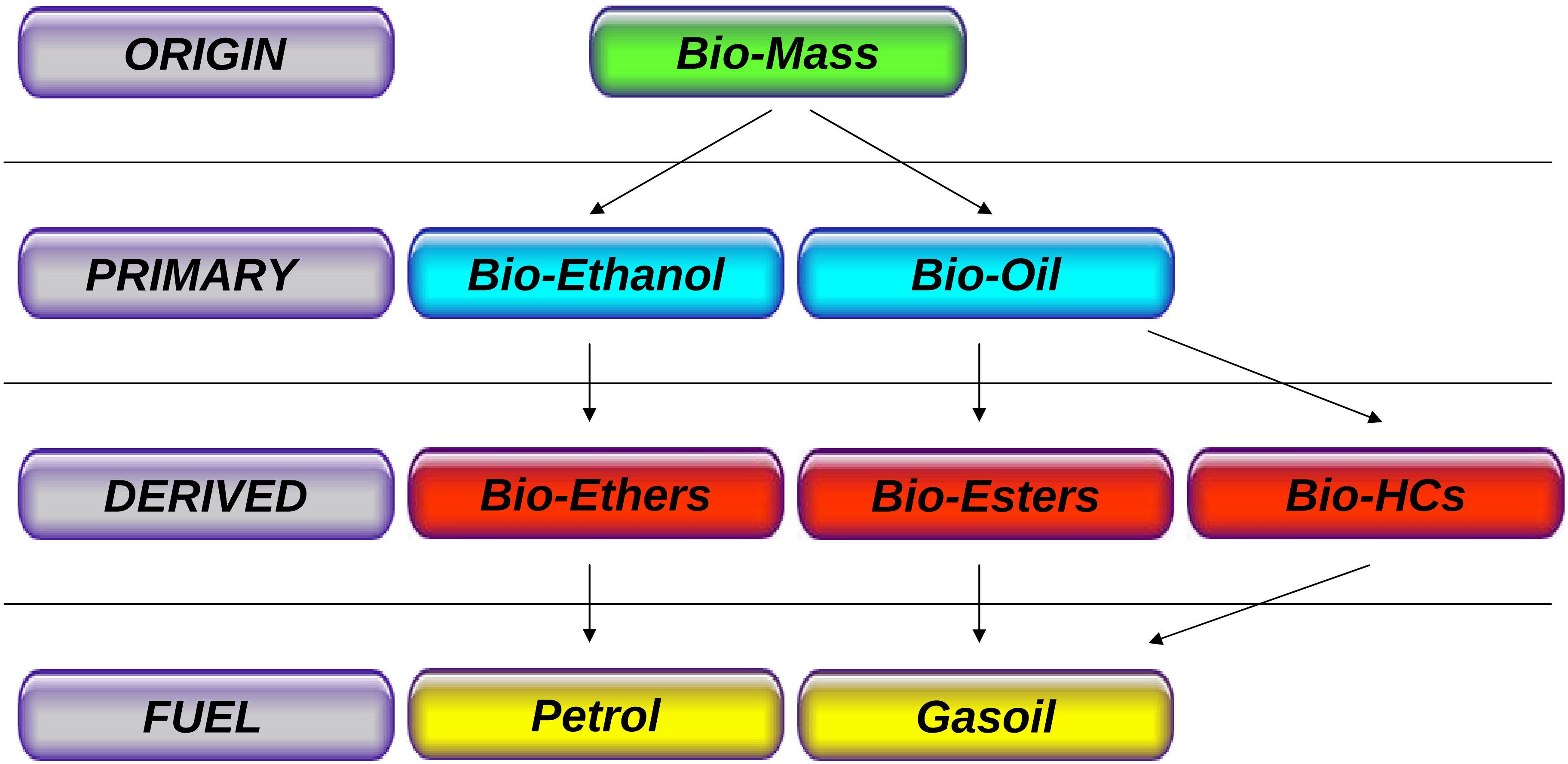
Bio-Ether (ETBE) is for Petrol what Bio-Ester (FAME) is for Gasoil



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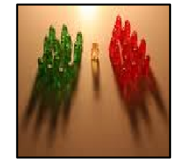
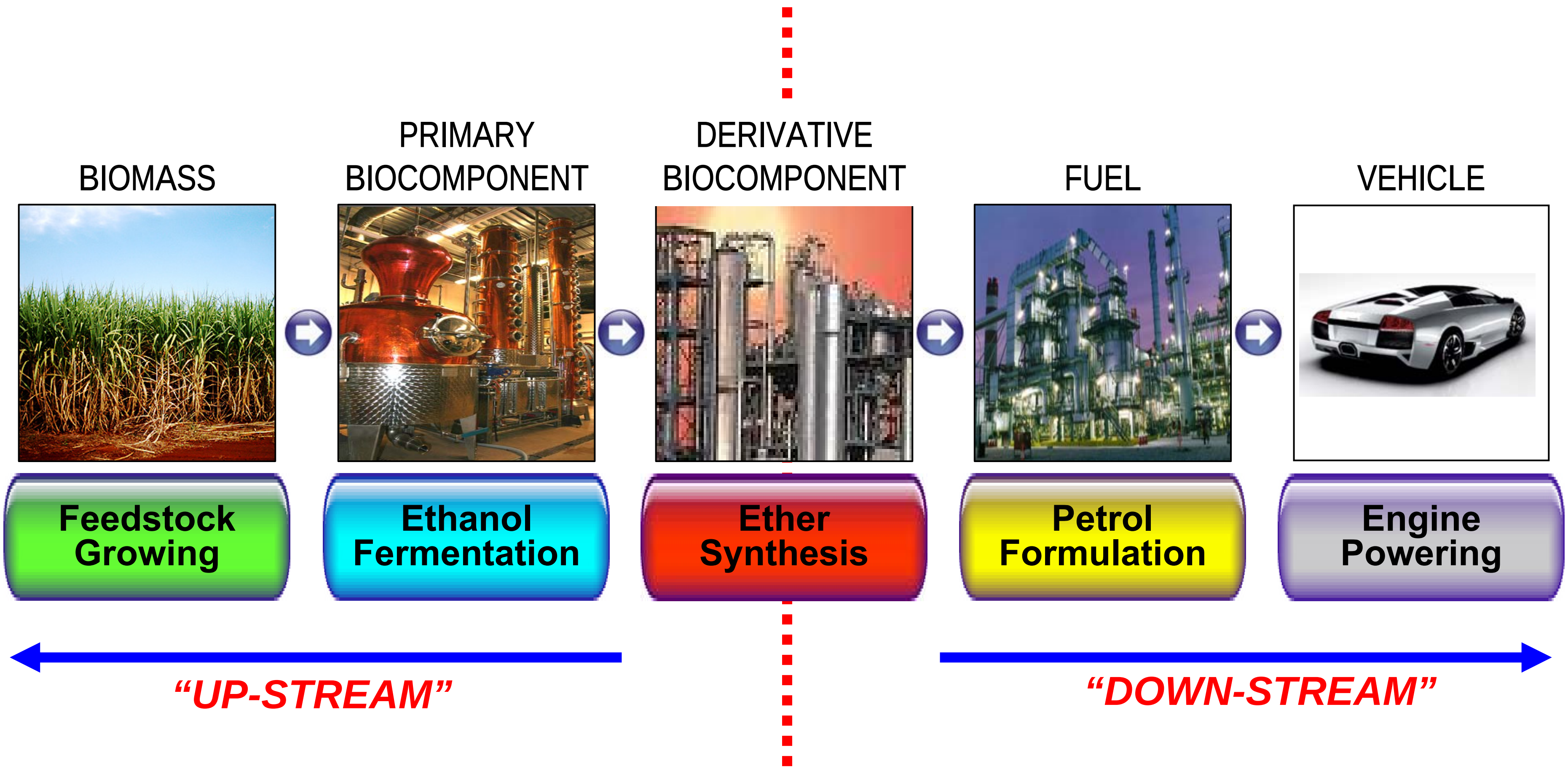
Bio-Petrol Supply Chain:
Ethers in Central Position





Bio-Ethers' "Up-stream": Embedding Ethanol "Goodness"

Ethanol → **ETBE**

Sustainable, Certified, Audited, ..
1st Generation, 2nd Gen., 3rd Gen...
Cellulosic, from Waste, …..

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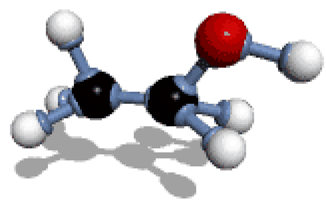
Bio-Ethers' "Down-stream": Enabling Lesser CO_2-Intensive Petrol Formulation

ETBE → ***Petrol***

High Octane
Low Volatility



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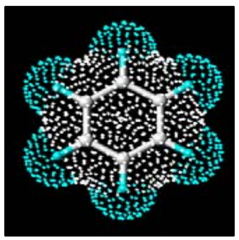
Bio-Ethers Reduce
Refinery Operations' CO_2 Emissions

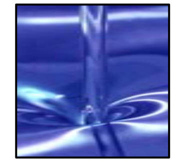
< Carbon Content



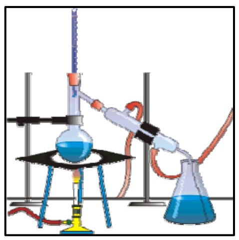
< Aromatics

< Refinery Fuel

Key Blending Properties Affecting Fuel Formulation



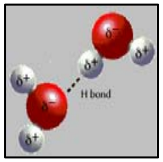
Vapour pressure



Distillation characteristics

Octane performance

ETBE: Further Enhancing ETOH Performances



< Blending Volatility

< VOCs Emissions

> Octane Barrel Delivery

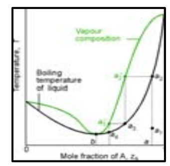
> CO_2 Emissions Reduction

> Crude-oil Replacement

No Commingling

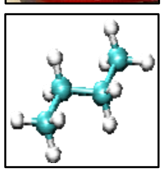
> Water Tolerance

No Azeotrope



< Logistic Complexity

> Blend-stocks Value



Butane Uptake/Upgrade

> Refining Flexibility

> Material Compatibility

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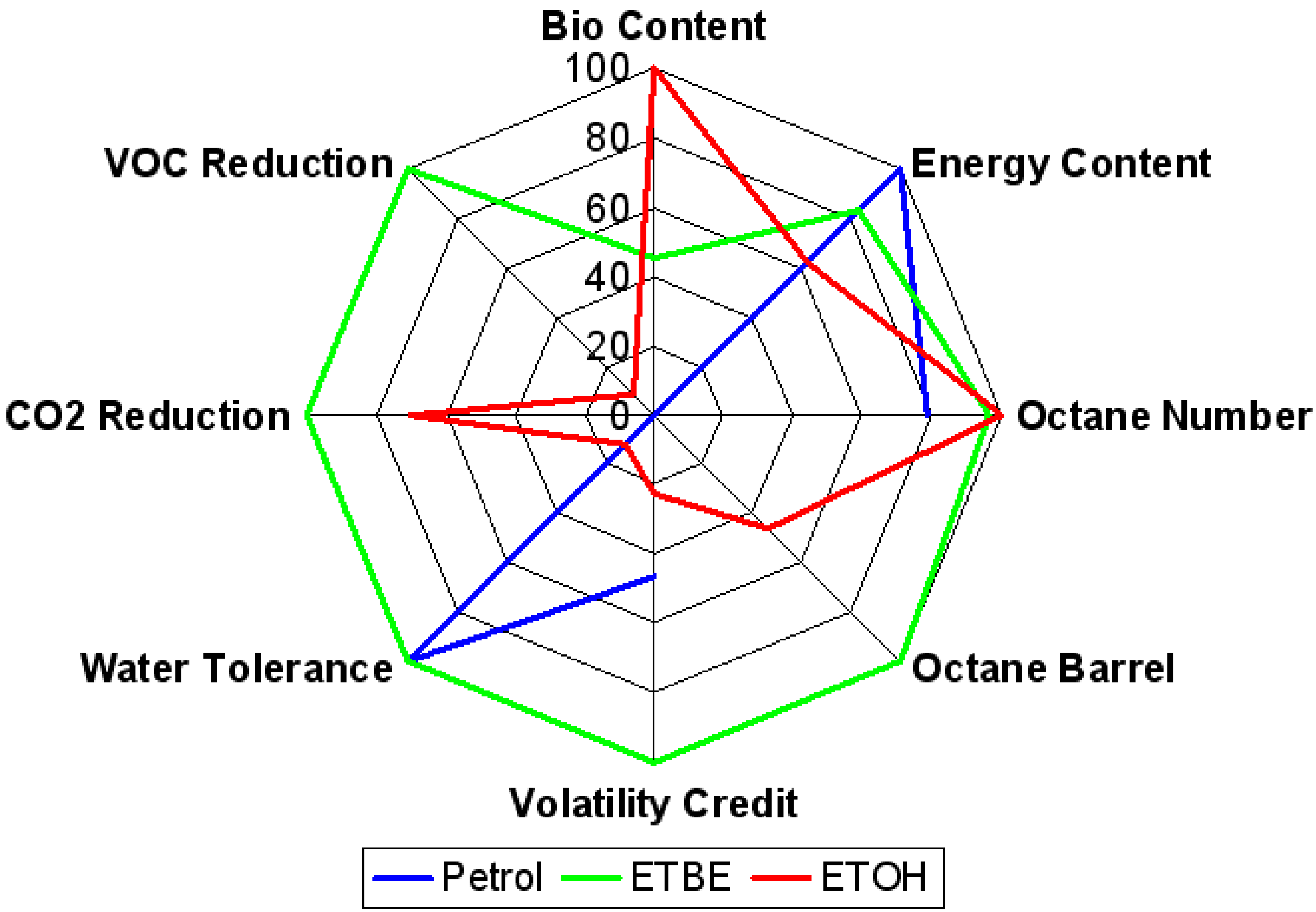
Ethanol/ETBE/Petrol Blending Performances

"Normalized" Comparison



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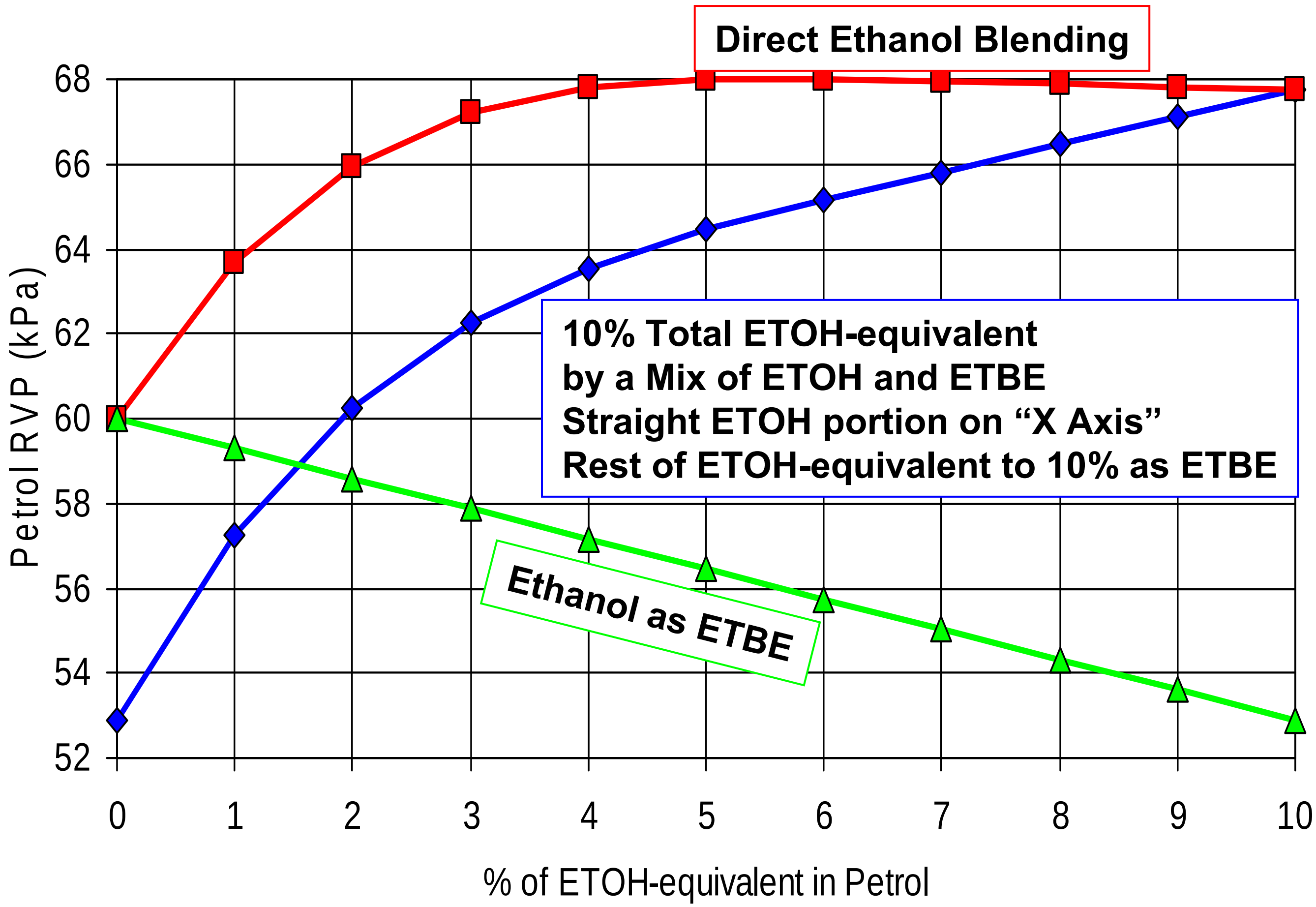
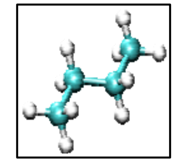
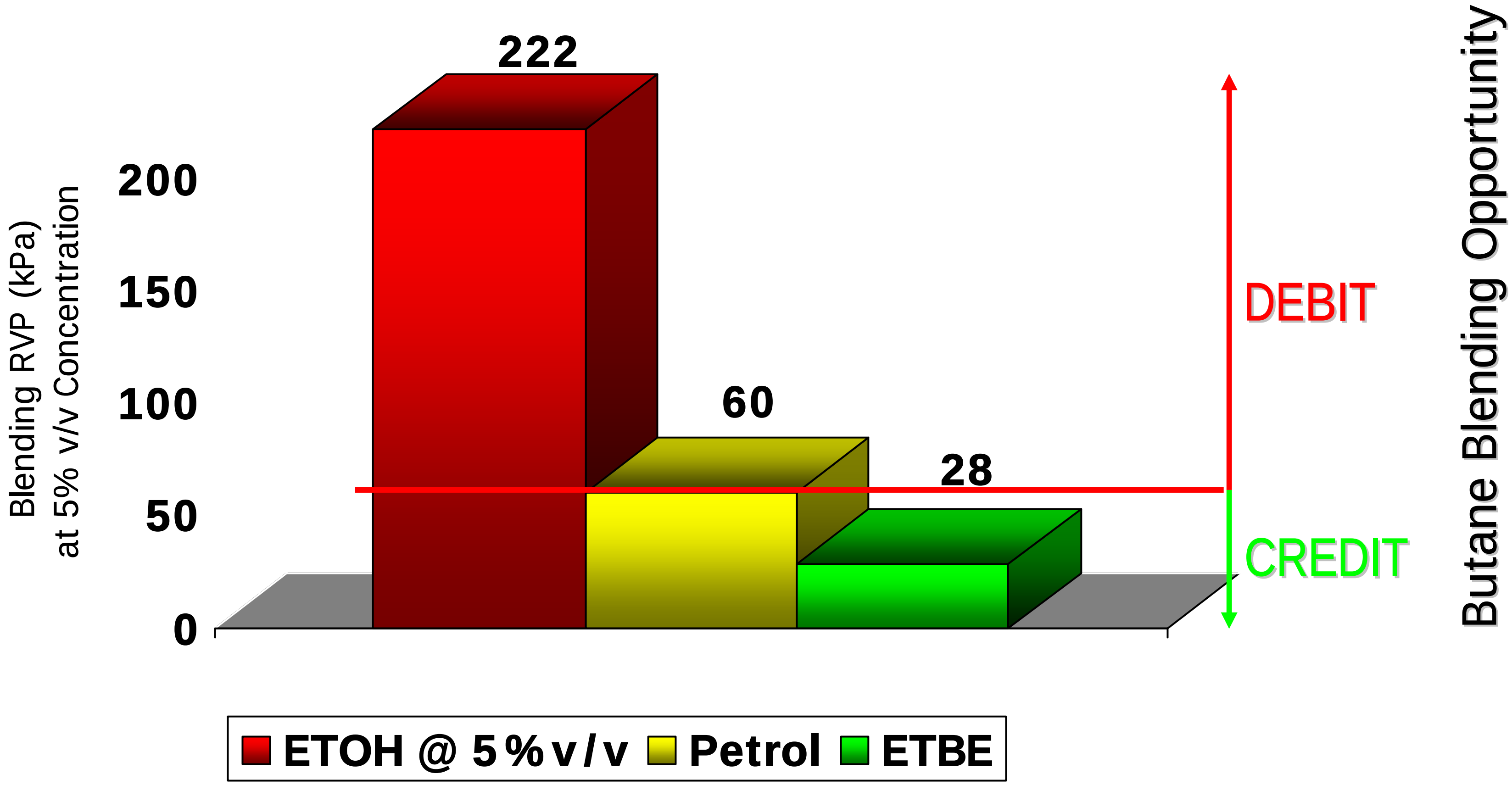
ETBE Helping Ethanol on Volatility





Butane Uptake/Upgrade Value



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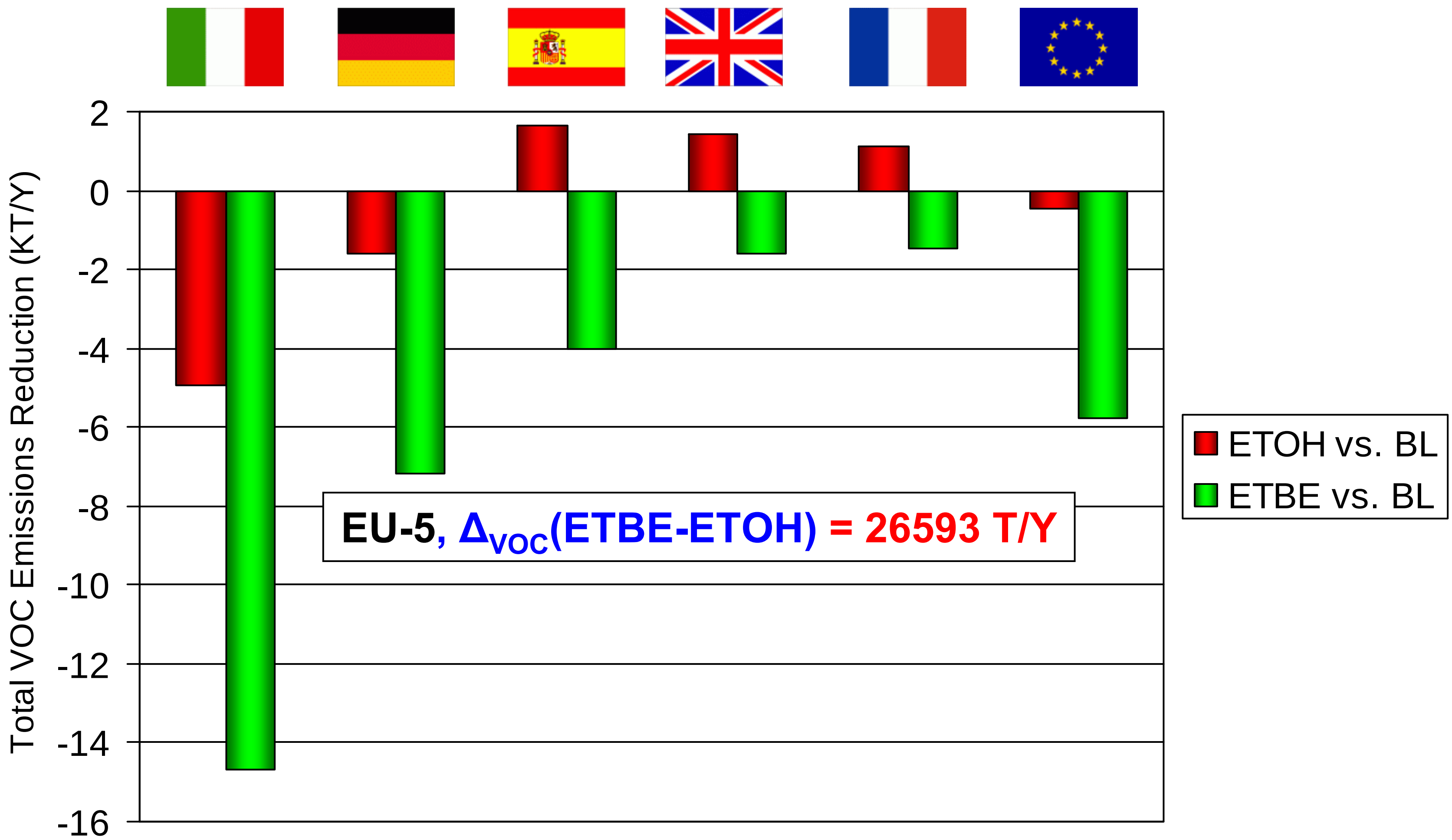
ETBE Further Addresses GHG's by Greatly Reducing VOCs Emissions



Source: Emissions and Health Unit - Institute of Environment and Sustainability - EC-JRC Ispra

"An assessment of the impact of ethanol-blended petrol on the total NMVOC emissions from road transport in selected countries"

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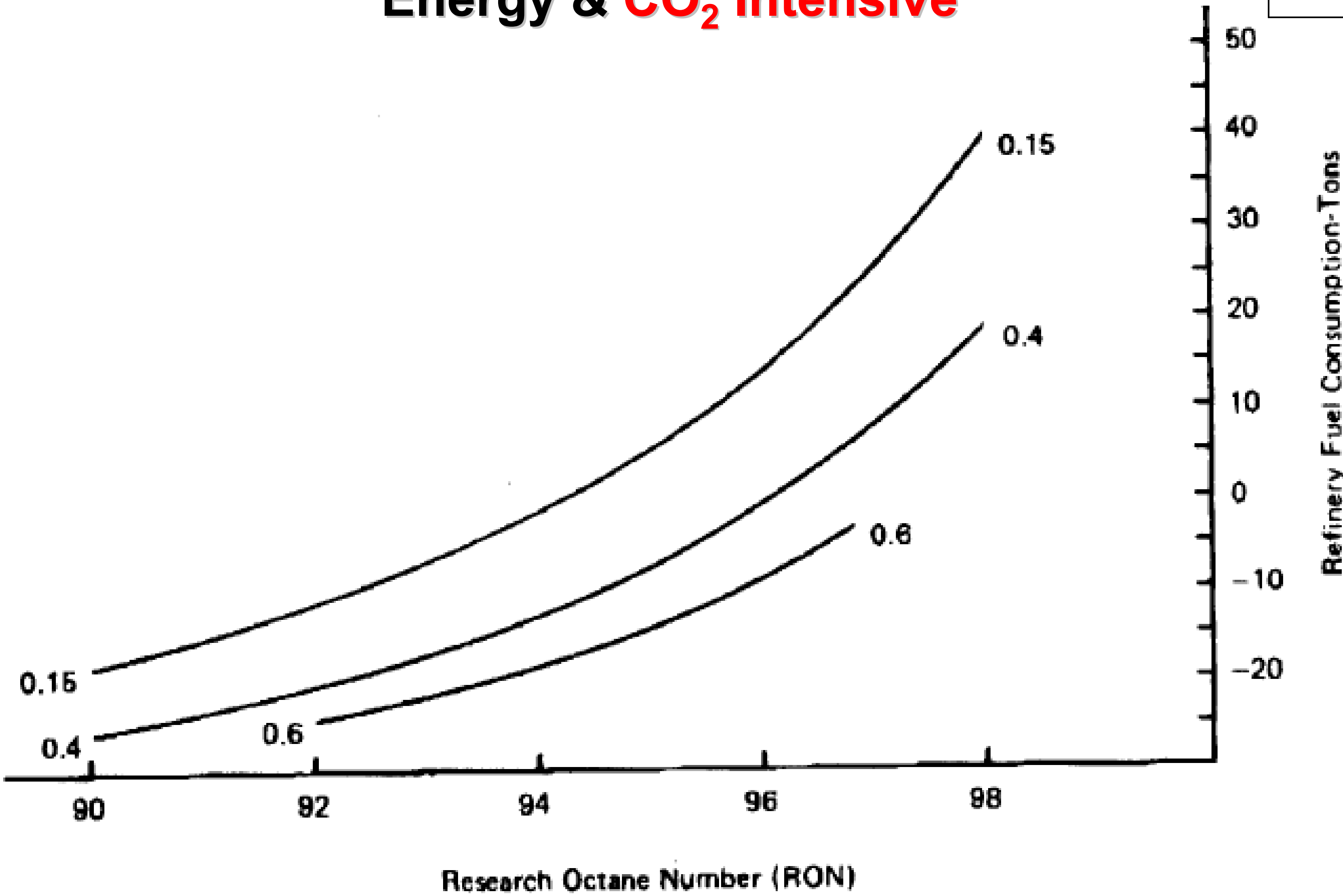
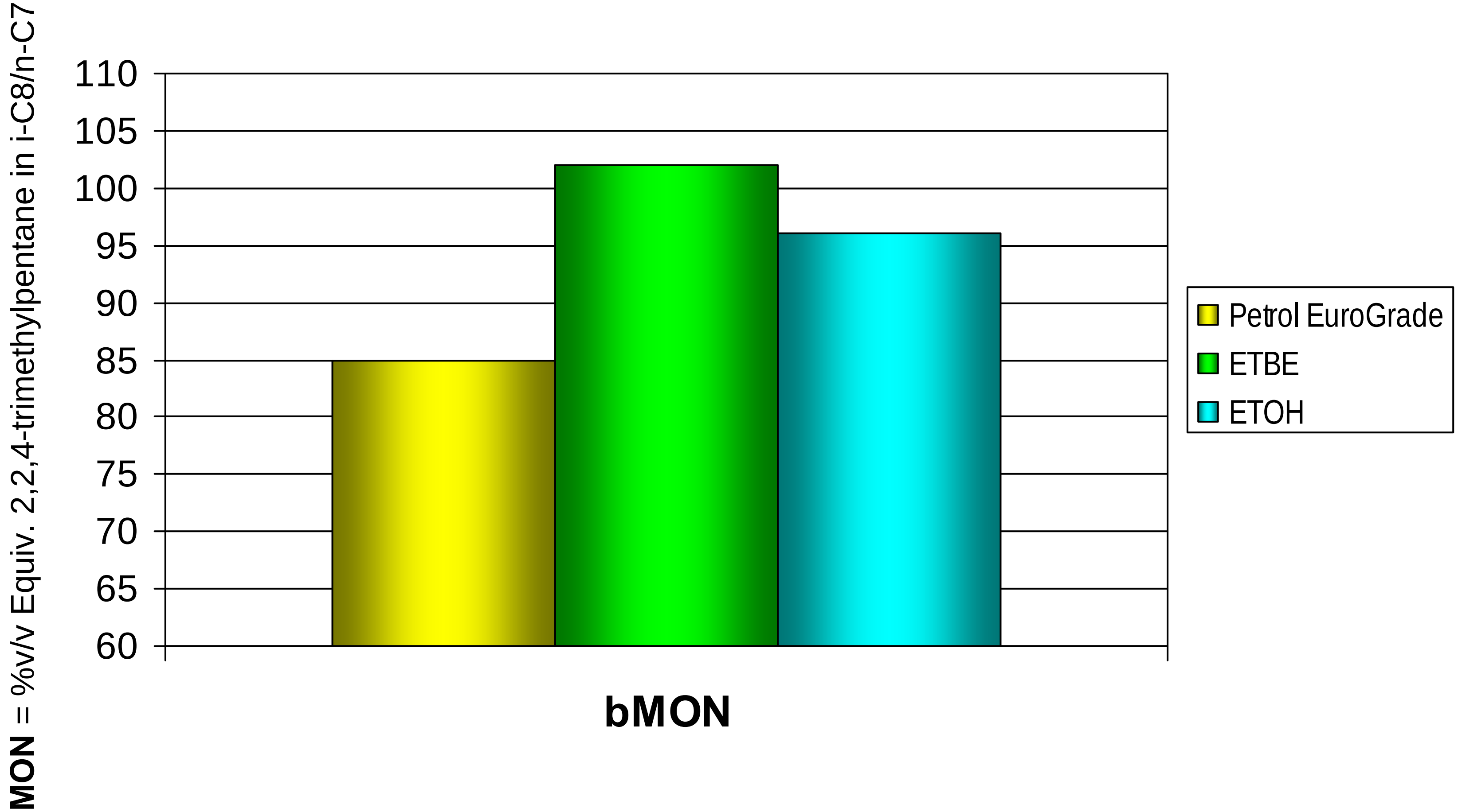
Refinery Octane Production: Energy & CO_2 Intensive

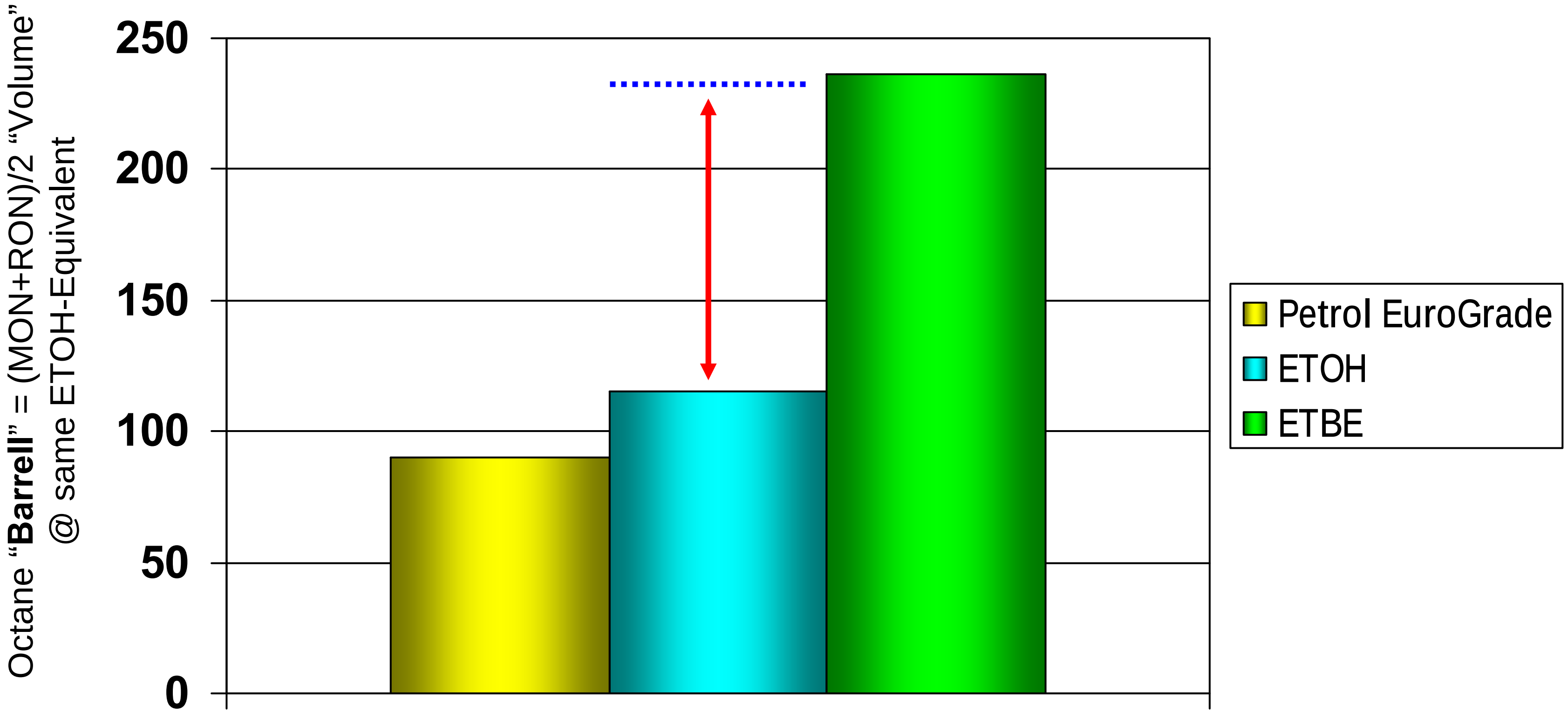


Source: CONCAWE's "RUFIT" report N° 6/78 (Dec. 1978)

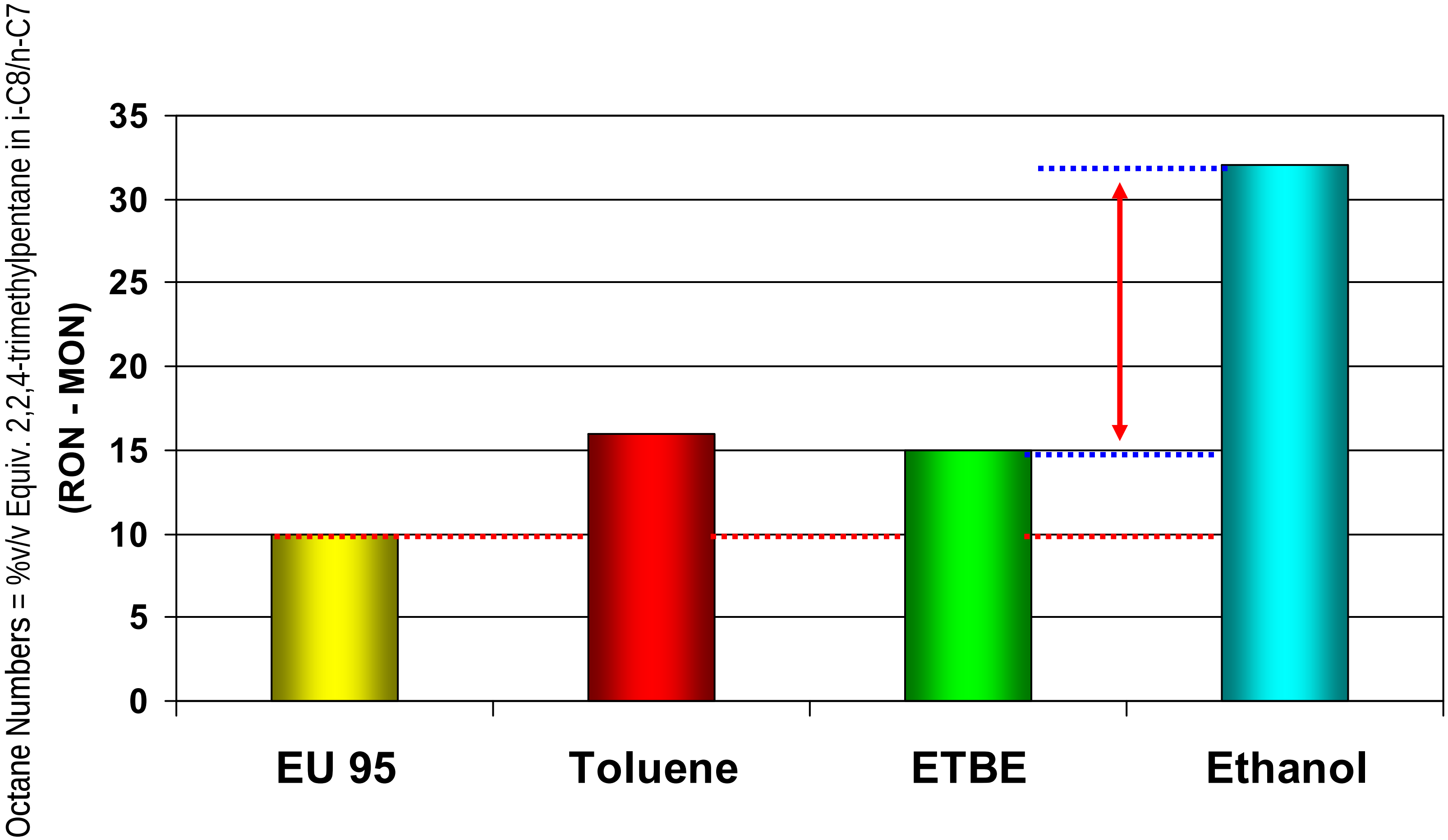
ETBE Delivers Superior MON Contribution: Most EU Refineries "*MON-Limited*"



ETBE Delivers > Twice "Octane Barrel" @ same Ethanol-equivalent

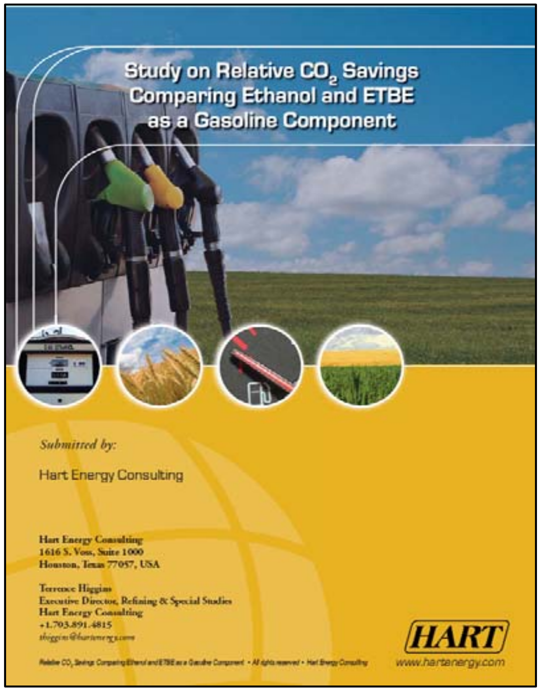


ETBE Helping Refiners vs. Octane Sensitivity Balance



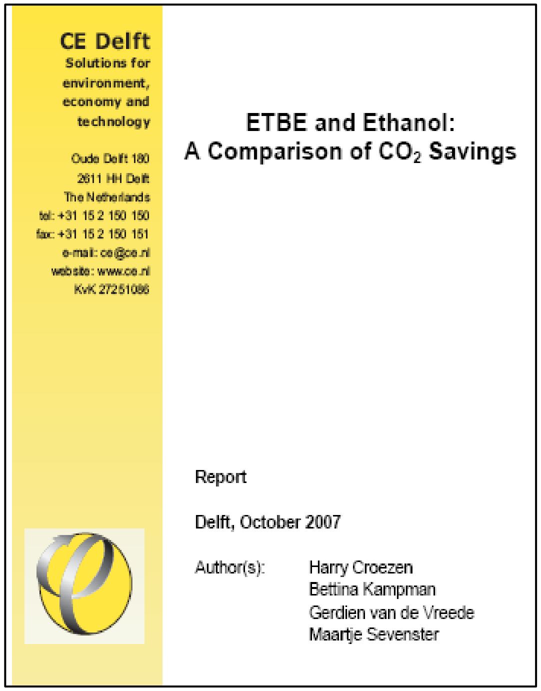
ETBE Reduces CO_2 Emissions

HART July 2007



> *"The use of bio-ETBE reduces refining crude-oil need and processing intensity, requires less fuel and, implying relevant petrol composition changes, allows the reduction of carbon factor and lesser CO_2 emissions"*

CE-Delft October 2007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ETBE and Ethanol:
A Comparison of CO_2 Savings

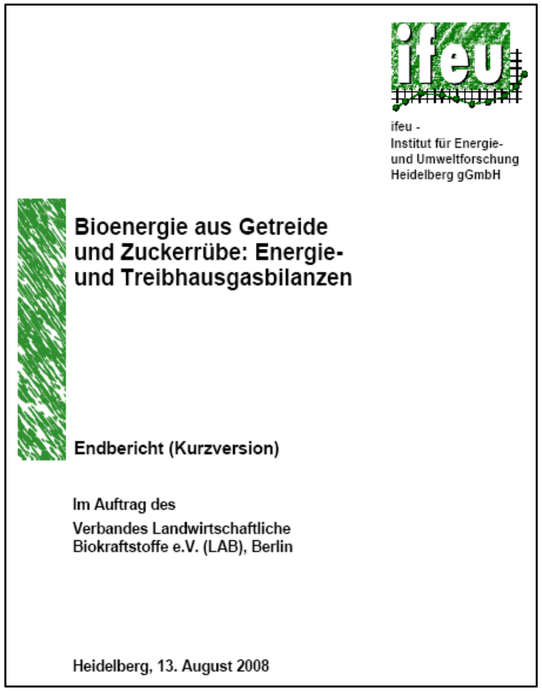
Report

Delft, October 2007

Author(s): Harry Croezen
Bettina Kampman
Gerdien van de Vreede
Maartje Sevenster

> *"This study indicated that, when bio-ETBE is used, the resulting modification of refinery operations determine a significant reduction of greenhouse gases emissions"*

IFEU August 2008


ifeu -
Institut für Energie- und Umweltforschung Heidelberg gGmbH

Bioenergie aus Getreide und Zuckerrübe: Energie- und Treibhausgasbilanzen

Endbericht (Kurzversion)

Im Auftrag des
Verbandes Landwirtschaftliche Biokraftstoffe e.V. (LAB), Berlin

Heidelberg, 13. August 2008

> *"Best results by far are obtained when ethanol is converted to bio-ETBE.*
> *The use of ETBE can allow the saving of 4 times the primary energy required to produce its fossil alternative.*
> *IFEU recommends to exploit the whole potential of bio-ETBE"*

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ETBE CO_2 Performance Studies: References

Study on Relative CO2 Savings Comparing Ethanol and ETBE as a Gasoline Component
Hart Energy Consulting
July 2007

ETBE and Ethanol: A Comparison of CO2 Savings
CE-Delft
October 2007
http://www.ce.nl/publicatie/etbe_and_ethanol%3A_a_comparison_of_co2_savings/715?PHPSESSID=37ad2bd9915bcf5711aed6292578b595

Bioenergy from grain and sugar beet: Energy and greenhouse gas balances
IFEU - Institute for Energy and Environmental Research Heidelberg
August 2008
http://papers.sae.org/2009-01-1951

Ethyl Tertiary Butyl Ether - A Review of the Technical Literature
SAE
June 2009
http://papers.sae.org/2009-01-1951

The impact of ethanol and ETBE blending on refinery operations and GHG-emissions
ELSEVIER - Energy Policy
2009
http://www.ce.nl/art/uploads/file/Artikelen%20(medewerkers)/EnergyPolicy_TheImpactofEthanolandETBEblending_HCBKa.pdf?PHPSESSID=4d91cd6d759b670b5c0f4d0c98735687

GHGs Emissions Calculation Formula: A Deeper Look

$$E = e_{ec} + e_{l} + e_{p} + e_{td} + e_{u} - e_{sca} - e_{ccs} - e_{ccr} - e_{ee}$$

where

E = total emissions from the use of the fuel;

e_{ec} = emissions from the extraction or cultivation of raw materials;

e_{l} = annualised emissions from carbon stock changes caused by land use change; 3

e_{p} = emissions from processing; 1

e_{td} = emissions from transport and distribution;

e_{u} = emissions from the fuel in use; 2

e_{sca} = emission savings from soil carbon accumulation via improved agricultural management;

e_{ccs} = emission savings from carbon capture and geological storage;

e_{ccr} = emission savings from carbon capture and replacement; and

e_{ee} = emission savings from excess electricity from cogeneration.

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Bio-Ethers allow Energy Processing Saving during Refinery Fuel Formulation !

$$E = e_{ec} + e_l + \mathbf{e_p} + e_{td} + e_u - e_{sca} - e_{ccs} - e_{ccr} - e_{ee}$$

Emissions from **Processing**

$\mathbf{e_p}$ = *process energy*

- \+ *consumed* *"upstream"*
- – *saved* *"downstream"*

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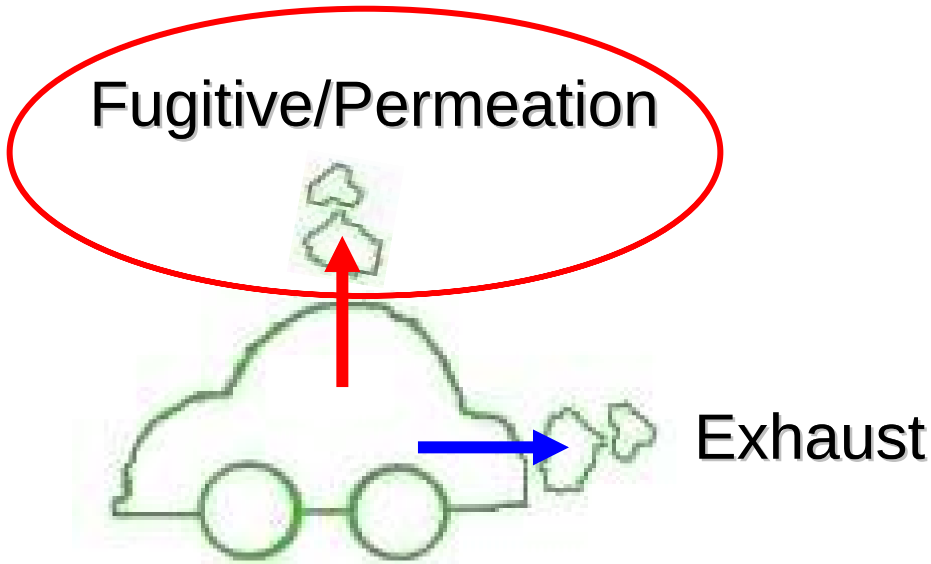
Converting ETOH into Ethanol-Ethers Avoids Vehicle Permeation Emissions & Secondary CO_2 Formation

$$E = e_{ec} + e_{l} + e_{p} + e_{td} + e_{u} - e_{sca} - e_{ccs} - e_{ccr} - e_{ee}$$

Emissions from the **Fuel in Use**



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ETBE: The MTBE "Substitution" Effect

$$E = e_{ec} + \mathbf{e_l} + e_p + e_{td} + e_u - e_{sca} - e_{ccs} - e_{ccr} - e_{ee}$$

Emissions from … land **use change**

LUC = Land Use Change

ARID LANDS

GOOD →

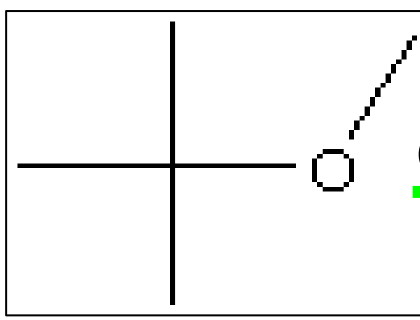
ENERGY CROPS

← BAD

RAINFOREST

PUC = Plant Use Change

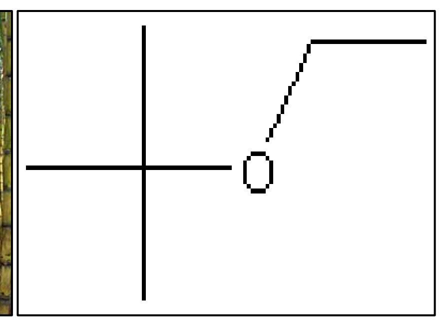
FOSSIL-ORIGIN



MTBE

GOOD →

BIO-ORIGIN



ETBE

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Conclusion

Ethanol-Ethers, via their Multiple Valuable Technical and Environmental Features, Contribute to Enhance Fuel-ETOH Sustainability Pathway, including very Relevant CO2 Emissions Reduction Improvement