FUEL OXYGENATES
AND THEIR ROLE
TO ENHANCE
THE USE OF
BIO ALCOHOLS

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BioFuels: 3 Key Entities

- European Fuel Oxygenates Association
- Italian Chemical Industry Federation
- Italian Biofuels Technology Platform
Bio-Ether (ETBE) is for Petrol what Bio-Ester (FAME) is for Gasoil
European Fuel-Ethers Production Capacities 2011 (KT/Y)
# Addressing RED & FQD EU Directives Challenge

| What                      | 10% Bio-energy in Fuels (RED)  
<table>
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<th>6% CO₂ Saving (FQD)</th>
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| Challenge                 | Sustainability: a Broader Concept  
|                          | Full Obligation but Partial "Control" ? |
|                          | Petrol/Gasoil - Supply/Demand Unbalance |
|                          | Balkanization of Implementation Rules in 27 EU Member States |
|                          | Consumers Resistance to “High-Bio” Grades (E10) |
|                          | Vehicle/Engines Compatibility/Operability |
|                          | Fuel Specifications Limits (Oxygenates/Oxygen/FAME) |
| How                      | CO₂ Reduction Effectiveness of Bio-components  
|                          | High Bio-components Blending Percentage |
|                          | Exploitation "best seller" Petrol Grade (Protection Grade) |
| Solution                  | Adopting Immediately Available Consolidated Solutions  
|                          | Maximizing Actual Bio-energy Blending within E5 |
|                          | Optimizing Logistics: ETBE "Dual-EEBE" [†] |
|                          | Capturing Bio-components' Well-to-Wheels CO₂ Saving Potential |
|                          | Harvesting Bio-components' Synergetic "Non-linear" Effects |

[†] Blend-stock Before Ethanol Blending
Two “Interactive” EU Directives

**FUEL QUALITY Directive**
**2009/30/EC**

**GHG Emissions Reduction**
6% (+2%+2%)

**RENEWABLE ENERGY Directive**
**2009/28/EC**

**Renewable Energy Transport**
10%

**Sustainability Threshold**
-35% (2010)
-50% (2017)
-60% (2018)
Bio-component to Address Broader Sustainability

**ECONOMIC**
- Capital Efficiency
- Growth Enhancement
- Innovation
- Margin Improvement
- Risk Management
- Shareholders Return

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

**SOCIAL**
- Access to Potable Water
- Crisis Management
- Environmental Justice
- Environmental Regulations
- Global Climate Change
- Safety & Health
- Community Outreach
- Diversity
- Human Rights
- Indigenous Communities
- Labour Relations

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

**SUSTAINABLE**
- Equitable
- Viable
- Bearable

**ENVIRONMENTAL**
- Life-Cycle Management
- Product Stewardship
- Products to Services
- Resource Efficiency

**SOCIAL**
- Skills Enhancement
- Social Investments

**ECONOMIC**
- Capital Efficiency
- Growth Enhancement
- Innovation
- Margin Improvement
- Risk Management
- Shareholders Return
FQD & Refiners big Challenge: Full Obligation vs. Partial "Control"

- 6% of total, - 40% of O.I. bit, - 60% of Refining one!
Petrol/Gasoil - Supply/Demand Unbalance: EU Gasoil/Petrol Ratio Growing

- Refineries not designed/structured for current fuels demand ratio
- Petrol export & gasoil import impacting economics & CO₂ emissions (transport)
- Diesel production maximisation disoptimising refinery operations & increasing CO₂ emissions
- FAME content specification (7%v/v) limiting actual bio-blending in diesel

Balkanization of National Bio-Blending Obligations

IRELAND
4,0% (v/v)

UNITED KINGDOM
3,5% (v/v)

FRANCE
7,0% (e/e)
Parallel Targets Pertrol & Gasoil

SPAIN
3,9% (e/e) Ind.
5.83% (e/e) Cum.

PORTUGAL
Gasoil 7,0% (v/v)

NETHERLANDS
4,0% (e/e)
Parallel Targets Pertrol & Gasoil

NETHERLANDS
4,0% (e/e)
Parallel Targets Pertrol & Gasoil

ITALY
4,0% (e/e)
Obiettivo cumulativo Pertrol + Gasoil

GERMANY
Gasoil 4,4% (e/e)
Pertrol 2,8% (e/e)

GERMANY
Gasoil 4,4% (e/e)
Pertrol 2,8% (e/e)

AUSTRIA
Gasoil 6,3% (e/e)
Pertrol 3,4% (e/e)

POLAND
5,75% (e/e)
Indicative

FINLANDI
4,0 (e/e)

FRANCE
7,0% (e/e)
Parallel Targets Pertrol & Gasoil

POLAND
5,75% (e/e)
Indicative

GERMANY
Gasoil 4,4% (e/e)
Pertrol 2,8% (e/e)

SLOVAKIA
5,75% (e/e)
Indicative

CZECH REPUBLIC
Gasoil 4,5% (v/v)
Pertrol 3,5% (v/v)

SLOVAKIA
5,75% (e/e)
Indicative

SWEDEN
5,75% (e/e)
Indicative

UNITED KINGDOM
3,5% (v/v)

NETHERLANDS
4,0% (e/e)
Parallel Targets Pertrol & Gasoil

IRELAND
4,0% (v/v)
Consumers Resistance to “High-Bio” Grades (E10)
Consumers Psychological Resistance to E10

“My car is on the E10 not-suitable list by OEM”

“It might damage my car”

“It will compromise my vehicle warranty”

“It will worsen car performances”

“It would provoke engine efficiency loss”

“I buy litres, but I need energy (oxygen doesn’t burn)”

“If «they» discount it, there must be something dirty”

“High bio compete with food and feed”

“This thing is too new: let others be the guinea pigs”
Vehicle/Engines Compatibility/Operability

- Fuel filter blockage
- Galvanic corrosion
- Enleanment
- Drivability
- Deposit formation
- Material compatibility
ETBE: A Multifaceted Benefits Carrier
..and “Co-blending” further offers Additional Specific Benefits!

- Blending more Bio-energy within Petrol Specs Limits
- Capturing Bio-components' Well-to-Wheels CO₂ Saving Potential
- Minimizing Quality “Give-away” and fossil base-stock cost, via ETBE-containing “Dual BBEB”[*] for E5/E10
- Harvesting Synergetic "Non-linear" Effects of Bio-components

[*] Blend-stock Before Ethanol Blending
Exploiting Bio-related Petrol Specifications Limits (E5)
53% more bio-energy into E5 via “Co-blending”

<table>
<thead>
<tr>
<th>Limiting Petrol Spec.</th>
<th>“Alcohol-only” Ethanol</th>
<th>“Ether-only” ETBE</th>
<th>“co-blending” ETBE+ETOH</th>
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<tbody>
<tr>
<td>Bio-energy Content</td>
<td>3.3%</td>
<td>4.6%</td>
<td>5.1%</td>
</tr>
<tr>
<td>ETBE Content</td>
<td>0%</td>
<td>15%</td>
<td>5.55%</td>
</tr>
<tr>
<td>Oxygen Content</td>
<td>1.8%</td>
<td>2.3%</td>
<td>2.7%</td>
</tr>
<tr>
<td>O₂ Limit Exploitation</td>
<td>68.2%</td>
<td>86.3%</td>
<td>100%</td>
</tr>
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German Example (1):
Bio-energy Targets and E5 Blend “Options”

- **5%v/vETOH**
- **15%v/vETBE**
- **E5 Co-blend**
- **B7**

- **Fuel-type-specific target**
- **Maximum bio-energy contribution above minimum target**
- **Excess from B7 available for petrol (excluding B100 contribution)**
- **Residual Gap to cumulative target (excluding B100 and E85 contribution)**
German Example (2):
53% more bio-energy into E5 via “Co-blending”

- 5.11
- 3.34

5%v/v ETOH
E5 Co-blend

- Residual contribution from biodiesel exceeding bio-energy cumulative target in gasoil (B7)
- Maximum bio-energy contribution
- Residual Gap to cumulative target (excluding B100 and E85 contribution)
German Example (3): E5: “Co-blending” Enables Significant Non-compliance Penalty Saving

“Alcohol-only” Ethanol

Bio-energy Content

- %e/e
- Bio-energy Content

Additional Penalty Avoidance Value

- €/T_{PET}
- Mill-€/Y

“co-blending” ETBE+ETOH

[1] On top of what achievable with 5%v/v ETOH directly blended into E5 “Protection Grade”

[2] Example based on an average refinery petrol production of 1.5 million tons per year
“Dual” BOBs for E5 and E10

BOBcb = ETBE-containing E5/E10-dual-BBEB that, when blended with 5%v/v ETOH, yields E5 @ 2.7%m/m O₂
BOBdb = Oxy-free E5/E10-dual-BOB, yielding E5 with 5%v/v ETOH, and E10 with 10%v/v ETOH
E5cb = E5 petrol (protection grade) “co-blend” ETBE/ETOH – 2.7%m/m O₂
E10cb = E10 petrol “co-blend” ETBE/ETOH – 3.7%m/m O₂
E5db = E5 petrol containing only ETOH @ 5%v/v
E10bd = E10 petrol containing only ETOH @ 10%v/v
CO-BLENDING: HC BLEND-Stock RVP & MON SAVINGS

**ETBE 5.85 %v/v**

**BOBcb**
- MON 83.2
- RVP 53.7

**Δ**
- MON 1.4%
- RVP 2.9%

**BOBdb**
- MON 84.4
- RVP 52.2

**BOBcb** = ETBE-containing E5/E10-dual-BBEB that, when blended with 5%v/v ETOH, yields E5 @ 2.7% m/m O2

**BOBdb** = Oxy-free E5/E10-dual-BOB, yielding E5 with 5%v/v ETOH, and E10 with 10%v/v ETOH

Conservatively neglecting positive non-linear “co-solvency” effects of ETBE
In order to be used for both E5 and E10 petrol grades, and due to the non-linear blending volatility behaviour of ethanol, the oxygen-free dual-BOB has to feature lower than specification volatility, to ensure RVP specs compliance of E5. This unwanted effect doesn’t occur with ETBE-containing dual BBEB.
Co-blending Addresses ETOH E70 Boost

Fossil HC Blendstock E5 Grade ETOH-only 5\%v/v E5 Grade Co-blend ETOH/ETBE E10 Grade ETOH-only 10\%v/v E10 Grade Co-blend ETOH/ETBE

- 6.4 (absolute)
- 40\% (increase)
ETBE Further Reduces CO₂ 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 CO₂ emissions"

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**CE-Delft October 2007**

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

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**IFEU 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"
ETBE: Two Relevant CO₂ Saving Contributions

65% UPSTREAM +54% DOWNSTREAM 35%[1] FIELD-TO-TANK

0.618 0.335 = 0.953

Tₜₙ₄/Tₖₑₜₜₑ

[1] Key ETBE blending properties, like vapour pressure, distillation characteristics and octane contribution, affecting fuel formulation, reduce refinery operations’ CO₂ emissions, by reducing carbon and aromatics content as well as the use of refinery fuel.

[2] Based on CO₂ cost at current ETS value of 20 €/Tₐₚ₉₂
Harvesting Synergetic "Non-linear" Effects of Bio-components

• Increasingly stringent technical and environmental petrol specifications, makes it relevant and urgent to try and fully exploit all the positive characteristics of various blend-stocks used by refiners for formulating finished fuels;

• Several studies have already demonstrated that co-mixing different blend-stocks can yield a better-than-linear blending performance;

• A specially interesting and relevant case is the co-blending of ethanol and ethers (ETBE), considering the key role that these two bio-components play in recent bio-fuels policies;

• Some of the chemical-physical reasons for the distinct synergetic blending effect of those oxygenated molecules comes from their polar nature, as well as from the hydrogen-bonding effects;

• New ad hoc studies are currently under going to better quantify and qualify those effects;

• Petrol specifications that benefit from the «co-blending effect» include volatility (BRVP), distillation curve (E70), octane performance (MON & RON) and water tolerance.
Conclusion

Harvesting the synergy of co-blending bio-ETBE and bio-Ethanol, represents an effective, immediate and practical avenue to address both EU and MSs ambitious bio-fuel targets. It actually enables significantly higher bio-energy content, while both enhancing environmental benefits and improving operators flexibility.