Relative CO₂ Savings Comparing Ethanol and TAEE as a Gasoline Component

March 23, 2011

Presented at

by

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Oxygenate Blending Overview

• Benefits
• Ethanol via ether vs. Ethanol direct blend

Assessing CO₂ Impacts TAEE/Ethanol Blending

• Approach/Modeling

Study Results:

• CO₂ Impacts Comparing TAEE and Ethanol

TAAE: tert-amyl ethyl ether (2-ethoxy-2-methylbutane) C₇H₁₆O
Oxygenate Blending Overview
Oxygenate Blending

Oxygenate blending results in net CO\textsubscript{2} emissions decrease

- Lower Carbon Content: Lower CO\textsubscript{2}
- Lower Aromatics (Octane): Lower CO\textsubscript{2}
- Reduced Refinery Fuel: Lower CO\textsubscript{2}
- Lower Energy Content: Higher CO\textsubscript{2}
- Increased Refinery H\textsubscript{2} Rqmts: Higher CO\textsubscript{2}

\[ \text{Net Lower CO}_2 \]
Blend via etherification to TAEE
- Replace methanol for TAME with ethanol for TAEE
- Existing ether capacity and infrastructure

Direct blend ethanol
- In finished gasoline or special blend stock (CBOB)
- Blending at terminal level
European TAME Capacity

- Porvoo refinery in Finland (Neste), 116 kt per year (*)
- Aspropyrgos refinery in Greece (Hellenic), 128 kt per year
- Gela, Ragusa refinery in Italy (ENI/Agip), 54 kt per year
- Sarroch refinery in Italy (Saras), 237 kt per year
- Killingholme refinery in the UK (Total), 65 kt per year
- Feyzin refinery in France (Total) 56 kt per year
- MOL (OMV) in Hungary 100 kt per year
- Petrom (OMV) Petrobrazi refinery in Ploiesti, Romania 50–60 kt per year
- Schwedt (PSK Raffinerie) in Germany, 160 kt per year (TAEE)

(*) This is the original TAME design capacity. The Porvoo unit has been producing TAEE since 2008 with a maximum capacity of 110 kt per year.
Ether provides benefits of ethanol with other positive impacts

Ether volatility credit, Ethanol volatility debt

Ethanol water solubility characteristics preclude blending at refinery – terminal blending

Ether compatible in distribution system – refinery blending

Higher volume of high octane component (ether) with same volume of ethanol
# Ethanol via TAAE vs. Ethanol Direct Blend

## Gasoline Blending Properties

<table>
<thead>
<tr>
<th></th>
<th>Blending RVP kPa</th>
<th>Octane</th>
<th>Max vol% at 2.7 wt% O&lt;sub&gt;2&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>TAAE</td>
<td>10</td>
<td>112</td>
<td>19.6</td>
</tr>
<tr>
<td>Ethanol</td>
<td>175*</td>
<td>129</td>
<td>7.8</td>
</tr>
<tr>
<td>Gasoline</td>
<td>60</td>
<td>95</td>
<td>-</td>
</tr>
</tbody>
</table>

*Varies with concentration – 5 vol% blend shown*
Assessing CO₂ Impacts
Approach/Modeling
CO₂ Impacts Quantified

• Changes in gasoline carbon content
• Changes in gasoline volume to maintain constant energy
• Changes in other product carbon content
• Changes in by product production/disposition
• Changes in refinery and merchant plant fuel consumption
• Changes in hydrogen and methanol production
## Cases Analyzed

<table>
<thead>
<tr>
<th>Case</th>
<th>Ethanol Blended</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Case - No Ethanol</td>
<td>-</td>
</tr>
<tr>
<td>Ethanol (direct blend)</td>
<td>3.0 vol%</td>
</tr>
<tr>
<td>Ethanol (direct blend)</td>
<td>5.0 vol%</td>
</tr>
<tr>
<td>TAEE – no direct blend*</td>
<td>3.0 vol%</td>
</tr>
<tr>
<td>TAEE – no direct blend*</td>
<td>5.0 vol%</td>
</tr>
</tbody>
</table>

*All ethanol converted to TAEE*
Blending Refinery Model

- Industry accepted/standard – AspenTech PIMS
- Assessed for 2010 capacities, operations, quality requirements and demand
- Model generated gasoline blends, processing operations
- Model determined gasoline components and qualities
- Model determined crude oil, hydrogen and process fuel requirements
Blending Analytical Approach

• Europe (includes EU, non-EU and Turkey) refinery LP simulation model

• Constant gasoline production – energy basis
• Final gasoline volume varied (to keep final energy constant)
• Constant other major refined product – energy basis
• Crude volume and LPG/Coke allowed to vary

• Study year 2010, 60 kPa gasoline no RVP waiver, constant refinery capacity (except alkylation in ethanol cases)
Study Results

- Previous study showed CO\textsubscript{2} benefit of blending ETBE*

- Current study focuses on higher ether - TAEE

*Study on Relative CO\textsubscript{2} Savings Comparing Ethanol and ETBE as a Gasoline Component, Hart Energy, July 2007
TAAE vs. Ethanol

- Lower crude oil/refinery fuel requirements
- Oxygenate reduced refinery octane requirement, in general lower gasoline aromatics
- Aromatics reduction in high TAAE case – lower gasoline carbon factor
- Lower gasoline consumption in TAAE cases vs. ethanol cases
- Higher hydrogen requirements in most cases - lower reformer runs
## Impact on Gasoline Quality

Small impact on aromatics, strong impact on olefins

<table>
<thead>
<tr>
<th></th>
<th>Base Case</th>
<th>Ethanol 3 vol%</th>
<th>Ethanol 5 vol%</th>
<th>TAEE 3 vol% EtOH</th>
<th>TAEE 5 vol% EtOH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity</td>
<td>0.74</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>Aromatics [vol%]</td>
<td>34.8</td>
<td>34.8</td>
<td>34.8</td>
<td>34.8</td>
<td>33.2</td>
</tr>
<tr>
<td>Olefin [vol%]</td>
<td>6.7</td>
<td>6.9</td>
<td>5.9</td>
<td>3.7</td>
<td>4.9</td>
</tr>
<tr>
<td>Ethanol [vol%]</td>
<td>-</td>
<td>3.0</td>
<td>5.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>TAEE [vol%]</td>
<td>- (1)</td>
<td>-</td>
<td>-</td>
<td>7.9</td>
<td>12.7</td>
</tr>
</tbody>
</table>

1MTBE = 1.3 vol%; TAME = 0.4 vol%
**Energy/CO₂ Characteristics**

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<tr>
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<th>TAAE 5 vol% EtOH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline Energy Content [MJ/kg]</td>
<td>31.69</td>
<td>31.59</td>
<td>31.51</td>
<td>31.74</td>
<td>31.54</td>
</tr>
<tr>
<td>Gasoline Consumption [million tons/year]</td>
<td>102.24</td>
<td>103.19</td>
<td>103.98</td>
<td>102.93</td>
<td>103.57</td>
</tr>
<tr>
<td>Gasoline Carbon Factor</td>
<td>0.866</td>
<td>0.859</td>
<td>0.853</td>
<td>0.858</td>
<td>0.850</td>
</tr>
<tr>
<td>Process Fuel [PJ/year]*</td>
<td>1,860</td>
<td>1,850</td>
<td>1,840</td>
<td>1,850</td>
<td>1,830</td>
</tr>
</tbody>
</table>

*Refinery fuel plus merchant methanol plant fuel*
CO₂ Emission Reduction

thousand tons per year

EtOH 3  EtOH 5  TAEE 3  TAEE 5

Gasoline Consumption  Refinery fuel  H₂ Production  MeOH & Other Impact

MARCH 23, 2011
Conclusions

- Ethanol and TAEE both result in reduction of CO$_2$

- TAEE option vs. direct blend ethanol results in reduced fuel consumption and crude oil requirements

- TAEE option results in lower overall CO$_2$ emissions than direct blend ethanol

- TAEE can be used with ethanol direct blend option
Thank you!

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