HART ENERGY

# Relative $CO_2$ Savings Comparing Ethanol and TAEE as a Gasoline Component

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**by**
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# Agenda


***Oxygenate Blending Overview***

- Benefits
- Ethanol via ether vs. Ethanol direct blend

***Assessing $CO_2$ Impacts TAEE/Ethanol Blending***

- Approach/Modeling

***Study Results:***

- **$CO_2$ Impacts Comparing TAEE and Ethanol**

TAEE: *tert*-amyl ethyl ether (2-ethoxy-2-methylbutane) $C_7H_{16}O$

# Oxygenate Blending Overview

# Oxygenate Blending

**Oxygenate blending results in net $CO_2$ emissions decrease**

| | |
|---|---|
| Lower Carbon Content: | Lower $CO_2$ |
| Lower Aromatics (Octane): | Lower $CO_2$ |
| Reduced Refinery Fuel: | Lower $CO_2$ |
| Lower Energy Content: | Higher $CO_2$ |
| Increased Refinery $H_2$ Rqmts: | Higher $CO_2$ |

➡ **Net Lower $CO_2$**

# Ethanol Blending Overview/Options

**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.

# Ethanol and Ether Characteristics for Gasoline Blending

- 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 TAEE vs. Ethanol Direct Blend

## Gasoline Blending Properties

| | Blending RVP kPa | Octane RON | Octane MON | Max vol% at 2.7 wt% $O_2$ |
|---|---|---|---|---|
| TAEE | 10 | 112 | 98 | 19.6 |
| Ethanol | 175* | 129 | 96 | 7.8 |
| Gasoline | 60 | 95 | 85 | - |

**Varies with concentration – 5 vol% blend shown*

# Assessing $CO_2$ Impacts Approach/Modeling

# $CO_2$ 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

| Case | Ethanol Blended |
|---|---|
| Base Case - No Ethanol | - |
| Ethanol (direct blend) | 3.0 vol% |
| Ethanol (direct blend) | 5.0 vol% |
| TAEE – no direct blend* | 3.0 vol% |
| TAEE – no direct blend* | 5.0 vol% |

**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 $CO_2$ benefit of blending ETBE*
- Current study focuses on higher ether - TAEE

*Study on Relative $CO_2$ Savings Comparing Ethanol and ETBE as a Gasoline Component, Hart Energy, July 2007

# TAEE vs. Ethanol

- Lower crude oil/refinery fuel requirements
- Oxygenate reduced refinery octane requirement, in general lower gasoline aromatics
- Aromatics reduction in high TAEE case – lower gasoline carbon factor
- Lower gasoline consumption in TAEE 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

| | Base Case | Ethanol 3 vol% | Ethanol 5 vol% | TAEE 3 vol% EtOH | TAEE 5 vol% EtOH |
|---|---|---|---|---|---|
| Specific Gravity | 0.74 | 0.75 | 0.75 | 0.75 | 0.75 |
| Aromatics [vol%] | 34.8 | 34.8 | 34.8 | 34.8 | 33.2 |
| Olefin [vol%] | 6.7 | 6.9 | 5.9 | 3.7 | 4.9 |
| Ethanol [vol%] | - | 3.0 | 5.0 | - | - |
| TAEE [vol%] | - (1) | - | - | 7.9 | 12.7 |

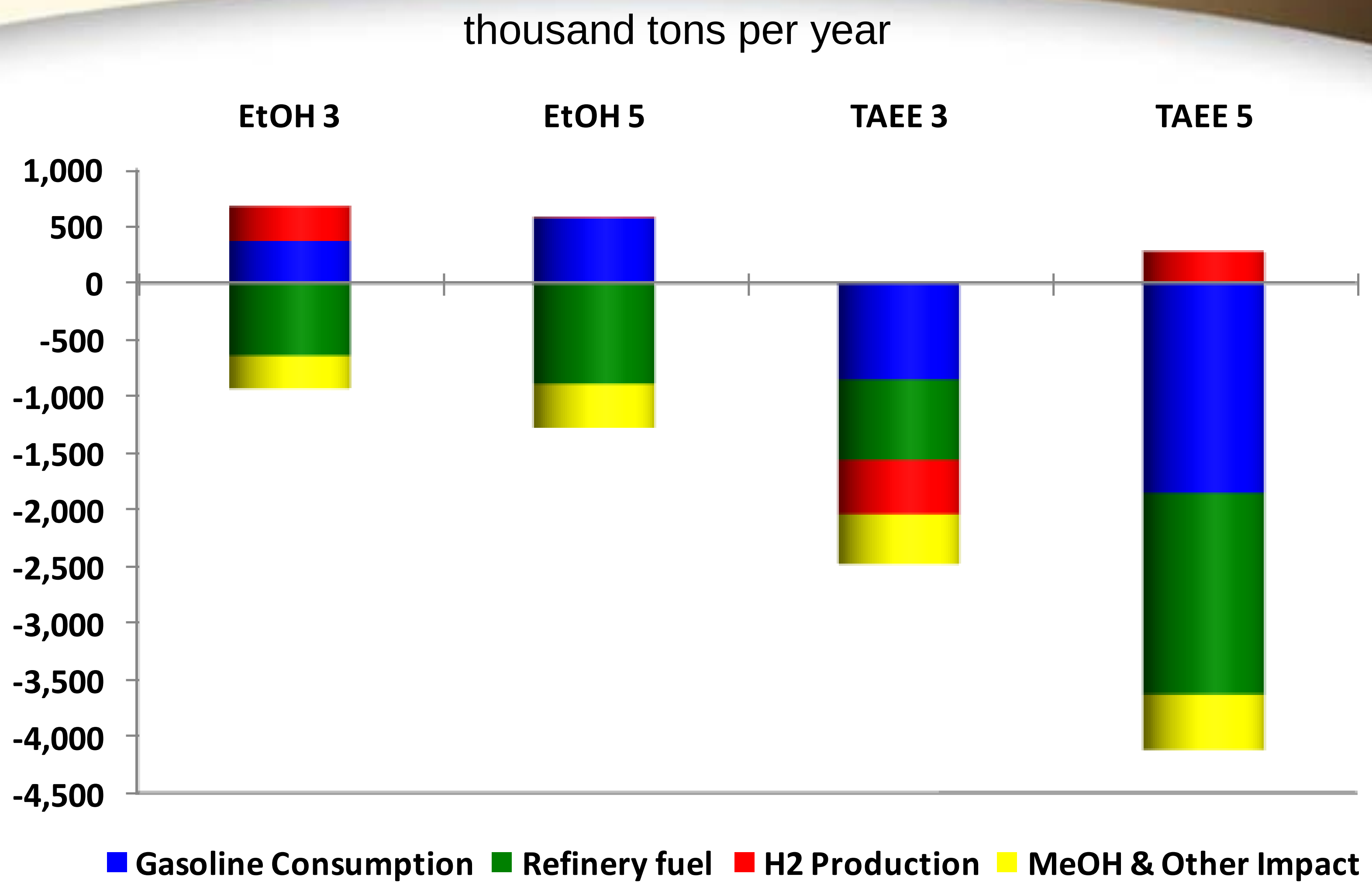
[1]MTBE = 1.3 vol%; TAME = 0.4 vol%

# Energy/$CO_2$ Characteristics

| | Base Case | Ethanol 3 vol% | Ethanol 5 vol% | TAEE 3 vol% EtOH | TAEE 5 vol% EtOH |
|---|---|---|---|---|---|
| Gasoline Energy Content [MJ/kg] | 31.69 | 31.59 | 31.51 | 31.74 | 31.54 |
| Gasoline Consumption [million tons/year] | 102.24 | 103.19 | 103.98 | 102.93 | 103.57 |
| Gasoline Carbon Factor | 0.866 | 0.859 | 0.853 | 0.858 | 0.850 |
| | | | | | |
| Process Fuel [PJ/year]* | 1,860 | 1,850 | 1,840 | 1,850 | 1,830 |

*Refinery fuel plus merchant methanol plant fuel

# $CO_2$ Emission Reduction



# 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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