Methanol as an alternative transportation fuel in the US

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US experience with Methanol

- Large scale pilot tests mostly in California during the 80’s and 90’s demonstrated that methanol is a viable fuel
- Both dedicated and Flex Fuel vehicles were marketed, in light duty and heavy duty (buses)
  - At peak
    - 21,000 M85 flexible fuel vehicles
    - 12 million gallons consumed (1993)
- Refueling stations provided limited distribution of methanol
  - Finding methanol station is a major consumer inconvenience
US experience with Methanol

- Methanol succumbed to decreasing oil prices and lack of advocacy, replaced by MTBE (now banned) and ethanol

History of petroleum price

- $/Barrel
- Decrease in demand, increase in non-OPEC supply
- Iran/Iraq War
- Iranian Revolution
- Oil from North Sea, Alaska
- Yom Kippur War
- Arab Oil Embargo
- Calif. Methanol program starts (1980)
- Methanol FFV vehicles peaked (1997)
- Calif. Methanol program ends (2005)

Event markers:
- Constant 2004$
- $ of the day
- US & world financial crisis
- Iraq war
- Demand of emerging market; limited refinery capacity
- Calif. Methanol program starts (1980)
- Methanol FFV vehicles peaked (1997)
- Calif. Methanol program ends (2005)
Methanol use worldwide: China

• Methanol production/consumption
  – China is the largest methanol producer (from coal)
  – China consumes the largest amount of methanol in transportation (2010 est. 1.5 to 2 billion gallons)

• Vehicles
  – Light-Duty vehicles are being introduced into regular fleets (private) as well as commercial fleets
  – No dedicated vehicles yet, but several methanol-capable models are in production

• Infrastructure
  – Distribution is becoming widespread, both with high and low methanol blends

• Lower fuel cost obtained by using methanol blends, driving customer interest
World methanol production

(1 MT corresponds to 338 gallons)
Production

• US produced ~ 20% of world methanol in 2000, present production down to ~ 2% of world methanol
  – Unfavorable economics in the US, with cheap “stranded” natural gas elsewhere
  – US production in 2010 ~ 1 million tons (300 million gallons)

• In the US, estimated present day price of methanol is comparable (at the pump, on same energy-basis) to gasoline
Ethanol: Includes subsidy of ~ $0.45 /gallon for ethanol

Methanol: wholesale+distribution+taxes
Methanol production

• Methanol can be produced from natural gas, coal or biomass
  – Established method
    ➢ Convert feed stock to synthesis gas
    ➢ Catalytic conversion of synthesis gas to liquid fuel
      – Process favors methanol output
Methanol production from fossil fuels

- Either coal or natural gas could provide enough methanol to satisfy a substantial fraction of the US liquid fuel in the near term.

Time-to-exhausting of US reserves if entirely committed to methanol (10% displacement of liquid transportation fuels)

| Reserves/Production methanol ratio (years) | NG to methanol |
|                                          | including shale gas |
|                                          | Coal to methanol |
|                                          | 121 |
|                                          | 429 |
|                                          | > 1000 |
Methanol in transportation
Sustainable transportation: biomass-to-methanol

- Alcohols can be manufactured through thermochemical processes (conversion of biomass to synthesis gas) followed by catalytic reactors:
  - Catalytic conversion favors methanol, rather than ethanol, production
  - It is an established alternative to biological production of cellulosic ethanol
Efficiency values take into consideration of feed stock, transportation, conversion, and distribution; each consideration is fuel specific.

Methanol in transportation
Sustainable transportation: biomass-to-methanol

• There is an abundance and variety of biomass sources in the US:
  – Agricultural residues, forest resources, energy crops, and municipal waste
  – A substantial fraction of liquid fuel consumption in the US could be met with bio-fuels from biomass
    ➢ With decrease in consumption, all liquid fuel consumption may be met

• Cost of methanol from biomass expected to be comparable to cost from natural gas
  – Cost of biomass feedstock is comparable to natural gas (including harvesting, transportation and handling of biomass)
Biomass-to-methanol production potential

(Ref: 2009 US consumes 138 billion gallons of gasoline; corresponds to 280 billion gallons of methanol)

Methanol in transportation
Fuel characteristics

• Combustion properties
  – Very high octane
    ➢ can be used in high compression, highly turbocharged engines
  – Dedicated methanol engines can have efficiency approaching that of today’s diesel engines, but potentially less expensive
    ➢ Lower cost-of-ownership to operator

• Exhaust emissions effectively controlled by a 3-way catalyst
Methanol in transportation

Fuel characteristics

• Energy density lower (45%) than diesel or gasoline (requires larger tank or decreases range)
• Phase separation from hydrocarbon an issue at lower blending ratios, requiring co-solvents
• Evaporative emissions from lower blending ratios requires increased canister size
• Requires corrosion-resistant hardware
• More difficult cold start

Technology for methanol in transportation has been proven; there is no technical hurdle for vehicle application and for distribution
Methanol in transportation

Health impact

• Prompt toxicity (median lethal dose) of methanol, ethanol, gasoline and diesel comparable
  – Exposure by ingestion, inhalation or contact

• Morbidity of methanol is more serious than ethanol
  – Affects central nervous system and can cause blindness

• In 2007, in the US, 11 deaths from over 2000 exposures

• Antidotes exist with early diagnosis and treatment

• In the US demonstration program in CA, with 20 years of experience and over 200 M miles driven on methanol, not a single harmful event

• There are existing commercial products with significant methanol content (e.g. wind shield wiper fluid)
Prompt toxicity

LD50: lethal dose for 50% kill
Methanol in transportation

Environmental impact

• Consequence of methanol spills
  – Half lives of methanol in soil, air and water longer than ethanol
  – Decays much faster than hydrocarbons

• Water soluble
  – Can migrate in the subsurface water, but decays within a few days (1-7 days)
Methanol in transportation

Safety

• Methanol safety characteristics:
  – Hard to ignite (much harder than gasoline and ethanol, comparable to diesel)
  – Lower radiant heat (lower flame temperatures)
  – Burns without smoke that obscure the objects for rescuers
  – Can be put out with water
  – However, methanol is nearly invisible in direct sunlight

• Fuel of choice in several racing categories: IRL (1996-2006), CART (1979-2007), drag racing, Monster Truck racing
Methanol in transportation

Distribution

• Distribution of methanol has comparable challenges to ethanol
  – Can be transported by barge, railroad or truck tanker
  – In the US, limited methanol pipeline transmission for short distances
  – However, methanol pipeline transmission demonstrated in Canada over long distances

• Methanol dispenser, pump and storage tanks at service station require appropriate materials
Methanol: the case for it

- **Energy security**
  - Must replace imported transportation fuel in a major way
    - Upwards of 50%; preferably 80-100%

- **Sustainability**
  - Low carbon intensity
  - Does not impact food chain
Methanol: the case for it

• Methanol is a safe and viable fuel
  – No technical hurdle for vehicle use and distribution

• Not as good as ethanol as a transportation fuel (energy density and ease of handling)

• Advantage of methanol from renewable biomass:
  – Thermo-chemical production is energetically efficient and has been well developed
  – In comparison, large scale ethanol production from cellulosic materials is promising but not yet ready
Bridging option

• Methanol from natural gas and coal as bridging option to renewable methanol
  – Large scale production, infra-structure and vehicle use can be developed
  – Such system is also amenable to the use of ethanol (or other renewable energy carriers), should large scale bio-production of cellulosic ethanol be realized in the future
Methanol: the case

• Methanol is the only option for large scale deployment of alternative transportation liquid fuel in the US for the intermediate future

• To realize this methanol option, large capital investment and substantial political leadership are needed