Calling all (Methanol) Cars

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Nexant provides services to help our clients make better decisions, in methanol and across the sector

Nexant Proposition		Differentiation
Market Analysis	▪ Corporate strategy development and business plan review; master planning ▪ Portfolio analysis and market segmentation studies, feasibility studies ▪ Strategic options and screening, innovation strategy, market entry, company and product acquisition screening, corporate vision development, management workshops	In-house databases Proven methodologies Primary and secondary research
Technology Assessment	▪ Technology and operational benchmarking ▪ Cost of production modelling and benchmarking ▪ Technology evaluation and screening	Strong team of engineers with deep understanding of chemicals process technology
Transaction Support	▪ Project finance: Lenders' independent market, technical and environmental consultant ▪ M&A (corporates and private equity): Commercial, technical and environmental due diligence support ▪ Buy-side due diligence and vendor due diligence	High-quality risk and value focused evaluation based on real market and technical insight
Strategic Planning	▪ Corporate strategy development and business plan review; master planning ▪ Portfolio analysis and market segmentation studies, feasibility studies ▪ Strategic options and screening, innovation strategy, market entry, company and product acquisition screening, corporate vision development, management workshops	Deep industry knowledge Able to identify commercially viable strategic options
Independent Expert	▪ Expert advisor ▪ Litigation support	Highly experienced and credible experts

Situation – search for a “better” auto fuel

- Low cost
- Stable supply (safe, secure)
- Performance/efficient in an internal combustion engine
- Available (infrastructure)
- Low emissions/air quality
- Renewable is a plus
- Energy security

Could methanol be a solution?

Why methanol? It's a good, clean fuel!

- 25% higher thermal efficiency over gasoline with lower emissions
  - High octane
  - Fast flame speed
  - High latent heat of vaporization (improved charge cooling)
- Burns more cleanly and efficiently than gasoline
  - Reduces NOx and CO formation
- EPA Fact Sheet – Methanol: Clean Alternative Fuel, with a Success Story (2002)
- Cost – increased control over cost, less cost volatility, less politicization (absolute cost assumed about on par)

We want it!!!!

Complications

- Very entrenched petroleum
- Fiercely protected sector
- Established infrastructure is key (vehicles, filling stations, etc.)
- Supply of methanol today – many new methanol plants would need to be built

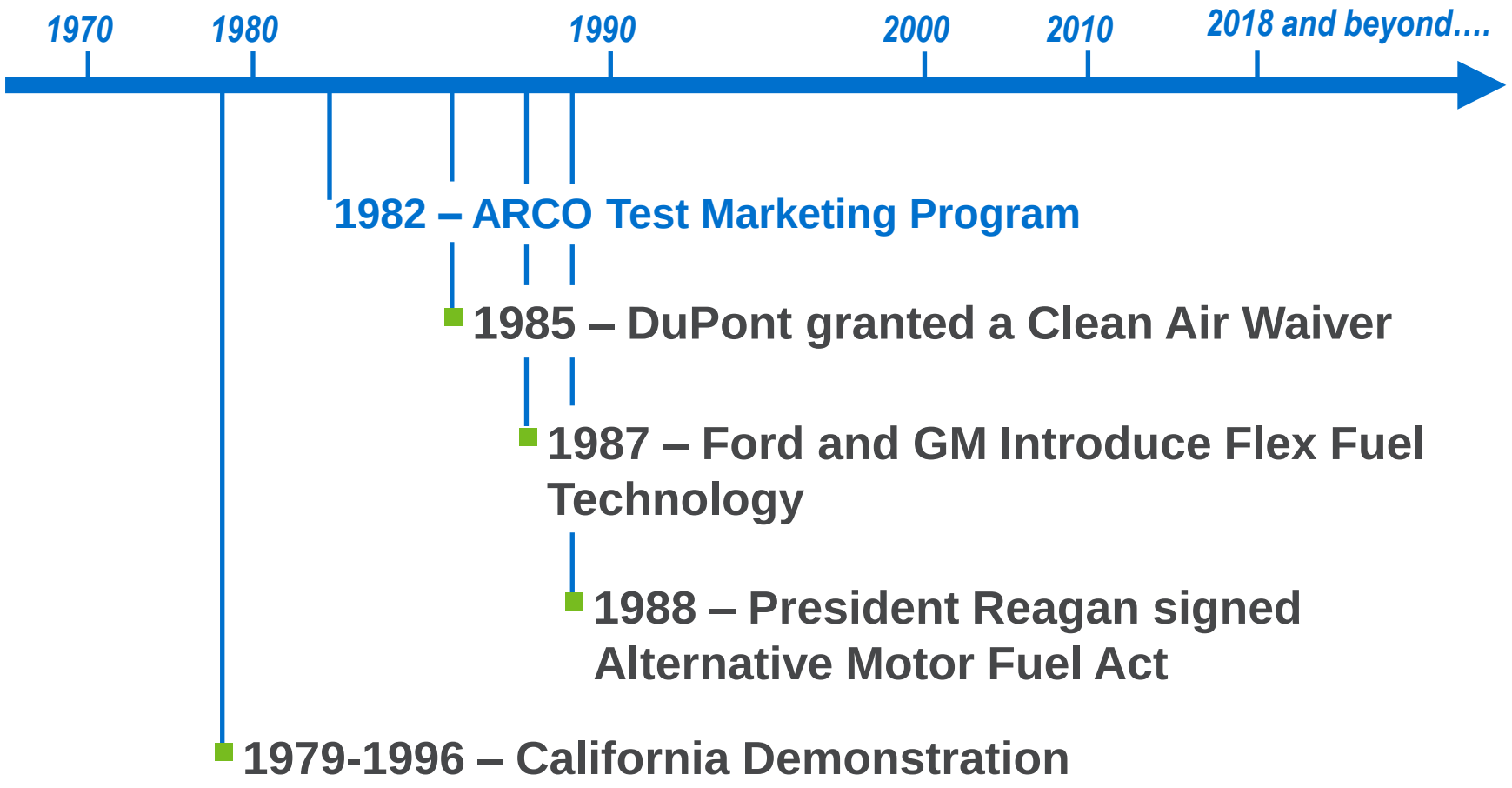
Can the positives outweigh the negatives?

Texas A&M Transportation Institute - Alternative Fuel Vehicle Forecasts, April 2016

- Alternative fuels considered
  - Electric
  - Natural gases
  - Ethanol
  - Propane
  - Hydrogen fuel cell
- Methanol was discussed but not considered an alternative

Why not methanol when it has a strong history of technical success?

Methanol's history as an auto fuel



ARCO test marketing program 1982

- OXINOL (Methanol/TBA blend)
- EPA granted a waiver for OXINOL's use in November 1981
- Blended into gasoline at Philadelphia refinery
- 100 filling stations in Pennsylvania
- Expanded to 1,300 filling stations in the Northeast
- At peak used ~35MM gallons/year of methanol in gasoline blends
- Sonoco participated and offered methanol blends

However, it did not catch on with other refiners and efforts were abandoned in 1986

DuPont was granted a Clean Air Waiver in 1985

- Allow methanol blending up to 5 percent
- Minimum 2.5 percent co-solvent alcohol
- Maximum 3.7 percent O2 (by weight)

Abandoned in favor of ethanol and MTBE

California demonstration 1979-1996

- Alternative fuels evaluated
  - Electricity
  - Natural gas
  - Methanol
  - Ethanol
  - Hydrogen
  - Propane

Methanol was selected as having the greatest potential for replacing petroleum fuels for internal combustion engines on a widespread basis (M85)

California demonstration 1979-1996 (Cont.)

- Three-Agency Methanol Task Force (Clean Fuels Working Group) with the California Air Resources Board (CARB) and the South Coast Air Quality Management District (SCAQMD)
- '80/'81 test included 3 fleets operating on methanol and ethanol

8 – 1980 Ford Pintos operating on MeOH and EtOH used in daily fleet service for approx. 18 months

39 – Volkswagen Rabbits and light-duty pickups operating on MeOH and EtOH, logging 350,000 miles

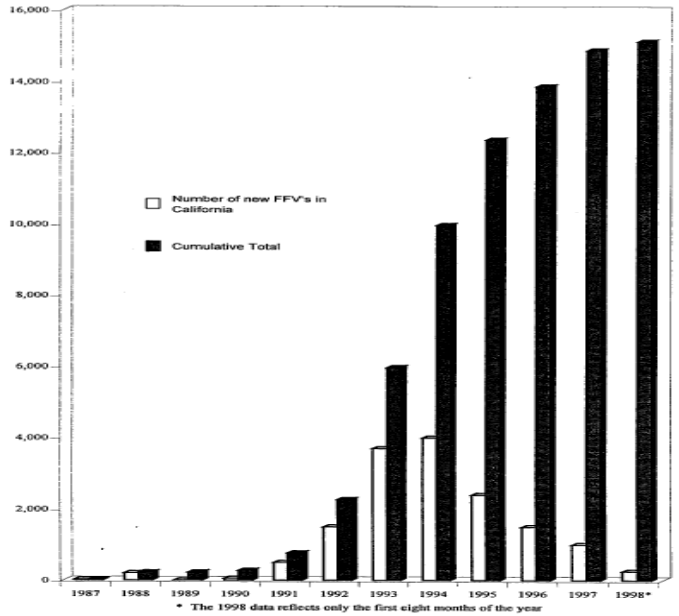
40 – Ford Escorts operating on MeOH, logging over 500,000 miles in LA Country

- Success led to '82-'87 demo of an additional 500 vehicles plus 18 filling stations

Technical success but limited filling stations prevented commercial success

This commercial limitation led to the development of truly Fuel-Flexible Vehicles (FFVs, M85, or gasoline)

Methanol FFVs in California ’87-’98 Revised 11-20-98



Major Fuel Retailers M85 Stations January 1996

Company	Stations in Operation
Arco	14
Chevron	13
Shell	12
Exxon	5
Mobil	3
Texaco	3
Ultramar	2
GET Corp	1
Total	**53**

- Ford and GM introduced flex fuel technology in 1987
- Demo 5,000 FFVs developed and major petro companies cooperated by establishing FFV filling stations
- Ultimately, there were about 15 000 methanol FFVs in California in 1998

But what happened to stop the momentum?

M85 was demonstrated in California in the 1990s as a fuel for FFVs capable of using either M85 or gasoline

- While much was learned from the methanol fuel demonstration, fuel retailers lost interest in the program
  - Chevron withdrew in 1992
  - ARCO and Shell announced in 1995 that they would not establish any more M85 retail stations
- Methanol could not economically compete with gasoline
  - Energy density is only one-half that of gasoline
  - Thermal efficiency of methanol in an internal combustion engine is similar to that of gasoline
- By 2001, natural gas became the leading alternative fuel in California in terms of commercially available vehicles and the number of filling stations

California M85 testing was a technical success and a commercial failure

Methanol had it's chance

- Methanol was envisioned as an auto fuel of the future in the 1980s, based on development work started in the 1970s
- Was tried from different perspectives by different stakeholders:
  - Ford - BP - Chevron - Mobil - Texaco - DuPont
  - GM - ARCO - Exxon - Shell - Texas Methanol
  - Chrysler
- Demo fleets validated in '80s (w/out optimization for MeOH fuel)
  - Ford 11% efficiency improvement
  - Buick 21% gain in 30,000 mile road tests of multiple vehicles
- Methanol lean burn technology developed by Toyota and Volkswagen
- In 1989, President GHWBush promised 0.5 MM MeOH cars on road by '96 and 1.0 MM by '98

Downside realities of methanol as an auto fuel

- M100/low concentration mixtures have cold start and other challenges, so M85 used
- M85 energy density much less than gasoline or diesel, less than ethanol
- It takes more than a gallon of M85 to provide same mileage as a gallon of gasoline, adding weight of fuel and the need for additional physical space in car
- Must establish an infrastructure for fuel distribution and fueling
- Big oil resistance
- MTBE diverted attention from alcohol fuels
- When MTBE fell out of favour, ethanol filled the void – ethanol infrastructure was established and it was institutionalized as the ubiquitous alcohol fuel
- Need to build methanol plants (expensive and time-consuming)

So…. Is that it for methanol as an auto fuel?

Methanol as an auto fuel today – China

- M15 standards
  - Lack of national standard
  - 15 provincial standards – led by use in Shanxi, Shaanxi, and Guizhou (coal regions)
  - Sinopec in Shanxi 1 000 filling stations, 400 000 mtpa of MeOH fuel
- M100 being used in Xi'an, China
  - 60 taxis in operation w/15 filling stations (as of Dec 2018)
  - Reporter test drive concludes very comfortable with improved power, control, and safety
  - Sees huge benefit in reduced carbon emissions, which is very important in complying with increased pollution controls
  - Target 10 000 M100 taxis and 45 filling stations by end of 2019
- High blend M85/M100 pilot expanded to at least 5 provinces

Chinese manufacturer, Geely has developed methanol cars for over 15 years

Geely's Emgrand M100

Geely Auto's M100 Rally Car in the 2019 Dakar Rally

- Geely's Emgrand M100 was the first mass-produced methanol vehicle
- Geely has methanol vehicle capacity of 300,000+ cars/year
- Geely's methanol taxis have been in operation for over 5 years, traveling nearly one billion kilometers
- Geely has introduced M100 bus, long-haul truck, medium duty truck
- Geely's M100 cars have also been tested in Iceland
  - Carbon Recycling International performed an 18 month test for six M100 cars, traveling over 150 000 km during the trial

Even in China, methanol as an auto fuel has its challenges

- Very dependent on price of crude
  - $100/bbl → 👍
  - $60/bbl → 👎
- Driven by coal availability, emissions benefits
- <10 percent of China methanol demand is for fuel
- Methanol comprises <5 percent of gasoline pool
- Competition
  - Ethanol
  - Hydrogen

Methanol as an auto fuel today – Israel

- Israeli Governmental Directive – reduce share of crude by 30 percent by 2020 and 60 percent by 2025
- M15 national standard approved, meets code, promoted by Dor
- M70 being tested
- Fiat/Chrysler partnering
- Natural gas newly available and accessible
- Nevertheless, tough road to haul
- Function of price of gasoline

Methanol as an auto fuel today – India

India M15 to displace crude imports

- 2019 BS IV-compliant vehicles to use M15 could fulfil PM Modi's target of displacing >10 percent of crude imports by 2030 (M15 alone could get this to 20 percent)
- Could be made from high ash coal
- Ethanol, LNG, e-cars are competition

What's changed? What's the practical potential now?

- Short term potential is tough
  - E10
  - E15
  - Electric
  - H2 fuel cells
  - DME
  - CNG, LPG, LNG
  - Biodiesel
  - Diesel+SCR
- Longer term potential challenging
  - Renewable potential is a plus
  - DOE supported cellulosic ethanol, why not renewable methanol
  - Need for many methanol plants
    - From a practical perspective are we ready to build that many (YOU are, Nexant is, but is the public?)

What do you think? How can we make methanol as an auto fuel a reality?

Conclusions

- As a conventional vehicle fuel, methanol is technically demonstrated but is not commercially attractive
- Methanol was tested for many years as an auto fuel as a strategy to reduce air pollutant emissions and reduce dependence on petroleum liquids. Despite these efforts, methanol was not a commercial success
- Methanol's relatively low energy density (roughly half of that of gasoline on a volumetric basis) has been a real impediment to acceptance in terms of vehicle range
- Methanol has not found enthusiastic consumer acceptance as it:
  - Offers insufficient advantages in price, convenience, or performance
  - Has not been subsidized as ethanol has and with lacking comparable political support, it seems unlikely it will receive required subsidies in the future

Conclusions (Cont.)

- To garner such political and consumer support for methanol as an auto fuel, can methanol position itself as a:
- Solution to natural gas flaring? Have TX/ND subsidize?
- New outlet for the U.S. coal sector? Have WY, WV, KY, PA, MT subsidize and have the coal lobby join with MI's efforts
- Methanol has high technical potential in many ways to dominate the fuel cell auto market, but its introduction and use would represent a major paradigm shift and a challenge for suppliers, distributors, regulators, and consumers
- Marine fuel seems to have more practical short term potential for commercial acceptance of methanol

Can methanol make a comeback as an auto fuel?

"Hope, like faith, is nothing if it is not courageous; it is nothing if it is not ridiculous."
-Thornton Wilder

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