Lessons Learned from US Experiences with Natural Gas, Ethanol, and Methanol as Transportation Fuels

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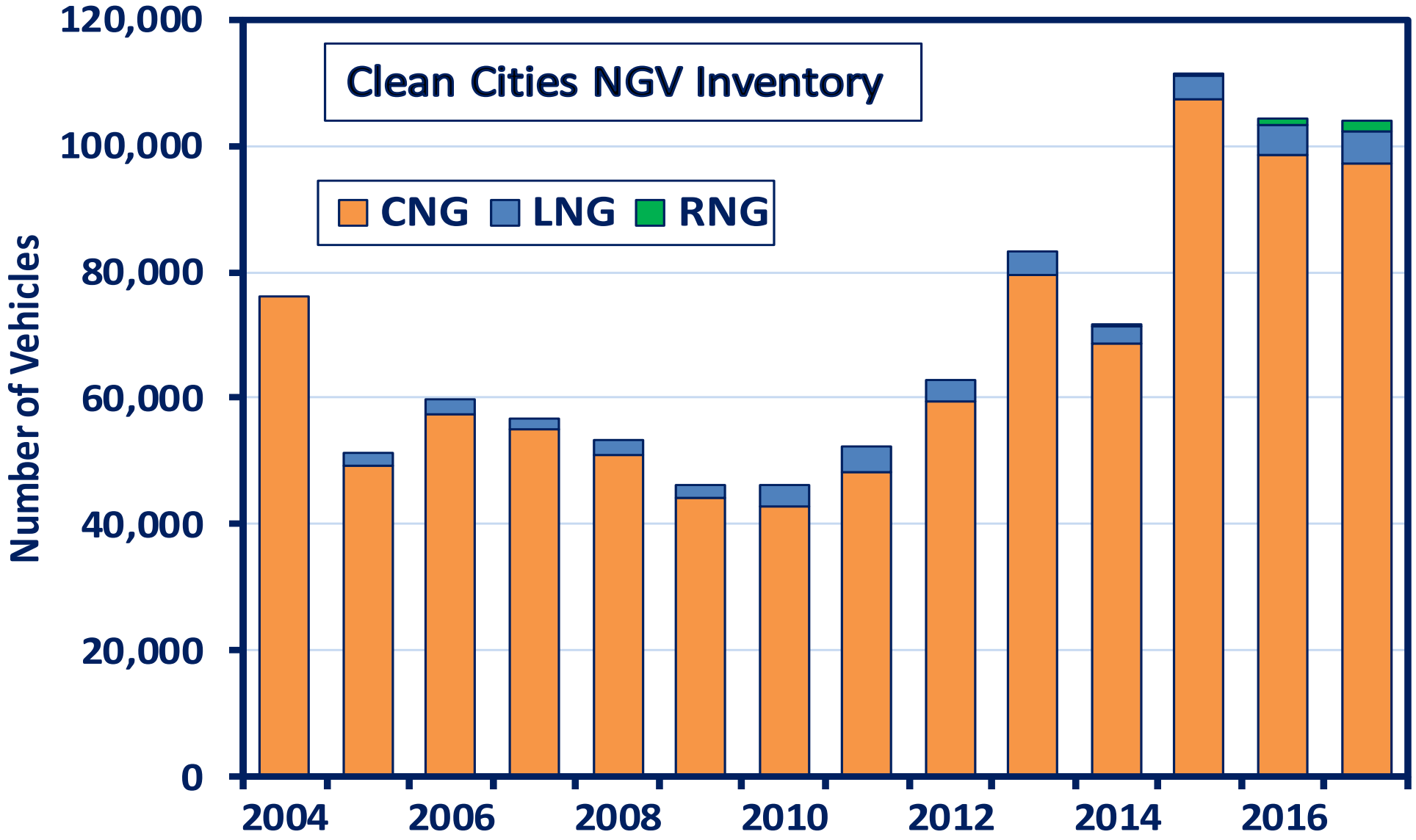
Natural gas vehicle motivations in the U.S.

- 1970s-1980s: oil reduction and energy security
- 1990s-2000s: air quality benefits
- 2000s and on: GHG reductions and economic benefits of domestic NG production

There are more than 100,000 NGVs in the U.S.



U.S. NGV Development 1965-2010 (characterized in 4 stages)

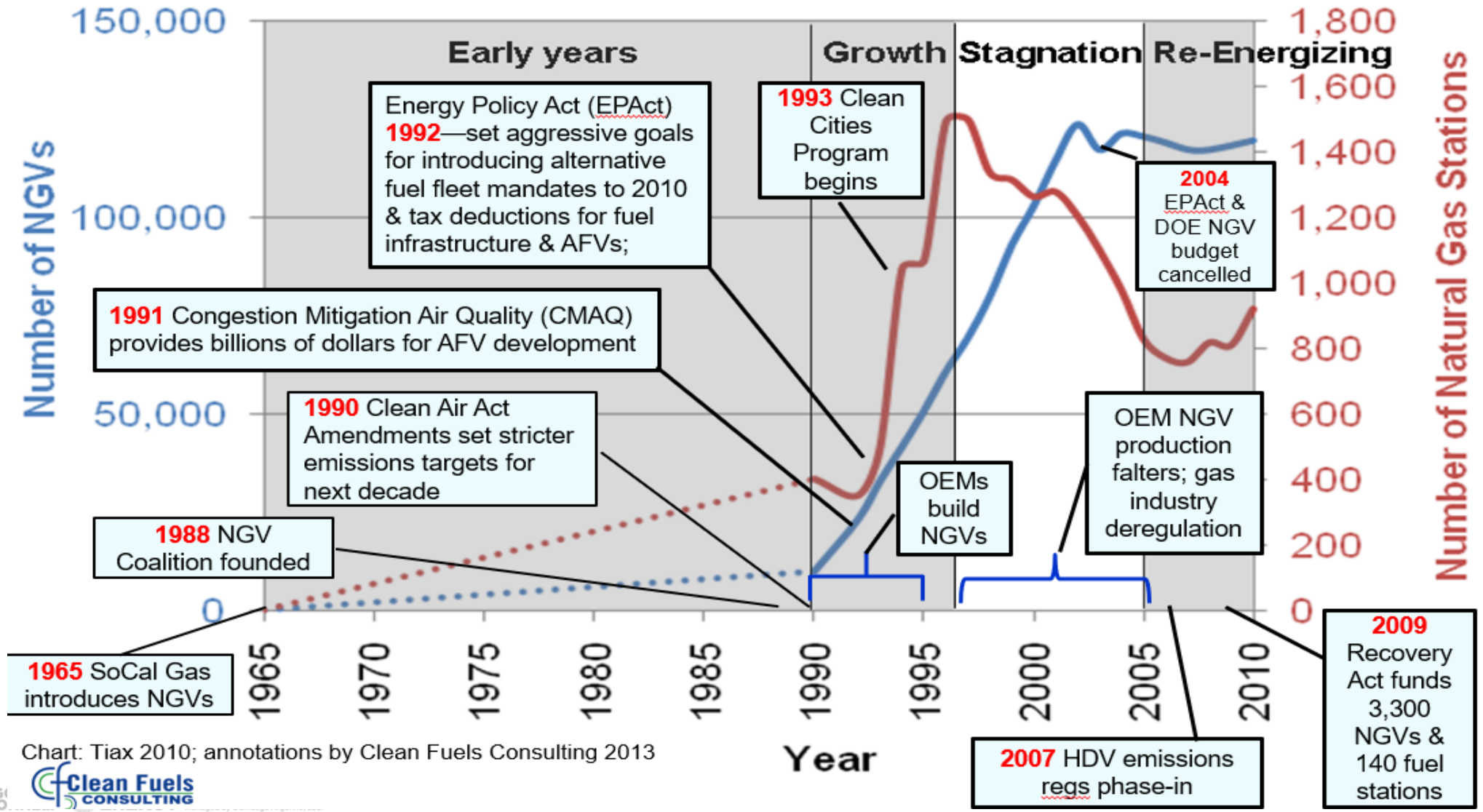
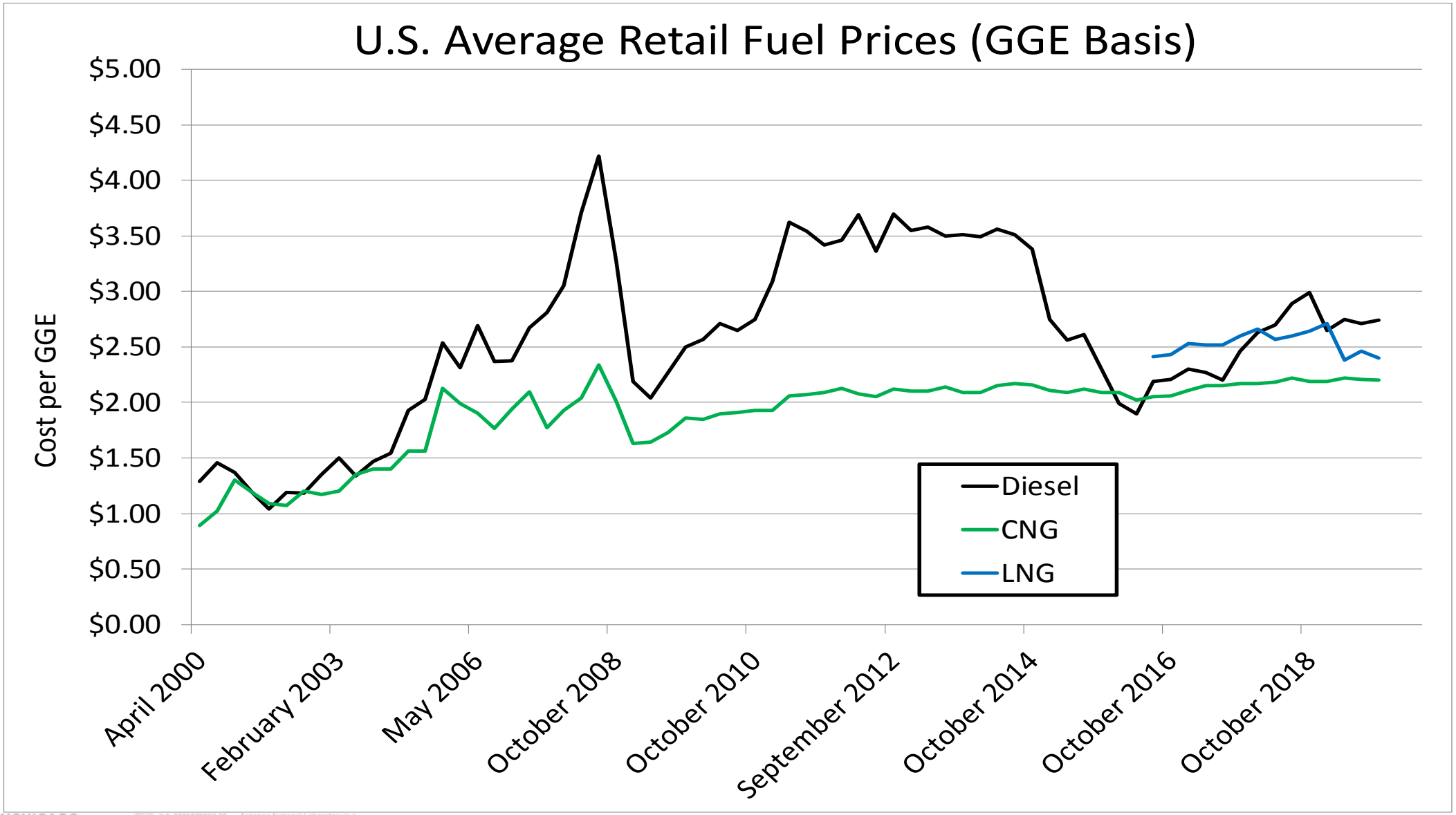


Chart: Tiax 2010; annotations by Clean Fuels Consulting 2013

Historically, NG had price discounts over petroleum fuels, this advantage is disappearing with the current historical low oil price



NGV challenges

- There are 895 public and 696 private CNG refueling stations; and 64 public and 55 private LNG refueling stations
- A large fast-fill CNG station can cost $1 million or more, primarily because high-flow compressors and storage tanks
- A large LNG station can cost $2 million
- At present, the U.S. market only has a few NGV models for medium-duty trucks
- On-board storage tanks are a major cost increase for NGVs
- A typical NG truck can cost $40,000 more than a diesel truck

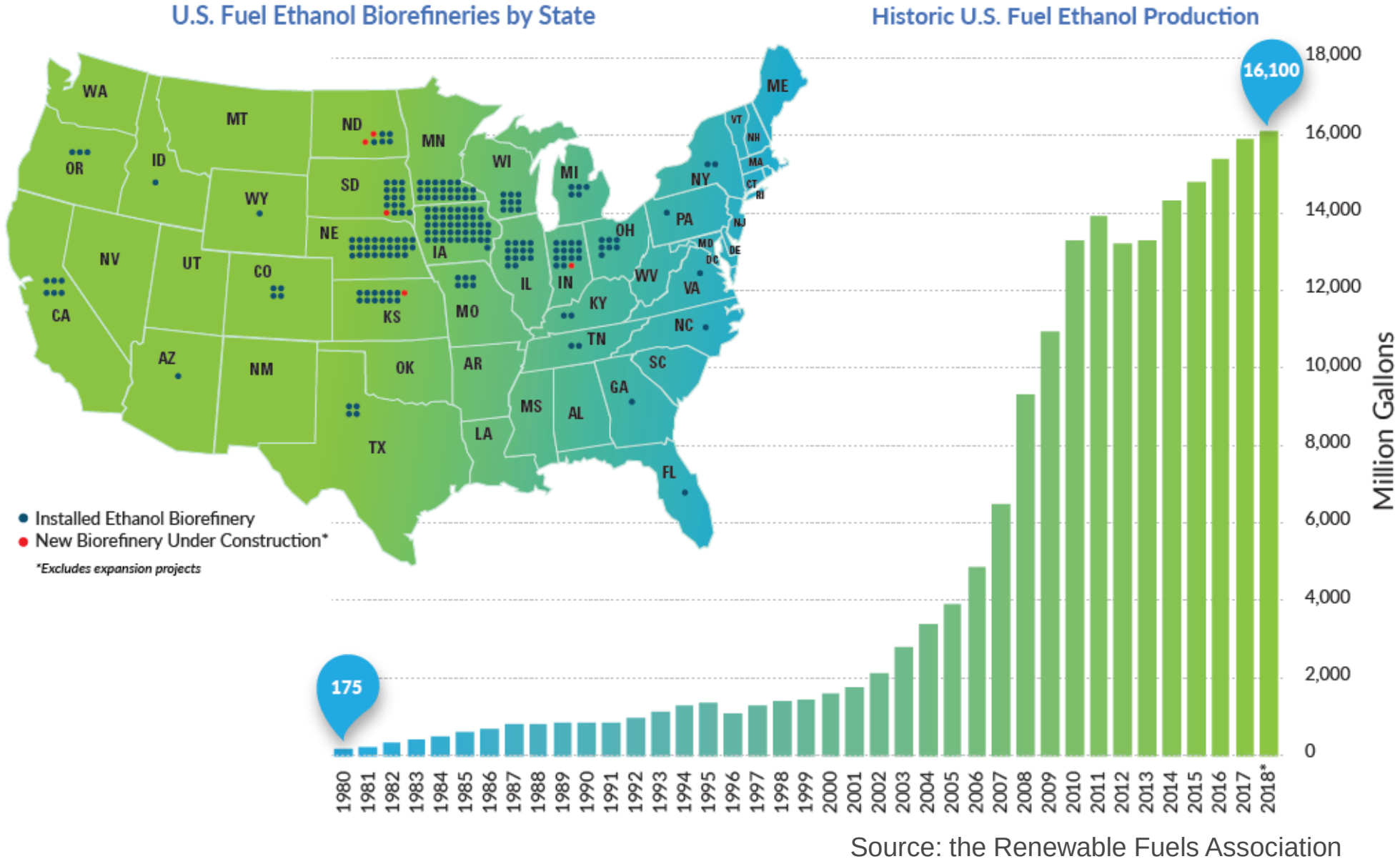
Lessons learned from NGVs in the U.S.

- Value proposition of NGVs has been changing since 1970s, creating inconsistent societal goals for NGVs
- Policies to increase market share are most effective when a long-term comprehensive strategy uses both financial and non-financial incentives
- Federal program aimed directly at supporting deployment of NGVs helps to build partnerships between private and public stakeholders and provide unbiased information to those stakeholders and the general public
- Heavy-duty fleets are the most attractive targets for NG because their high fuel use can lead to significant operational savings from low price NG.
  - However, in many cases, the economic arguments for NGVs are a challenge due to the high cost of the vehicles
  - Fluctuations in oil prices can have strong impacts on the enthusiasm for such vehicles

Timeline of U.S. policies promoting ethanol fuel use

- 1975: Energy Policy and Conservation Act (EPAct) established Corporate Average Fuel Economy (CAFE) standards for cars and trucks
- 1988: The Alternative Motor Fuels Act establishes incentives under CAFE for alternative fuel vehicles.
- 1992: The Energy Policy Act of 1992 defines alternative fuels and establishes programs at the federal level to increase the use and research of alternative fuels.
- 2005: The Energy Policy Act of 2005 established the Renewable Fuel Standard (RFS) with a minimum volume of renewable biofuels to be blended into the transportation fuel supply.
- 2007: The Energy Independence and Security Act (EISA) with significantly increased volume of renewable fuels mandated
- 2009: California established the Low Carbon Fuel Standard

The U.S. is No.1 country of ethanol production and consumption

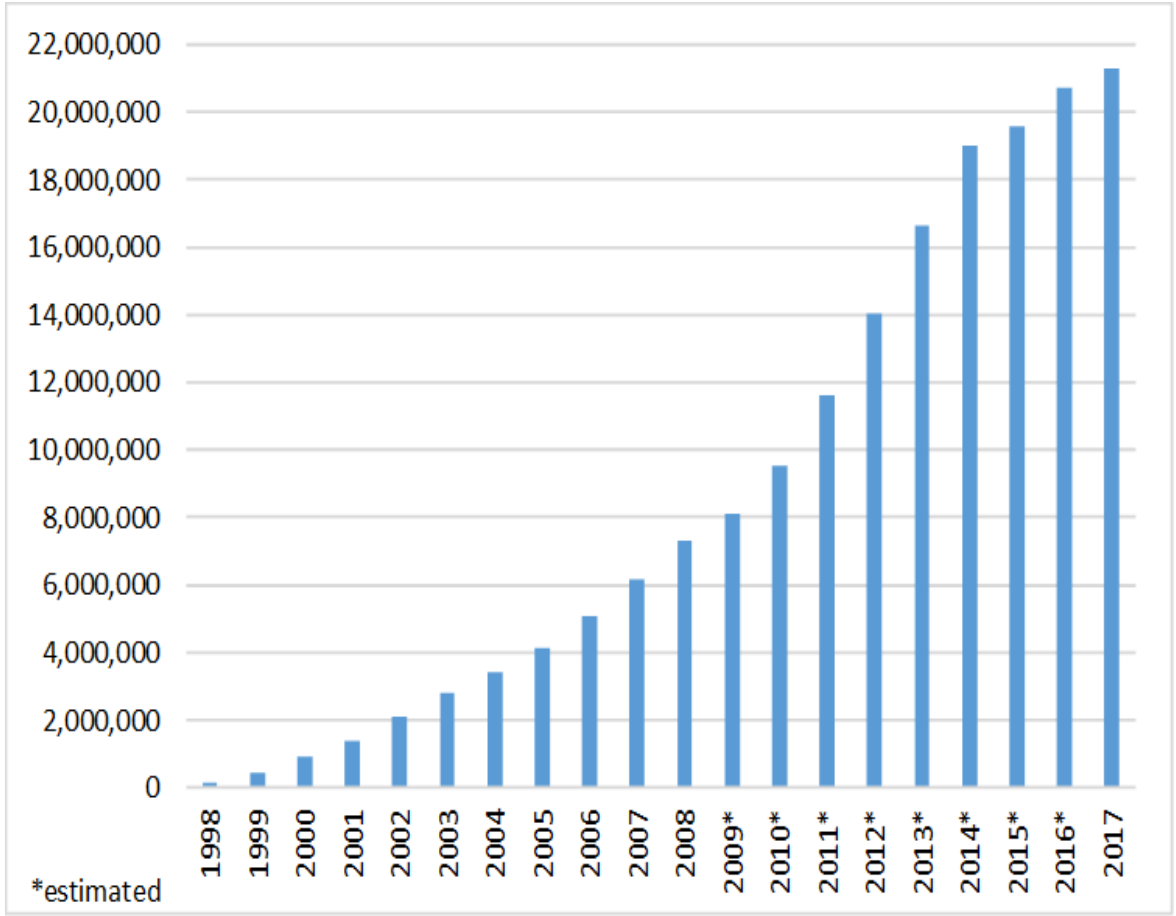


Source: the Renewable Fuels Association

Technical challenges of ethanol fuel

- Low-level blending: historically E10 and now E15
  - Blending wall has been limiting total ethanol fuel volume in the U.S.
- High-level blending up to E85
  - Need new vehicles such as flexible fuel vehicles (FFVs)
  - Need stations with E85 available
- Low energy content of ethanol vs. gasoline
  - Volumetric fuel economy reduction

E85 FFV Stock in the U.S.



Though 22 million FFVs are significant, they are a small share of 260 million vehicles in the U.S.

Successes of ethanol policies

- State and federal regulation was aimed at targets for ozone and aromatics reduction in early years
- Active advocacy by stakeholders to increase domestically produced ethanol in the transportation fuel market under policies such as the federal renewable fuel standard
- Positive production margins and price-competitiveness in fuel octane enhancers
- Ethanol in reducing carbon intensities of transportation fuel pools in state-level low-carbon fuel standards such as the California Low Carbon Fuel Standard and the Oregon Clean Fuel Program

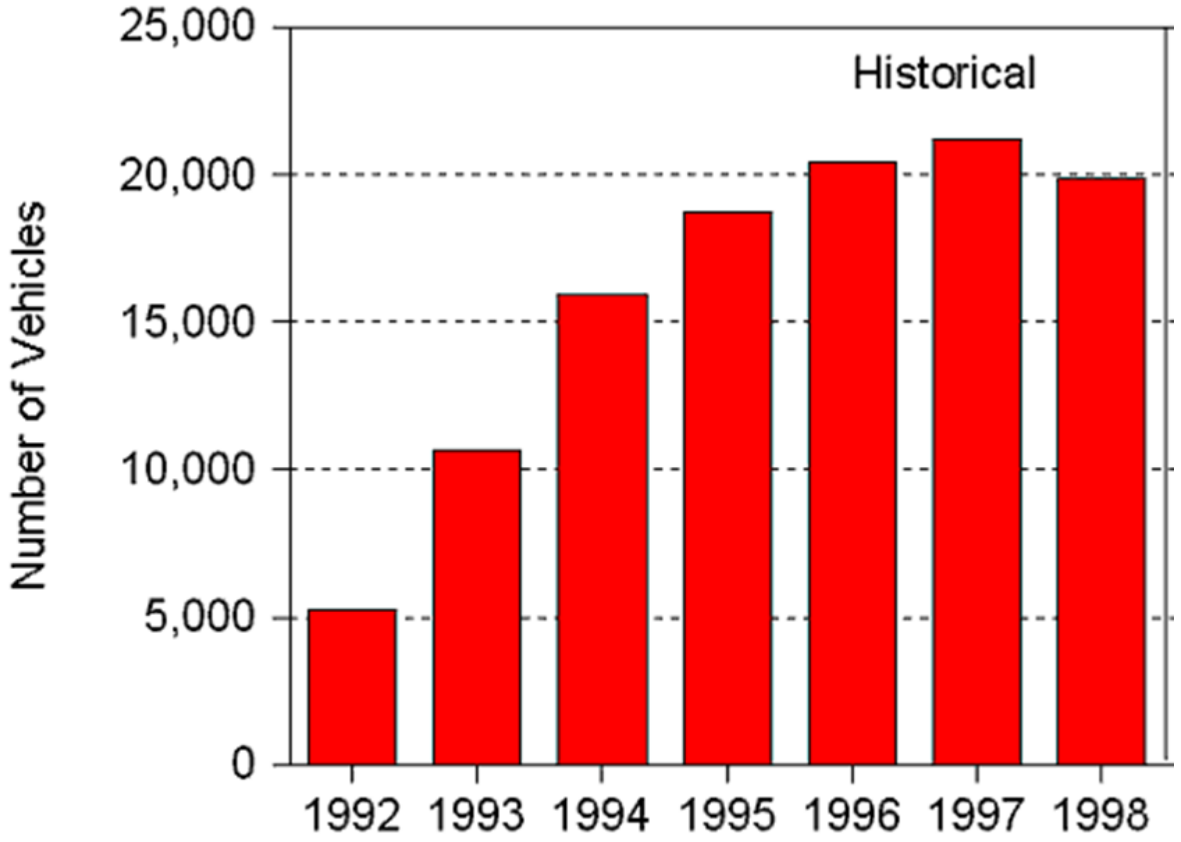
Lessons learned from U.S. ethanol experiences

- Ethanol has long held a prominent position in the agricultural sector and the U.S. economy at large
- Ethanol provides a renewable domestic component in gasoline and contributes to improved octane and reduce ozone precursor emissions
- Arguments for ethanol as a necessary gasoline component for ozone control have become less persuasive. This has created a political situation that has positioned oil-refining interests against those of the agricultural sector
- The strongest case for ethanol in the fuel mix has now shifted to its property as a net reducer of greenhouse gas emissions. This argument for advancing the cellulosic ethanol production pathway remains strong
- Ethanol‘s greater challenges ahead will be posed by competition from other alternative fuels (e.g., electricity), and strong domestic petroleum production

Promotion and use of methanol in the U.S. have a long history

- 1965: Introduction to Indy car competition
- 1979: Introduction of methanol as a gasoline blending agent, in concentrations of 5 to 15%, in 1979 Honda Civics
- 1981: Introduction of dedicated methanol vehicles (40 Ford Escorts, 39 VW of America Rabbits); 500 Escorts in 1983
- 1981-1990: Period of dedicated methanol vehicles (16 models, including transit buses); total over 900 vehicles
- 1985-1992: Ford delivered about 500 experimental FFVs, incl. Escort, Taurus, and Crown Victoria LTDs, plus a few 5L Econoline vans
- 1988: 150 methanol (both M100 and M85) school buses delivered to California schools
- 1991: First production of M85 vehicles (GM Lumina)
- 1992: Ford began delivering production M85 FFV Taurus
- 1992-1995: ARCO, Shell and Chevron pulled back on their refueling station commitments
- 1993-1996: Hertz began renting M85 FFVs, starting with 100 Ford Taurus's in 1993, maximum purchases of over 700 vehicles in both 1995 and 1996
- 1997: Maximum methanol vehicle fleet of over 21,000 vehicles, 15,000 in California
- 1998: Methanol vehicle production ends

Historical M85 FFV sales in the U.S. and challenges



The annual M85 FFV sales were far less than E85 FFV sales

Challenges for methanol in the U.S.

- Introduction of reformulated gasoline canceled methanol's emissions advantages
- Reluctance on the part of fuel providers to embrace methanol as a fuel option
- The environmental failure of MTBE and its tarnishing of its methanol feedstock

Lessons learned from U.S. methanol experiences

- Gasoline vehicles are strong competitor in terms of cost and reliability
- Fuel marketers may have little incentive to cooperate with the rollout of an alternative fuel
- Lack of experience with the new fuel is magnified by the comparison with the current gasoline and diesel.
- The difficulties of replacing gasoline with an alternative fuel implies that strong advocacy must be present for a replacement to have any chance at all. In the case of methanol, the strongest potential advocates initially were the environmental community and the methanol chemical industry.
- During the period in which methanol was being rolled out, it was more expensive (on a “per mile” basis) than regular unleaded gasoline, thus yielding little incentive for owners of flex-fueled vehicles to purchase the fuel and little incentive for potential methanol-capable vehicle purchasers to buy them

Questions?