California Alternative Fuels Market Assessment 2006

Joint Workshop on
Increasing the Use of Alternative Transportation Fuels
California Energy Commission
Sacramento, California

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Background

- **California's transportation sector remains nearly 100% reliant on petroleum fuels.**
  - 14.1 billion gal gasoline, 4.1 billion gal diesel fuel (2004)
  - Remains so despite over two decades of effort aimed at introducing alternative fuels into the motor vehicle fuel marketplace
  - Even though ethanol is now a component of CaRFG3 (E5.7)
- **The state has looked to alternative fuels to aid in reducing this dependence on petroleum.**
- **The California Alternative Fuels Market Assessment is a periodic review of the state's progress toward increasing transportation sector alternative fuels use.**
  - 2001 initial
  - 2003 update
  - 2006 update

Background

The 2006 California Alternative Fuels Market Assessment focuses on establishing the baseline to lead into the State Alternative Fuels Plan required by AB 2007.

For each alternative fuel, the Assessment documents current market conditions in terms of:

- **Quantities of Use**
- **Availability of Vehicles**
- **Fueling Infrastructure and Special Needs**
- **Barriers and Opportunities for Expansion**
- **Overall Assessment**

Business as usual projections attempted.

Following discussion is by fuel: Natural Gas, LPG, Electricity, Ethanol, Alternative Diesel Fuels, Hydrogen.

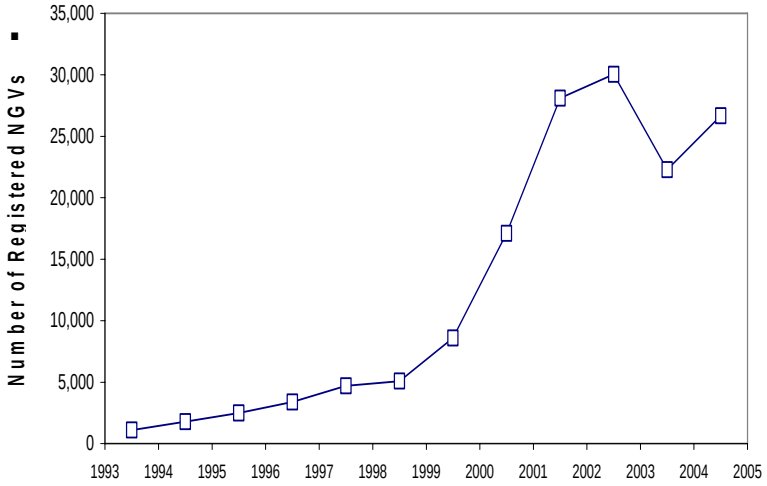
California NGV use indicator summary

Number of NGVs (2004)	**26,700[1]**
Fraction of on-road population, %	**0.11**
OEM LDV models offered (2006)	**3[2]**
LDV engines certified (2006)	**7[3]**
HDV engines certified (2006)	**6**
CNG stations, total (2004)	**365[4]**
public access	**148**
LNG, L/CNG stations, total (2006)	**41**
public access	**— [a]**
CNG dispensed, billion scf (2004)	**3.84**
million gge	**31**
Fraction of petroleum fuel, %	**0.16**
LNG dispensed, million gal (2006)	**36**
million gge	**23**
Fraction of petroleum fuel, %	**0.12**

[a] Some offer access with advance arrangements, rarely used

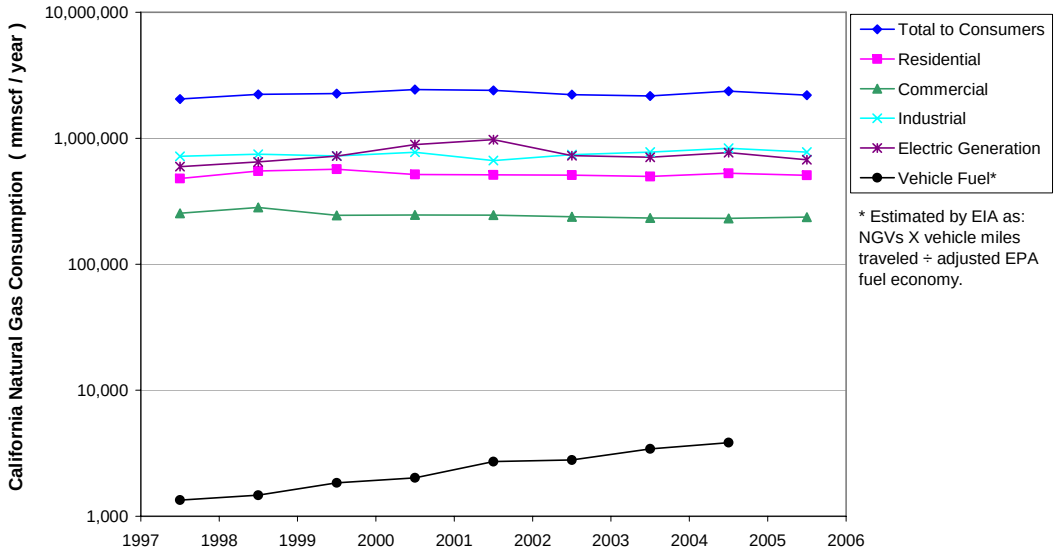
[1] DMV data
[2] NREL AFDC
[3] ARB certification database
[4] 2005 IEPR

Natural Gas Quantities of Use

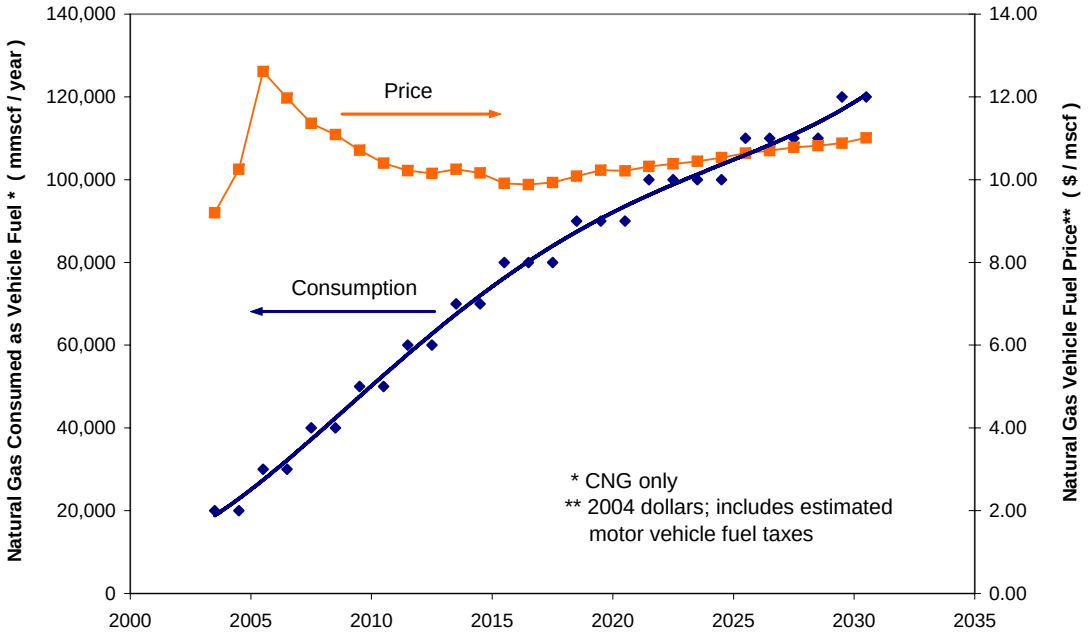


Natural gas vehicle growth

California natural gas consumption



DOE EIA Annual Energy Outlook forecasts growth in consumption, real price stability through 2030.



	2012	2017	2022	2030
Natural gas vehicle fuel consumption, bcf				
U.S.	60	80	100	120
California	11	15	19	22
Petroleum fuel displaced, mmgge				
California	88	120	152	176

The number of light duty OEM NGV offerings has steadily decreased.

Manufacturer	Model	Powertrain	Emissions Certification	CNG Fuel System
General Motors	Chevrolet Silverado, GMC Sierra Pickup Truck	6.0-L V8	ULEV & CA SULEV	Dedicated
General Motors	Chevrolet Silverado, GMC Sierra Pickup Truck	6.0-L V8	ULEV	Bi-Fuel
Honda	GX Sedan	1.7-L I4	SULEV Tier 2, Bin II	Dedicated

Source: DOE NREL AFDC

Ford, Daimler-Chrysler, Toyota have discontinued NGV product offerings.

Honda GX

Heavy duty NG fueled engines remain available.

Manufacturer	Engine Model, Displacement (L)	Power Rating (hp)	Fuel Type	Service Class	Certif. Std. (g/hp-hr) NO_x+NMHC, PM
Cummins	BG, 5.9	195, 200, 230	CNG&LNG	MHD, UB	1.8, 0.01
Cummins	CG, 8.3	250, 275, 280	CNG&LNG	MHD, UB	1.8, 0.01
Cummins	LG, 8.9	320	CNG&LNG	MHD	1.5, 0.01
Deere	8.1	275, 280	CNG&LNG	HHD	1.2, 0.01
Deere	8.1	250	CNG&LNG	MHD	1.2, 0.01
Deere	8.1	250, 275, 280	CNG&LNG	UB	1.2, 0.01
Mack	E7G, 11.9	325, 425	CNG&LNG	HHD	2.4, 0.10
Westport	ISXG, 14.9	425, 464	LNG; DF	HHD	1.2, 0.02

Source: ARB Certification database:

How many refueling stations are there?

- **CNG**
  - Conflicting citations:
    - Low: 118 more or less publicly accessible (CNGVC)
    - High: 365, 40% public access (2005 IEPR, used in preceding slide)
  - Successful stations have anchor fleets.
- **LNG**
  - 28 LNG
  - 10 LNG and L/CNG
  - 3 L/CNG
  - All have anchor fleets

Past projections haven't been met.

- **CNGVP 2002 objectives**
  - 33,000 and 90,000 new light duty NGVs by 2005 and 2007
  - 10,000 and 25,000 new heavy duty NGVs by 2005 and 2007
  - 2004 actual: 21,200 light duty NGVs, 5,400 heavy duty NGVs

Vehicle cost premium, inconvenience not overcome by decreased fuel price.

- **Future relative cost uncertainties**
  - Heavy duty diesel cost disadvantage shrinks as 2010 standards kick in
  - Emission control approaches for NGVs to meet 2010 standards not certain
- **Incentives from EPAct, & Highway bill have yet to play a role**

Business as usual sees some market growth.

- **176 million gge displaced in 2030**
- **Growth fueled by heavy duty sector**
  - Favorable economics
  - Inconvenience only minor issue w/ fleets
  - Continued availability of engine offerings in the heavy duty marketplace essential, expansion into HHD applications would greatly benefit (11 L, 400 hp and larger)

California LPG vehicle fuel use indicator summary

Number of LPG vehicles(2004)	**22,000**
Fraction of on-road population, %	**0.091**
OEM LDV models offered (2006)	**0**
LDV engines certified (2006)	**0**
HDV engines certified (2006)	**4**
LPG stations, total	**235**
public assess	**234**
LPG dispensed, million gal	**26**
million gge	**19**
petroleum fuel fraction, %	**0.098**

Source: Clean Fuel USA

LPG use, U.S. and California

	U.S.	California
Number of LPG on road vehicles		
1999	141,000[a]	33,000
2004	115,000[b]	22,000
LPG vehicle fuel sold, mmgge		
1999	210	29
2004	242	19

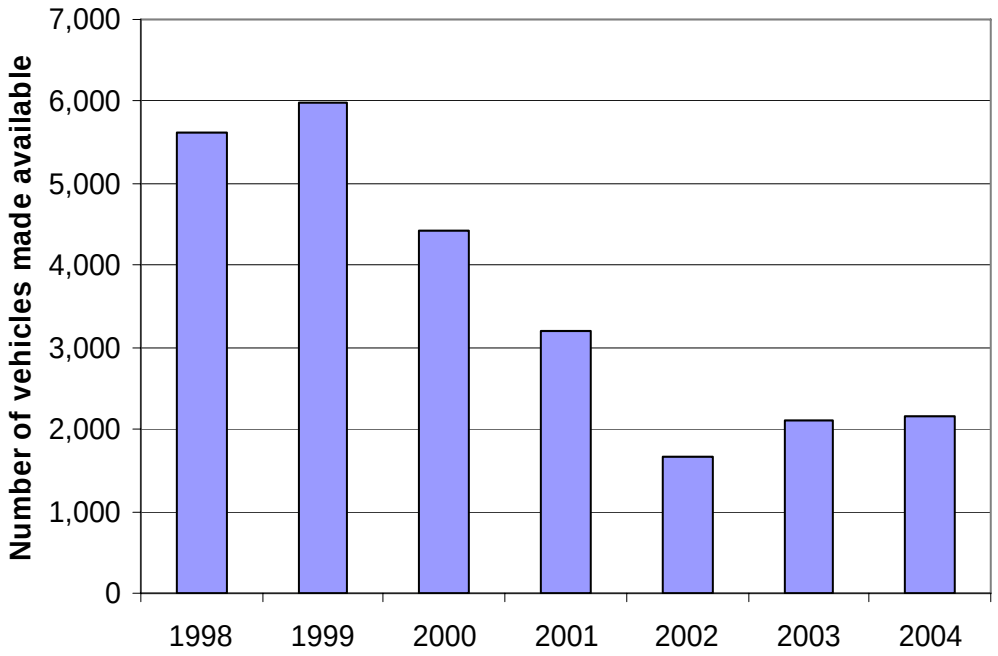
a.1997

b 2002

Source: Propane Education & Research Council, DOE EIA

LPG vehicle fuel use only 1.7% of the total sold in the U.S.

On road LPG vehicles made available in the U.S.



Source: DOE EIA

The number OEM LPG offerings has also steadily decreased.

- **No OEM LPG LDV vehicles have been sold since 2004; only the Ford F-150 bi-fuel pickup trucks were available in 2003 & 2004**
  - No aftermarket conversion kits have been certified since 2002
- **Only 4 MHD MY 2006 LPG engines have been certified**

Manufacturer	Model	Service Type[a]	Fuel System	Displace-ment (L)	NO_x+NMHC (g/bhp-hr)	Cert. Std. NO_x+NMHC
BAF Technologies	V-10	HDO	Dedicated	6.8	0.4	1.0
Baytech	L18	HDO	Dedicated	8.1	0.4	1.0
	L18	HDO	Bi-fuel	8.1	0.3-0.9	1.0
Cummins	B5.9 LPG	MHD	Dedicated	5.9	2.1	2.2

[a] HDO: Heavy Duty Otto, MHD: Medium Heavy Duty

Source: ARB certification database

How many LPG refueling stations are there?

- **Conflicting citations**
  - Low: 172 (Caltrans website)
  - Mid: 235, 234 cited as public access (NREL AFDC , used in table above)
  - High: 1,500, 900 of which are motor vehicle friendly (2005 IEPR, from Clean Fuel USA)
- **Mainstream fuel (though not for vehicle use)**
  - BBQs, outdoor heaters, forklifts, RVs
  - Infrastructure self sustaining, though few pump island user friendly “gasoline“ stations

Vehicle cost premium, inconvenience not overcome by periodic decreased fuel prices.

- **Current LPG prices are attractive**
  - Spot CA LPG/gasoline has averaged 56%; price advantage at <71%
  - Seasonal prices can be disadvantageous, though smooth out if bi-fuel

No LDV vehicle platforms.

Few HDV engines: high cost of certification difficult to recoup.

In-place relatively extensive infrastructure could be used to benefit if vehicles were also in place.

LPG industry continues to support vehicle fuel use R&D.

Business as usual sees very little vehicle fuel market growth.

- **No, or very few vehicle platforms**
- **Price drivers are not compelling**
- **Vehicle fuel is small fraction of the LPG market, not conducive to stimulating investment by LPG suppliers**
- **No remaining strong emissions benefit driver**

Niche fleet use where government AFV vehicle use is mandated represents the sole likely future.

Must have some significant electric only operating range

- **BEV, NEV, PHEV**

California EV use indicator summary

Number of on road EVs (2006)	**500-1,000[1]**
Number of NEVs (2006)	**15,000[2]**
OEM on road EV models offered (2006)	**0**
OEM NEV models offered (2006)	**5[3]**
EV charging stations, total	**400[4]**
public assess	**340**

[1] ARB staff
[2] Mightycomm
[3] Driveclean.ca.gov website
[4] DOE NREL AFDC

The California ZEV regulation provided the impetus for the development of BEVs by automaker OEMs.

- GM, Ford, Daimler-Chrysler, Toyota, Nissan, Honda produced several thousand
- Despite ramped production, BEV costs remained very high,
- Despite battery technology advances, vehicle range remained limited

Modification of the ZEV regulation (2003) presented a new ZEV pathway.

- PZEV, ATPEV option, flexibility in meeting emission reduction targets
- OEMs focus on alternatives, BEV production stopped by 2004
- ZEV credits for NEVs

Current BEV offerings limited to:

- Off-road vehicles & equipment
- NEVs: 5 GEM models certified in 2000
- LDV conversion kits (small in number)
- Specialty BEVs to targeted consumers (Tesla)

Substantial BEV charging station network developed to support the once anticipated fleet.

- **3,000 EV chargers by mid 2001**
  - **59% inductive**
  - **41% conductive**
- **400 still exist (340 public access)**
  - **Clustered in Los Angeles basin, San Francisco Bay Area, Sacramento**
  - **Rarely used**

Little growth for traditional on road BEVs forecast.

- **Barriers**
  - **Cost, range, battery life**
  - **Even though BEVs offer attractive fuel economy (up to 130 mpgge)**
- **Use of significant grid electricity as a viable alternative fuel in on road vehicles relies on PHEV development**
- **Specialty BEVs in the meantime**

NEV, offroad BEV market exists, will grow, and can offer significant petroleum fuel displacement.

Use of Grid Supplied Electricity as a Transportation Fuel in On Road Vehicles not Likely in the Near Term.

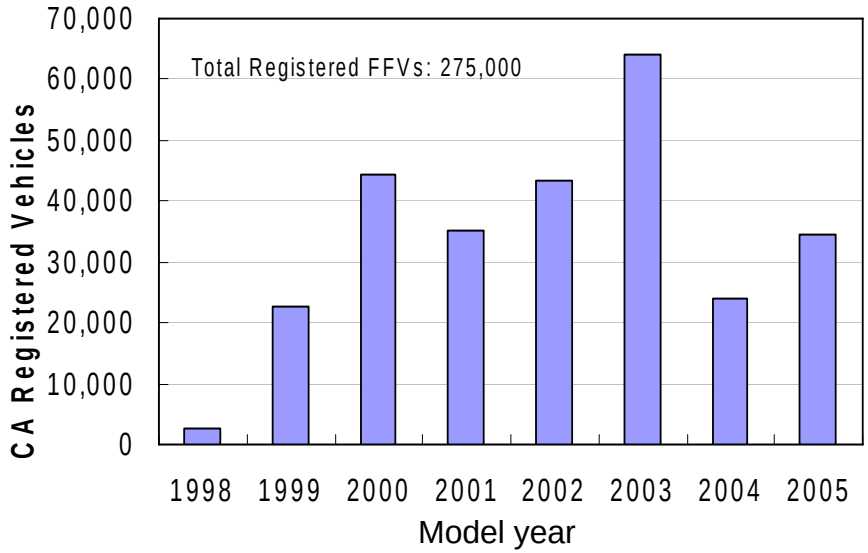
- **Some PHEV demand**
- **Dramatic improvements in battery technology (energy density and lifetime) required before BEVs return to the marketplace as a significant player for on road vehicle use**
- **NEV use will continue and likely grow**

Battery electric off road vehicles and equipment offer significant growth potential and substantial petroleum fuel displacement.

California FFV vehicle use indicator summary

Number of E85 vehicles(2005)	**250,000**
Fraction of on-road population, %	**1.0**
OEM LDV FFV models offered (2006)	**21**
LDV FFV engines certified (2006)	**10**
HDV engines certified (2006)	**0**
E85 stations, total	**4**
public assess	**1**
E85 dispensed, million gal (2005)	**0.1**
million gge	**0.07**
petroleum fuel fraction, %	**0.0005**
Ethanol blended in gasoline, million gal (2005)	**900**
million gge	**648**
petroleum fuel fraction, %	**4.4**

California light duty FFV population, October 2005



Source: California DMV

Ethanol finds use in the California Transportation Sector as:

- **Low level blends**
  - **CARFG3 contains 5.7% ethanol to replace MTBE as oxygenate to meet (former) federal requirement**
    - **900 million gal consumed in 2005**
  - **Blends up to 10% (E10) compatible with on road LDV fleet**
    - **Air quality issues (permeation)**
  - **Additive, not alternative fuel, but does displace petroleum**
- **High level blends**
  - **E85, true alternative fuel**
  - **Can only fuel FFVs**
  - **Virtually none sold to date (2005)**

Several OEM LDV Models Available

Manufacturer	Available Models as E85 FFVs	2006 Offerings
GMC / Chevrolet	Various SUVs (Chevy Tahoe, GMC Yukon, Chevy Suburban) and pickups (Chevy Silverado, GMC Sierra), Chevy Impala, Monte Carlo	10
Chrysler / Dodge	Various minivans; Chrysler Sebring and Dodge Stratus sedans / convertibles, Dodge Ram Pickup, Dodge Durango SUV	5
Ford / Mercury	Taurus sedans and wagons; selected Sables; Explorer and Mountaineer SUVs; F150 pickups, Lincoln Town Car, Crown Victoria (excluding police and taxi), Mercury Grand Marquis	5
Mercedes-Benz	C320 sedan and coupe, C240 sedan and wagon	0
Nissan	Titan King and Crew Cab	1

Source: National Ethanol Vehicle Coalition website [www. E85fuel.com/ffvs.htm]
EPA Fuel Economy Guide [www.fueleconomy.gov]

- **Offered for CAFE credit, even if no E85 is used**

Ethanol Production

- **3.5 billion gal in U.S. in 2005**
- **Most consumed by the transportation fuel market**
- **40 million gal in California**
- **Bioenergy Plan has 3 billion gal/yr from cellulosic sources**

Ethanol Consumption

- **California 900 million gal in E5.7**
- **200 million more gal for 250,000 FFVs operating half time on E85**
- **700 more million gal if all E5.7 were E10**
- **Production capacity, with planned increases, can meet demand**

Distribution Infrastructure

- **Current blendstock infrastructure adequate**
  - **Railcar & tanker ships for import**
  - **Tanker truck for distribution**
  - **Petroleum products pipeline not feasible**

Fueling Station Infrastructure

- **E85 fueling station equipment similar to gasoline**
  - **Need vapor recovery, but compatible systems available; would need to be tested**
- **Would need 275 stations statewide to handle the volume for 250,000 vehicles with 50% E85 usage**
  - **Utilization low at 900 vehicle/station, compared to 2,500 vehicle/station for gasoline**
  - **275 stations is 3% of existing infrastructure, rule of thumb for new alternative fuel is 5-10% of stations, Minnesota 6% of stations offer E85**

- **Current California ethanol production is far below the demand for ethanol as a blending component; growth in in-state production only displaces imports.**
- **Business case for expanding an E85 dispenser population not compelling.**
  - **Midwest E85 marketplace uses E85 is an outlet for excess local capacity; this will not exist in California for some time**
  - **California producers can sell ethanol at a gasoline equivalent price instead of a much lower energy equivalent price; no incentive to expand capacity for an E85 market**
- **OEM FFVs are produced for CAFE reasons.**
  - **This incentive does not require California vehicle sales**
  - **OEMs may choose different CAFE compliance strategies**
- **Increasing petroleum displacement by increased ethanol content in low level blends (E10) has issues.**
  - **Permeation emissions**

Ethanol Use in E85 Fueled FFVs Could See Substantial Growth.

- **Vehicle platforms are commonplace standard OEM light duty vehicle offerings**
- **Fueling infrastructure needs to be established, which requires development of a good business model**
- **OEM interest in marketing E85 growing (federal tax credit and renewable fuels requirements)**

Increased ethanol use in higher level low level blends not likely.

- **Permeation issue needs resolution, “non-permeable” fuel system component materials need to be identified and applied**

Alternative Diesel Fuels Are Those with Non-petroleum Component that can be Used in Unmodified Diesel Vehicles.

- **Biodiesel**
- **Fischer-Tropsch Diesel (GTL, CTL, BTL)**

Alternative Diesel Fuel Production in 2005

	Biodiesel (B100)[a]	FT diesel
Production capacity, million gal/yr		
Global	1,800	3,000
U.S.	395	Neg[b]
California	11.6	Neg
Production, million gal/yr		
Global	955	3,000
U.S.	75	Neg
California	4	Neg

A Biodiesel production capacity and production are for the European Union (EU). The combination of the U.S. and E.U. production accounts for most of the global levels.

B Neg = negligible

Source: European Biodiesel Board, National Biodiesel Board, Energy Commission

Biodiesel Fuels Can be Used in Virtually All Conventional Diesel Fueled Engines and Vehicles.

- **B5 any vehicle**
- **B20**
  - **Almost any vehicle**
  - **Most manufacturers honor warranties**
  - **ARB policy: Biodiesel portion meets ASTM 6715, diesel portion must be CARB diesel**
- **B100**
  - **Most newer engines**
  - **Warranty may be voided**
  - **7% lower energy content than No. 2 diesel; range and fuel economy implications**
  - **Not currently regulated by ARB**
- **All**
  - **Decreased PM, CO, HC emissions**
  - **NOx emissions affects under further investigation**

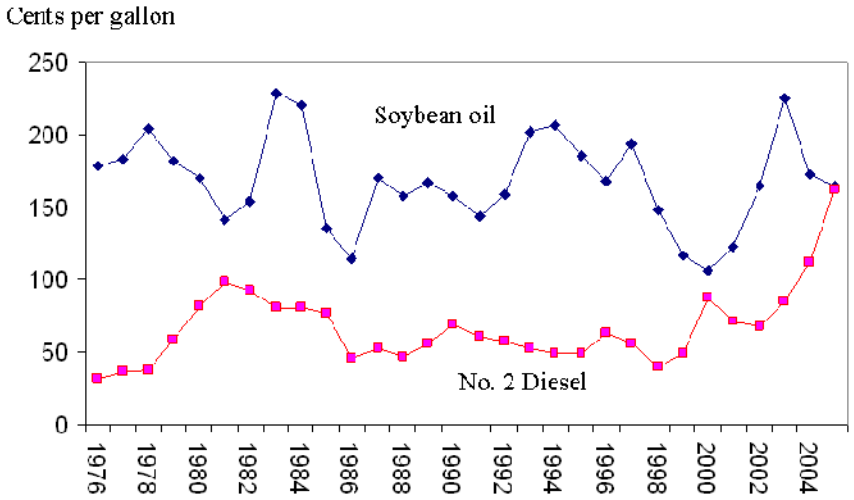
FT Diesel Fuels Can be Used in Virtually All Conventional Diesel Fueled Engines and Vehicles.

- **FT diesel considered blendstock**
- **FT diesel blends considered premium fuel in Europe**
- **PM, CO, HC, and NOx decreased, most notably PM**
- **GTL fuels compete with LNG in exploiting stranded gas reserves**

Alternative Diesel Fuels Have No Special Fueling Infrastructure Requirements.

- **Biodiesel**
  - **30 California stations sell biodiesel or biodiesel blends, 25 are public access (AFDC)**
  - **Price parity with No. 2 diesel depends on feedstock commodity prices compared to petroleum products prices**

- **FT diesel fits directly into the existing diesel fuel infrastructure.**
  - **GTL plants overseas (large volumes of low cost natural gas)**
  - **Competes with LNG for these deposits**



FT Diesel Fuels Are Currently in the Marketplace, so they face no Barriers to Entry. Expansion Limited by the Amount Produced, as Determined by Market Forces.

Many Issues Remain to be Addressed with Biodiesel which Could Limit the Ultimate Use of this Fuel:

- Fuel stability
- Engine durability
- Increases in NOx emissions
- Compatibility with 2007 and 2010 heavy duty engine emission control systems
- Cold weather performance
- Fuel specifications for different fuel blends
- Fuel quality control
- Effect of feedstock on criteria pollutant and air toxics emissions
- Fuel multimedia evaluations
  - Triggered by establishing fuel specifications
- Issues relating to pipeline transport of biodiesel

FT Diesel Fuels are Already in the Marketplace.

- **Currently planned production capacity expected to grow to 3.8 billion gal/yr by 2011**
- **Extent of use to decrease California's petroleum diesel fuel demand will be determined by worldwide markets**

Biodiesel Fuels are Already in the Worldwide Marketplace.

- **Technical issues need resolution.**
- **Production capacity will determine how much can be used to displace petroleum fuels.**
  - **California capacity 11.6 million gal/yr, U.S. 395 million gal/yr, global 1,800 million gal/yr**
  - **Capacity will grow**
  - **How much can be absorbed into the California market**

Why Hydrogen?

- Zero vehicle emissions
- Fuel cycle emissions minimized
  - Opportunity for GHG capture and sequestration
  - Opportunity for fuel production from renewable resources

Hydrogen Transportation Fuel Use in California

Number of Hydrogen vehicles (2006)[a]	160
Fraction of on-road population, %	0
OEM LDV models offered (2006)	1
LDV engines certified (2006)	1
HDV engines certified (2006)	0
Hydrogen stations, total	33
public assess	5
Hydrogen dispensed, million kg	0.02
million gge	0.02
petroleum fuel fraction, %	0.0001
Based on 9 hydrogen buses, 10,000 mi/yr 6 mi/kg 60 cars, 4000 mi/yr, 50 mi/kg	

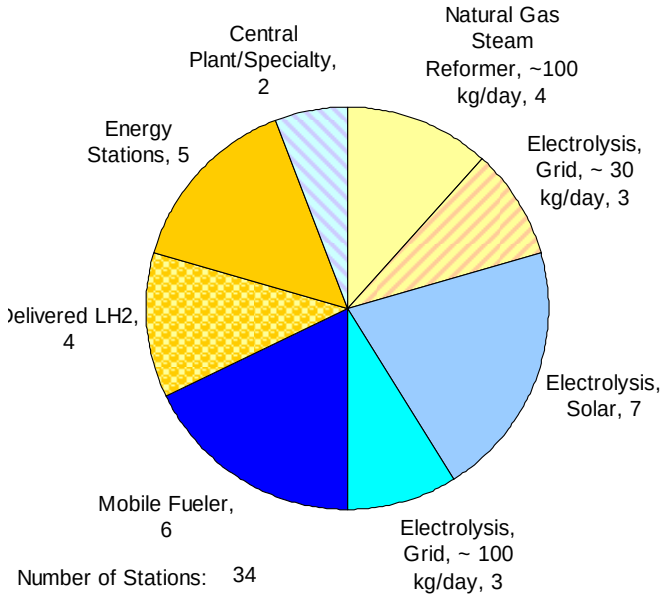
[A] Estimate includes vehicles from fuel cell car, ICE car, and bus programs.

Source: This analysis

Offerings of Hydrogen Vehicles Have Been Limited to Demonstration Vehicles for Government Programs.

- **Light duty vehicles**
  - **Fuel cell vehicles**
    - **CaFCP has placed 136 FCVs in California, 473,000 vehicle-miles logged**
    - **Commercial vehicles many years away, DOE demonstration program has commercial launch after 2015**
    - **Honda FCX certified in California**
  - **Hydrogen ICE vehicles**
    - **Both conventional and hybrid drive trains built**
    - **30 Quantm Technologies hydrogen hybrid Prius conversions at SCAQMD**
- **Heavy duty vehicles**
  - **Fuel cell buses**
    - **9 deployed: SunLine Transit, AC Transit, SCVTA**

As of June 2006, 22 Facilities in California Designed to Dispense Hydrogen as a Motor Vehicle Fuel, with Several More Planned.



Existing and Planned Hydrogen Fueling Stations by Supply Option

Locations of Hydrogen Fueling Stations in California

Source: California Hydrogen Highway Blueprint Plan

Hydrogen Vehicle Success Long Term Will Require Meeting Many Technical Challenges with both Vehicles and Fuel Infrastructure. Barriers to Wide-scale Commercialization Include:

- **Storing and delivering hydrogen are very costly; these costs must be significantly reduced.**
- **High capital investment for fueling stations and underutilized capital during the build up of vehicle population results in greater investment risk than other fuel technologies. These risks need to be understood and managed.**
- **Vehicles must achieve performance, durability, and cost comparable to conventional vehicles. Breakthroughs in hydrogen storage need to be developed that will allow storing 5 kg of hydrogen on board the vehicle.**
- **Codes, standards, and permitting requirements need to accommodate hydrogen in urban areas and hydrogen fueling technologies may need to adapt to these requirements.**

Hydrogen Vehicles can Provide Most of All Vehicle Transportation Needs with No Vehicle Emissions and Minimized Fuel Cycle Emissions.

- **Direct-hydrogen fuel cell will likely replace internal combustion engines as the predominant transportation prime mover.**
- **Time frame uncertain, though long term.**

Questions?