"Oxygenate Issues and Options"

SCAQMD Ethanol Forum and Technical Roundtable

Paul Wuebben
Clean Fuels Officer
SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

June 15, 2006
Diamond Bar, CA

Outline

- Background
- Low Level Blends
- E-85 Fuel Ethanol in FFV's
- Energy Balance of Ethanol
- Conclusions

Background

- **President Bush's State of Union**
  - **E-85, FFV's & cellulosic ethanol**
- **Governor's Executive Order 06-06**
  - ***Biofuels production and use targets***
- **Federal Renewable Fuel Standard (RFS)**
- **California ethanol industry economic development**
- **Need to address greenhouse gases**
- **Oil resource depletion = need for alt fuels**
- **AQ concerns about permeation / commingling**

2005 Consumption
Billions of Gallons

	U.S.	California
Gasoline	**140**	**16**
Ethanol	**4 ***	**1**

**** 2.86% exceeds RFS "collective liability" for 2006 of 2.78%***

Federal Renewable Fuel Standard Requirements

Calendar year	Billion gallons
2006	4.0
2007	4.7
2008	5.4
2009	6.1
2010	6.8
2011	7.4
2012	7.5

Issues for this Forum

- Need for near-term permeation emissions relief
- Long term summer oxygenate policy options
- Summertime commingling of E-0 with E-5.7 blends
- Role of E-85 and FFV's
  - **Status of Enhanced Vapor Recovery**
- Biofuels Executive Order implementation
- Vehicle certification with Phase 3 gasoline
  - **Rather than with 11% MTBE (i.e., phase 2 gasoline)**

- ✓ AQMP revisions to attain / maintain NAAQS
- ✓ Renewable / sustainable transportation fuels

Urgent Questions:

- How do we adjust the Predictive Model?
- **What mitigation options exist to offset added permeation HC emissions?**
- Can we do something different in summer?
- Should wide-spread use E-85 be encouraged?
- How would gasoline supply be affected if ethanol use was restricted during the summer?
- What do we need to do to get a long term solution?
- ✓ **What oxygenate fuel policies should be reflected in the Revised Air Quality Management Plan?**

Overall SCAQMD Perspective

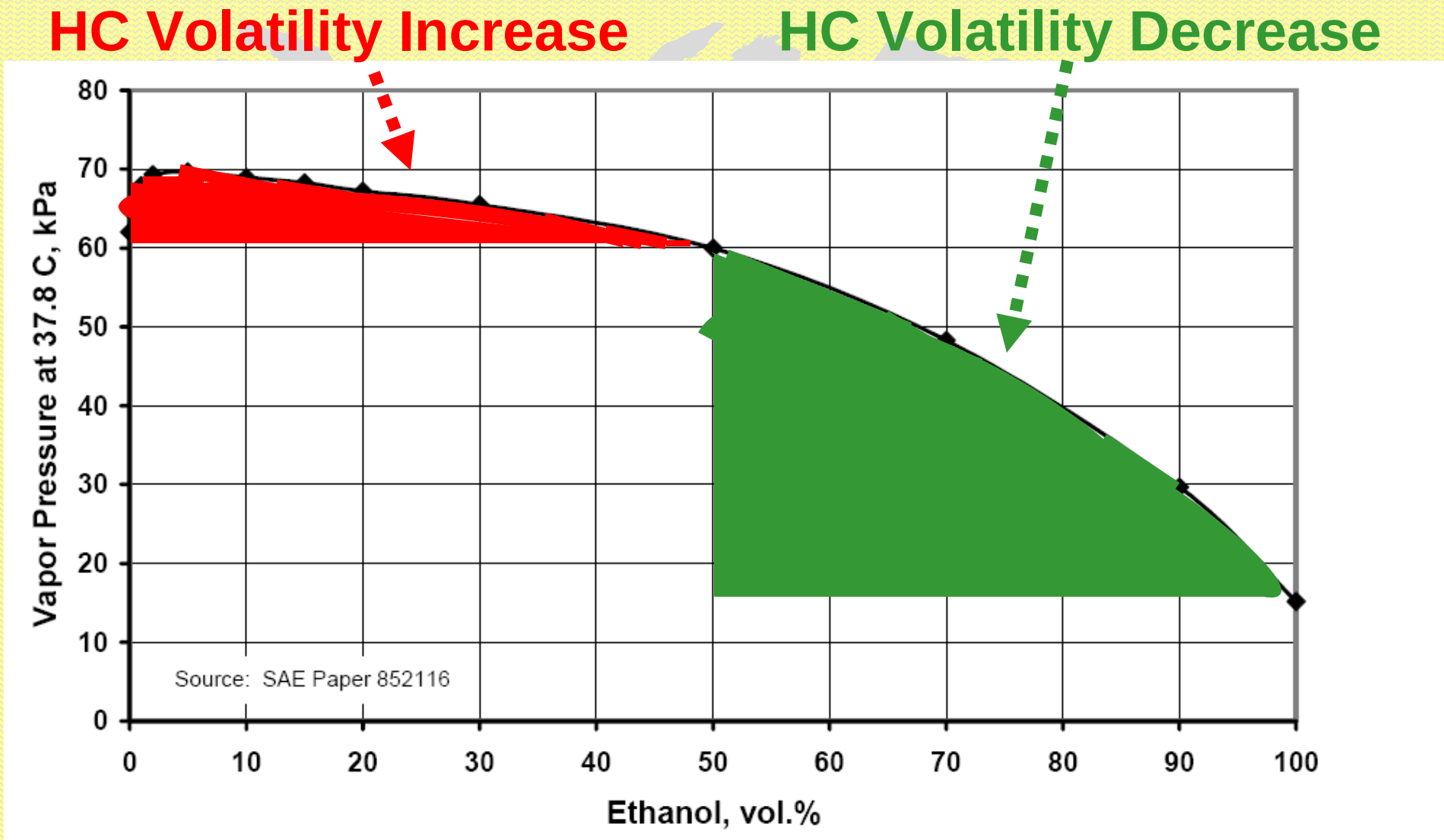
- **Concerns about permeation effects of low level blends**
- **Concerns about commingling effects in E-85 Flexible Fuel Vehicles**
- **Significant challenge to attain 8-hour ozone and PM 2.5 standard**
- **Better data needed on ethanol impacts**
- **AQMD has an open mind**
  - ***Policy issues will be assessed in the context of the upcoming 2007 Revision to the AQMP***

Low Level Ethanol Blends in Gasoline

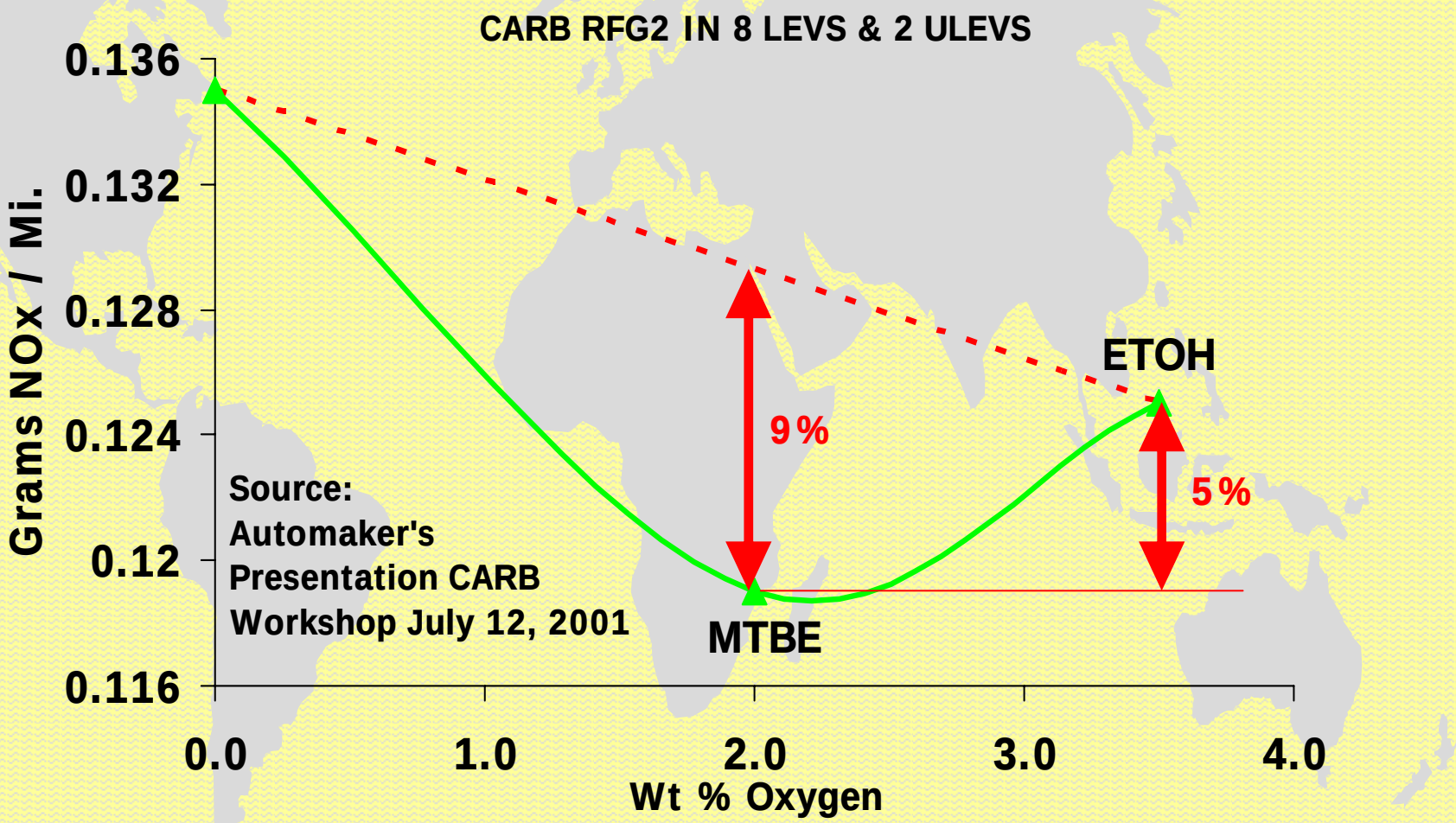
E.5.7 - E-10

Ethanol's Effect on HC Volatility:

- Peaks at about 6% by volume in gasoline
- Reduces volatility in higher level blends


HC Volatility Increase
HC Volatility Decrease
Vapor Pressure at 37.8 C, kPa
0
10
20
30
40
50
60
70
80
Source: SAE Paper 852116
0
10
20
30
40
50
60
70
80
90
100
Ethanol, vol.%

Ethanol Increases NOx Emissions



Auto/Oil showed ethanol increased NOx 5%

Phase 2 *vs* Phase 3 Gasoline

	Flat Limits		Averaging Limits		Cap Limits	
Property	**CaRFG2**	**CaRFG3**	**CaRFG2**	**CaRFG3**	**CaRFG2**	**CaRFG3**
Summer RVP, psi	7.0	7.0(1)	na(2)	none	7.0	6.4-7.2
Sulfur, ppmw	40	20	30	15	80	60/30(3)
Benzene, vol%	1.00	0.80	0.80	0.70	1.20	1.10
Aromatics, vol%	25	no change	22	no change	30	35
Olefins, vol%	6.0	no change	4.0	no change	10.0	no change
T50,degF.	210	213	200	203	220	no change
T90, degF.	300	305	290	295	330	no change
Oxygen, wt%	1.8 to 2.2	no change	na(2)	no change	0-3.5	0-3.7(4)

(1) 6.9 if using the evaporative element of the Predictive Model

(2) Not Applicable

(3) 60ppmw beginning 12-31-02. 30ppmw beginning 12/31/04

(4) 3.7 cap if the blend contains more than 3.5 wt % oxygen & **no more than 10 vol% ethanol.**

Ethanol Use Causes Significant Permeation Emissions

- Recent CRC study: All but one car had significant **emission increases of 65% relative to Phase 2 gasoline** (with MTBE)
- **Increase of 45% relative to non-oxygenated fuel** which would be allowed if California is granted the oxy fuel waiver.
- **For every 10 degree C (18 degree F) increase, evaporative emissions doubled**.

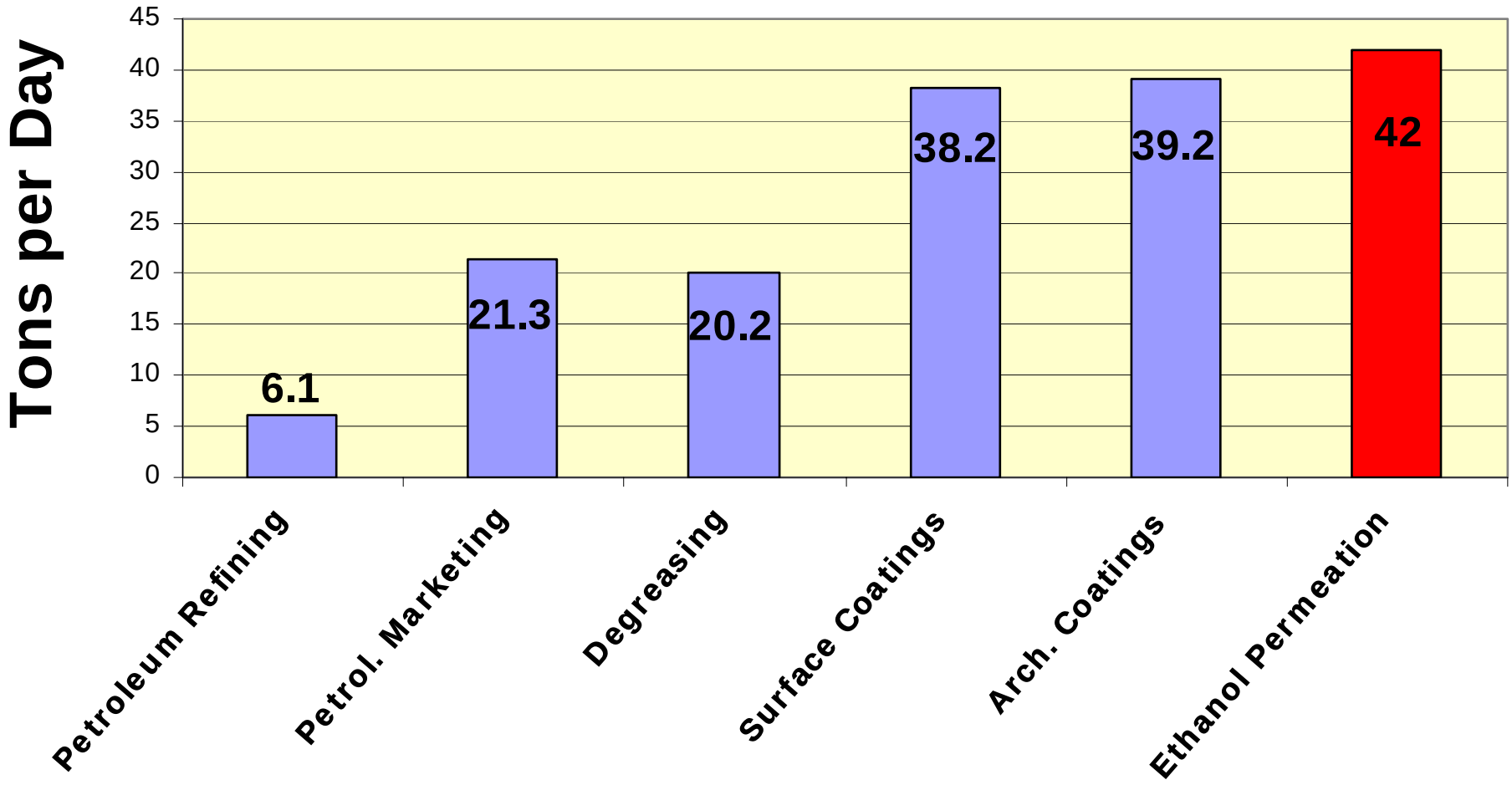
ARB estimates that vehicles emit an additional 1.4 grams per vehicle per day more than was emitted under RFG2 conditions operative in 2002.

Permeation HC Increases Not Accounted For In Current ARB Predictive Model (tpd)

	Moderate Summer Day 83 ° F		Hot Summer Day 97 ° F	
	SCAB	Statewide	SCAB	Statewide
On-road	17.5	49.2	29.5	82.9
Off-road	7.4	20.8	12.5	35.1
Total	24.9	70.0	42.0	118.0

Preliminary estimates based on ARB data, Nov. 3, 2005 draft analysis

2003 ROG Inventory, SCAB



Impact of Permeation Outweighs CO

- "Our preliminary analysis indicates that the model **simulation results are consistent with the previous reactivity-based findings** in assessing the ozone impact of permeation VOC relative to CO emissions. Overall, the results tend to support that **the ozone impact of permeation VOC relative to CO is overwhelming and significant."**

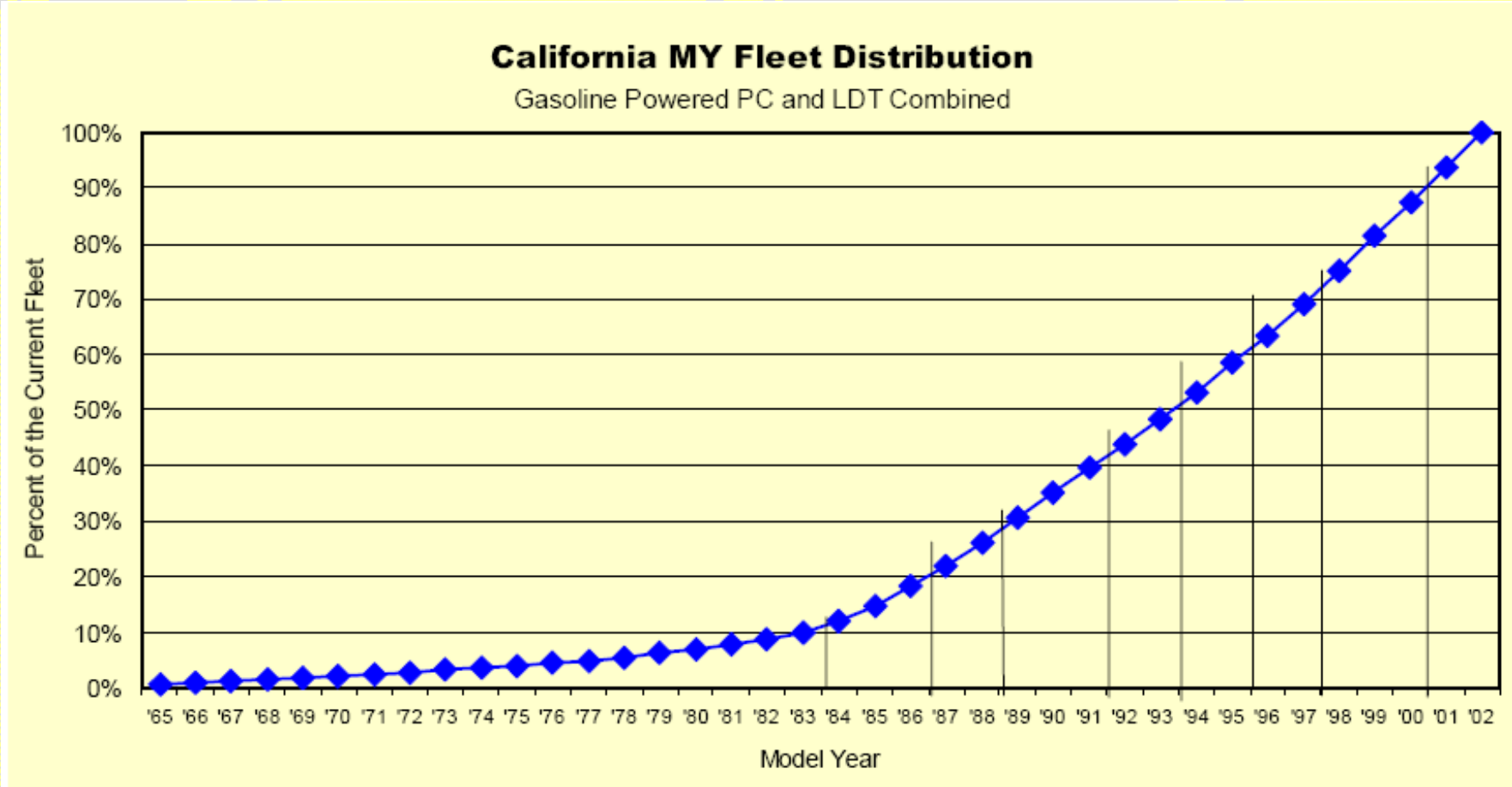
  - Source: "DRAFT The Ozone Impact of Permeation VOC Relative to Carbon Monoxide", Dongmin Luo, Ph.D. , P.E., Research Division, CARB, January 2006

Refiners Face Near-term Constraints in Terms of Ethanol Use

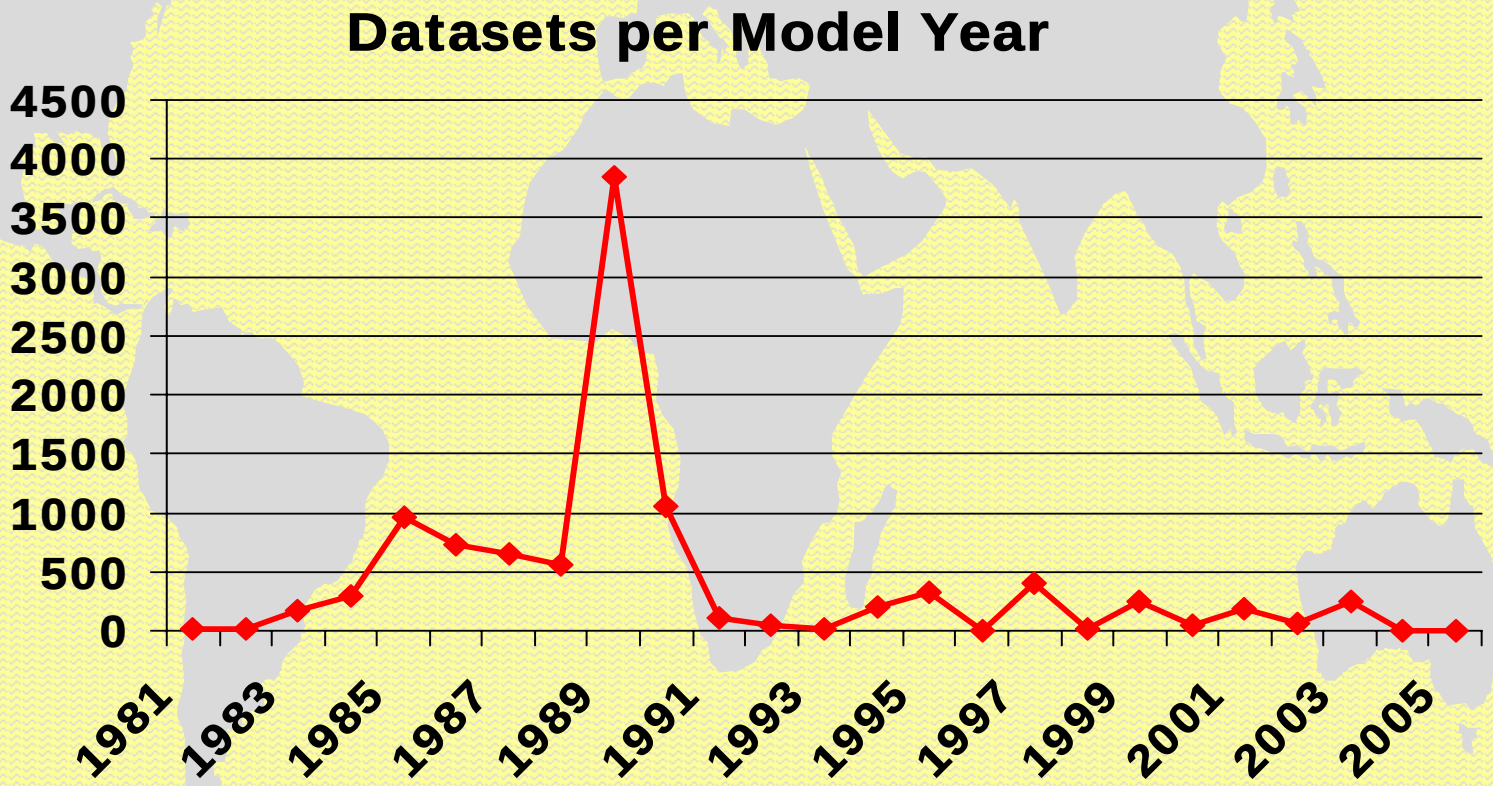
- ***Congress lifted the oxygenate mandate. But:***
- Octane shortage may force continued use
  - **Can't increase use of aromatics due to PM limits**
  - **Can't use ethers**
  - **Isomerate, alkylate and isooctane use would have to increase dramatically**
  - **4 to 5 years may be needed to reconfigure refineries**
- Congress' ethanol RFS mandate must be met.
- Refiners may be in a "box"…

MUCH BETTER DATA IS NEEDED

An Ideal Data Distribution For the Predictive Model (PM):



In Contrast:
PM Test Data is Getting Stale



Source: pmdatabase06, ARB

Next Steps Related to Low Level Blends of Ethanol in Gasoline?

- More “Tech 5 & 6”cars in PM data base
- Gasoline vehicles tested on RFG 3, not RFG 2
- Updated commingling assessment for worse case summer scenario
  - ½ RFS compliance within the basin
  - ½ outside California
- Refinery assessment of supply options
- Consumer education on air quality impacts of commingling

Options for Mitigating Permeation HC Increases

- Lower RVP for summertime gasoline?
- Adjust other gasoline parameters (T-50?)
- Accelerate E-85 deployment & use
- Catalyst replacement on old vehicles?
- Tighter I/M limits?
- Accelerated LEV 2 / LEV 3?
- Older vehicle early retirement?
- Mitigation fees?
- Summertime prohibition on ethanol use?
- Other?

E-85 Fuel Ethanol:

A Renewable Roadway…

Current Market Status of E-85

- 1,000 of the nation's approximately 170,000 retail gas stations offer E-85
- > 5 million FFV's nationwide
- By the end of 2006 Ford & GM plan additional 2 MM and 1.5 MM FFV's sales, respectively…
- *However, there is only one public E-85 station in CA today…*

Certain Benefits:

- Much lower volatility when E-85 is used;
  - the “depth” of the reduction is much greater than the “height” of the increase from 0 to 10% blends. It appears to peak around 6%
- Toxic emission reductions
  - On a toxicity-weighted basis
- Fuel diversity + renewable fuel cycle

Less Certain Benefits Needing More Refinement:

- **Ozone reactivity and PM2.5 effects**
  - **Newer MY emissions speciation is needed…**
- **Lower MIR reactivity with mid-1990's FFV's**
- **Confirmation of latest test data showing lower NOx when running on E-85**
- **With newer vehicles, mass emission rates may be less significant that speciation**
  - **Gasoline *P-ZEV's now in mg per mile range***

Concerns + Potential Problems:

- **Use of gasoline rather than E-85 in FFV's**
  - **Commingling effect on evaporative emissions**
  - **Permeation effect**
- **"E-85" can be as low as E-70 – what then…?**
- **Photochemistry implications of increased aldehyde emissions on PAN generation compared to gasoline**
  - **In the context of lower benzene and other aromatic HC's**
- **Potential durability issues with fuel system, ECS and OBD II components of FFV's compared to gasoline P-ZEV's**

Other Questions:

- Since newer FFV's are tested on E-10 as well as E-85, is commingling less of an issue for 2000 MY and later FFV's?
- Since E-10 is the most stringent evap benchmark, are FFV's certified under EPA's Supplemental Standards slightly cleaner than gasoline vehicles running on E-0 to E-6 blends?

Infrastructure Issues:

- **How can Enhanced Vapor Recovery E-85 technology be expedited?**
- **What incentives are appropriate for FFV infrastructure, since dedicated fuel use cannot be guaranteed?**

Future Options For FFV Optimization:

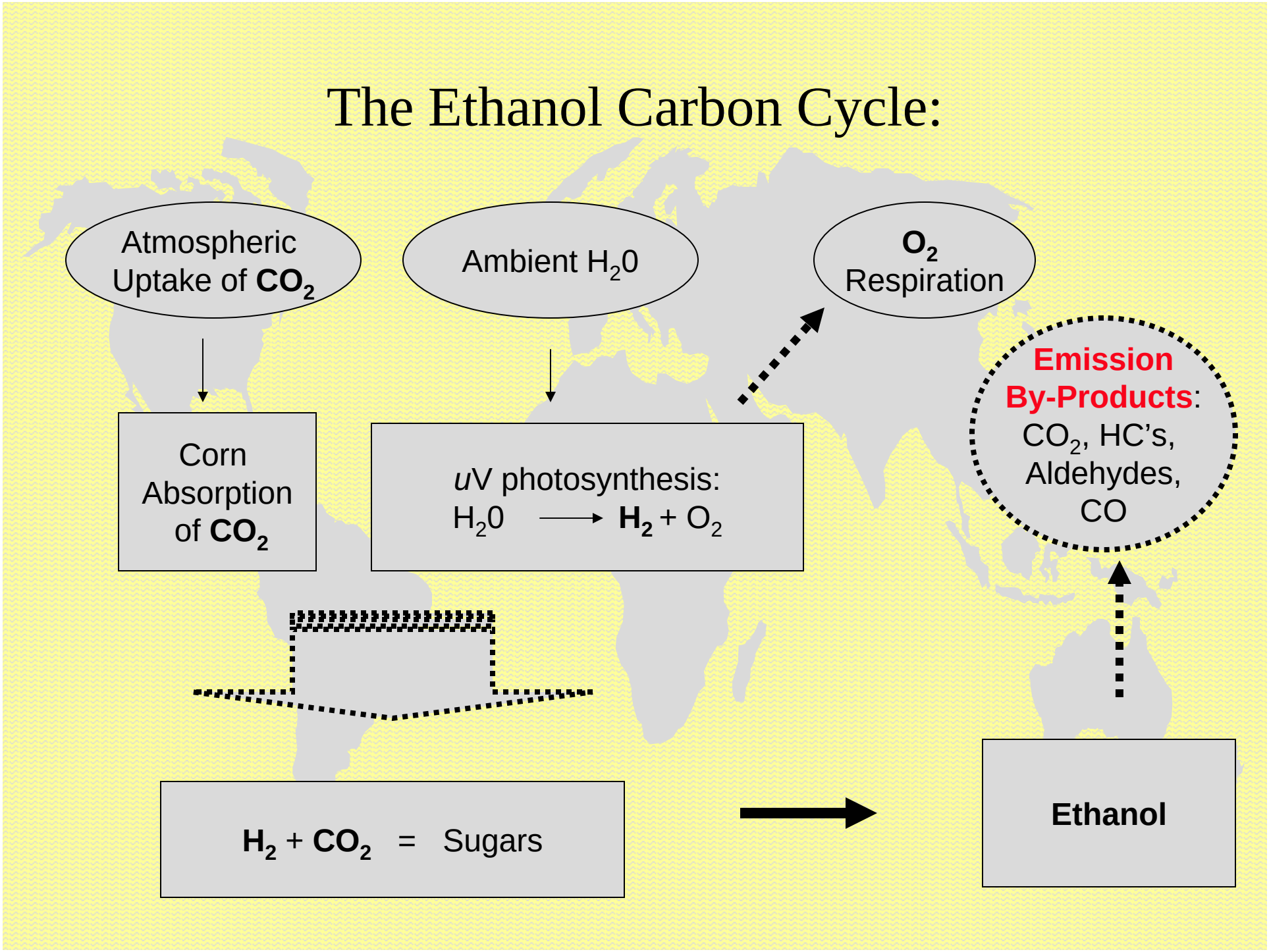
- ✓ Direct Injection
- ✓ Plug-in Capability
- ✓ P-ZEV compliant
- ✓ E-100 ?
- ✓ Ethanol-to H_2 FC

Saab 9-3 Prototype: P-HEV FFV (E-100)

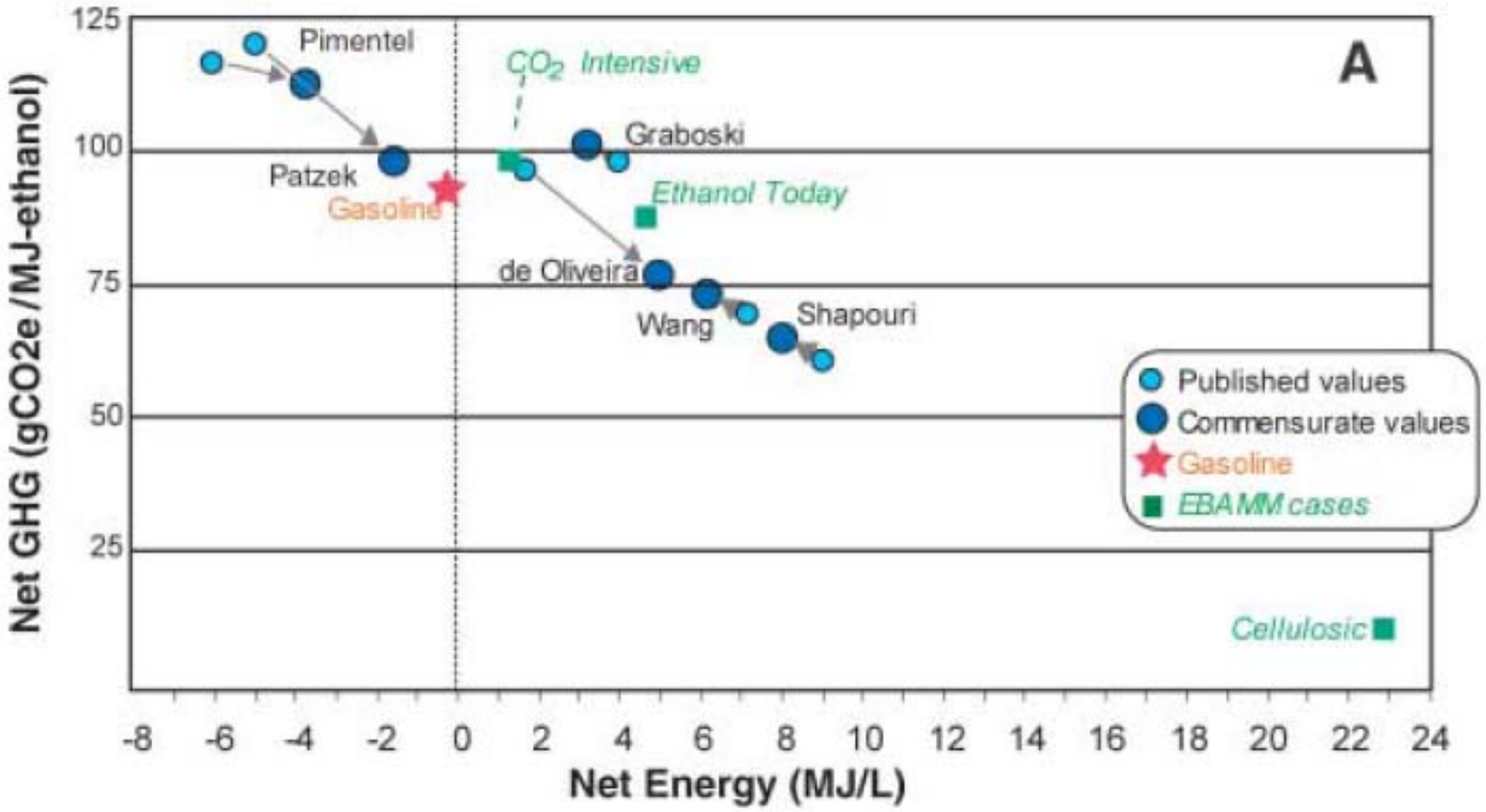
	Gasoline Version	P-HEV FFV	*Comparison*
Horsepower	210	**260**	***better***
Torque (ft-lbs)	220	**276**	***better***
0 to 60 mph, seconds	8.8	**7**	***better***
# of electric motors	0	**2**	***better***
Electric motor output, kW	0	**53**	***better***
Miles of zero emission range	0	**12.4**	***better***
Engine type	Otto cycle	Spark ignited direct injection	***better***
Fuel Economy, mpg	31	**31**	***Better per Btu***
Cellulosic E-100 compatibility	no	**yes**	***better***
Hybrid ?	no	**yes**	***better***
Fuel Flexibility / agility ?	no	**yes**	***better***
Plug In ?	no	**yes**	***better***
Toxics	baseline	**lower**	***better***
Volatile HC's	baseline	**lower**	***better***
Petroleum dependency	baseline	**lower**	***better***

Energy Balance of Corn-based Ethanol

The Ethanol Carbon Cycle:



Varied Estimates of Net Energy Balance for Ethanol



Source: Farrel, Kammen et. al., Science, Jan 27, 2006

Recent Argonne Lab Assessment:

For every 1MM Btu's of energy:

- Ethanol production consumes 0.74MM Btu's
- Gasoline production consumes 1.23 MM Btu's

Other key consideration

- Ethanol distribution is constrained due to inability to transport it in existing gasoline pipeline system

Source: Michael Wang, Argonne National Laboratory

Candidate Production Pathways

- ***Sugar Based Bio-refinery:*** Hydrolysis of fibrous biomass to form soluble sugars, using enzymes or acid catalysts, followed by microbial conversion of sugars to ethanol and other products.
- ***Syngas Based Bio-refinery:*** Thermo-chemical production of biofuels using gasification to form synthesis gas, with subsequent production of methanol, ethanol and/or FT-diesel.

  [key challenge: reduce excess carbon in syngas through hydrogenation]
- ***Renewable Diesel from Fats and Oils:*** The use of natural oils through biological and thermo-chemical routes for biodiesel.

Summary:

- Low level ethanol blends create permeation impacts which need mitigation
- E-10 transition not justified so far based on ARB's Predictive Model
- E-85 FFV's can present commingling challenges
- ARB's revision to Predictive Model needs better data on ethanol blend effects
- Biofuels such as ethanol can contribute to reducing GHG's and provide added energy diversification
- California-based ethanol production can enhance the state's economic base

"When one tugs at a single thing in nature, he finds it attached to the rest of the world."

John Muir