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# Emissions of HFC-134a from Light-Duty Vehicles in California

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# Overview

- ARB's Activities in Mobile AC
- Information on HFC Emissions
- ARB's Approach to Estimation
- Results of Analysis
- Caveats and Comparisons

# AB 1493 (Pavley, 2002)

- ARB must set standards on GHG emissions from new LDVs, 2009 et seq. models.
- Maximize emission reductions for GHGs at acceptable cost to consumer.
- No specific treatment of HFCs is required.
- Proposal: GHG std. on vehicle; credit for low-leak systems & change of refrigerant
- Workshop July 7 (on web)
- Board hearing Sept 2004

# ARB Staff Activities

- SAE ARCRP Phase II
- EPA Enhanced HFC-134a System Development Effort
- 2005 MACS Summit in Sacramento (ARB will sponsor)

# Three Modes of Emission

<u>Mode</u>	<u>Nature</u>	<u>When occurs</u>
Leakage	gradual & continuous	during "life"
Accidental releases	sudden random events	during life
Scrapping release	one event	end of life

# Emission Measurements

## Leakage

- Ford (Siegl): diurnal loss tests, cold vehicles
- EMPA (Stemmler): Swiss tunnel study

## Leakage + Accidental

- Öko-Recherche: state-of-charge, 276 in-use European vehicles (Schwarz)

# Probable Factors in Leakage

- Make, model, and year (different designs, materials & assembly practices)
- Variability among vehicles
- Age & accumulated hours of operation
- Under-hood temperature
- Compressor on vs. off
- Maintenance practices

# Alternative: Lifetime Emissions by Mass Balance

- Over a vehicle's life,

**Emissions = Net inputs**

= initial charge + recharges  
- amount recovered at end

- Net inputs: only ~3 discrete events
- Data are accessible for many vehicles

# Lifetime Emission Model

$$LE = C * (1 - g + N*f)$$

C -- capacity (kg)

"1" -- initial charge

g -- fraction of charge recovered at scrapping

N -- number of recharges

f -- fraction of capacity recharged

# Our Data Sources

*Number of recharges* : 12,000 vehicles in 9 fleets; surveys of 966 vehicle owners

*System capacity & amount per recharge* : 288 evacuations & recharges

*End-of-life recovery* : survey of dismantlers, discussions with EPA & reclaimers

*Lifetime* : EMFAC emission model (16 yrs)

# Estimating N (number of recharges) from Fleet Data

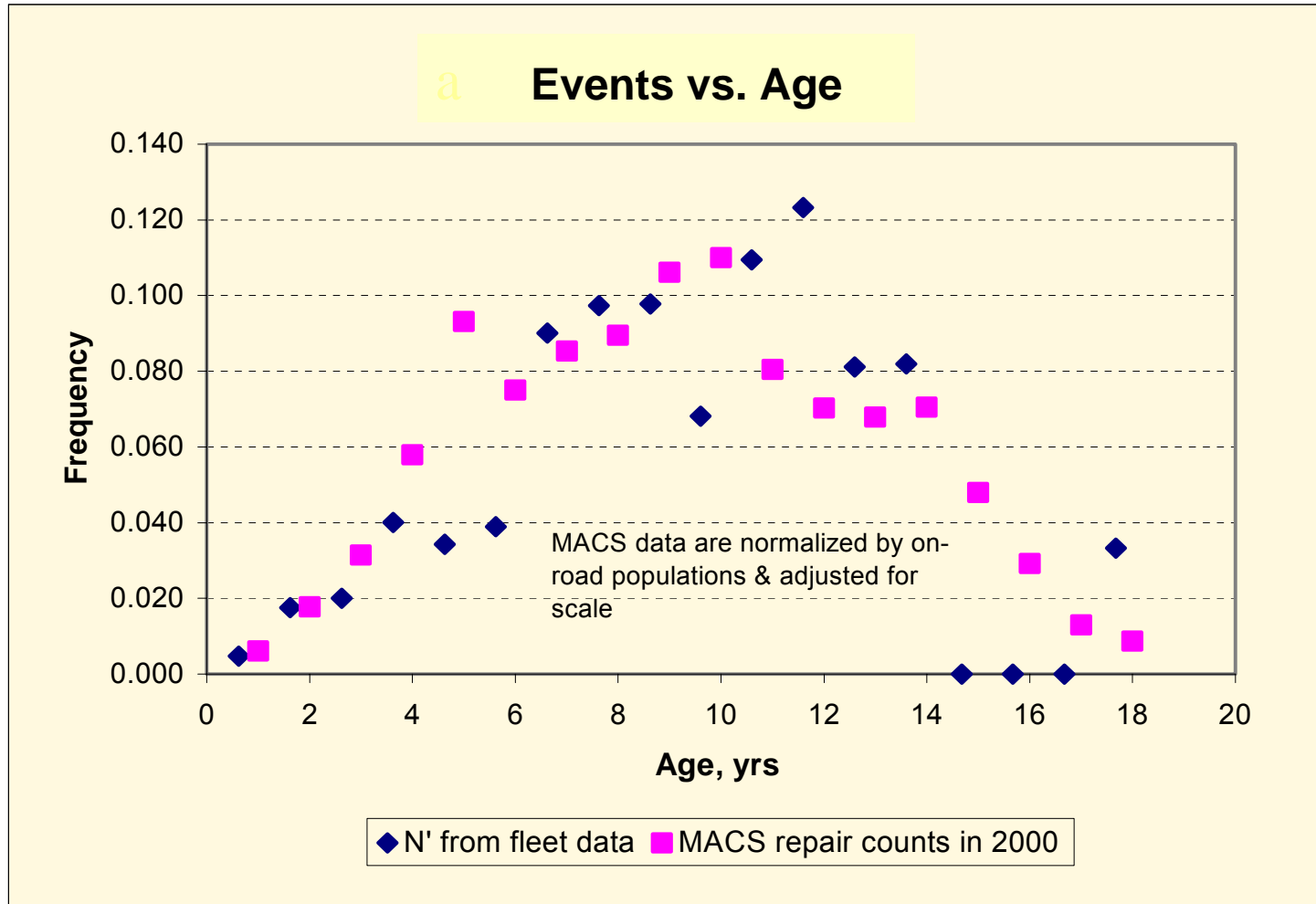
$N'_i$ : the fraction of HFC-134a vehicles of age  $i$  that receive recharges during a year

Estimated as:

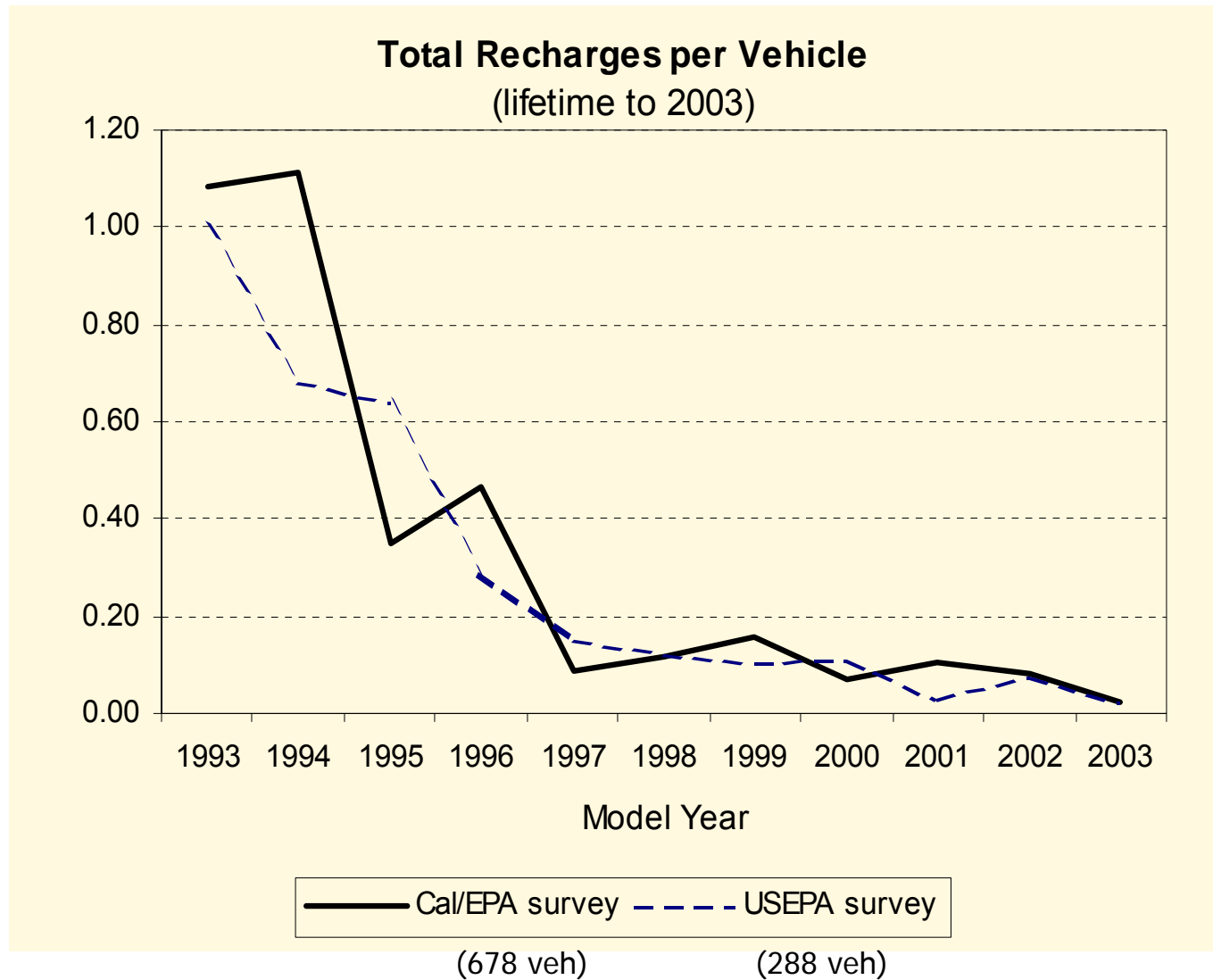
$[\# \text{ recharges in 12 mo.} / \# \text{ vehicles}]_i$   
( $i = \text{age}$ )

$$\sum_{1}^{16} N' (\text{recharges/veh/yr}) \approx N (\text{recharges per 16-yr life})$$

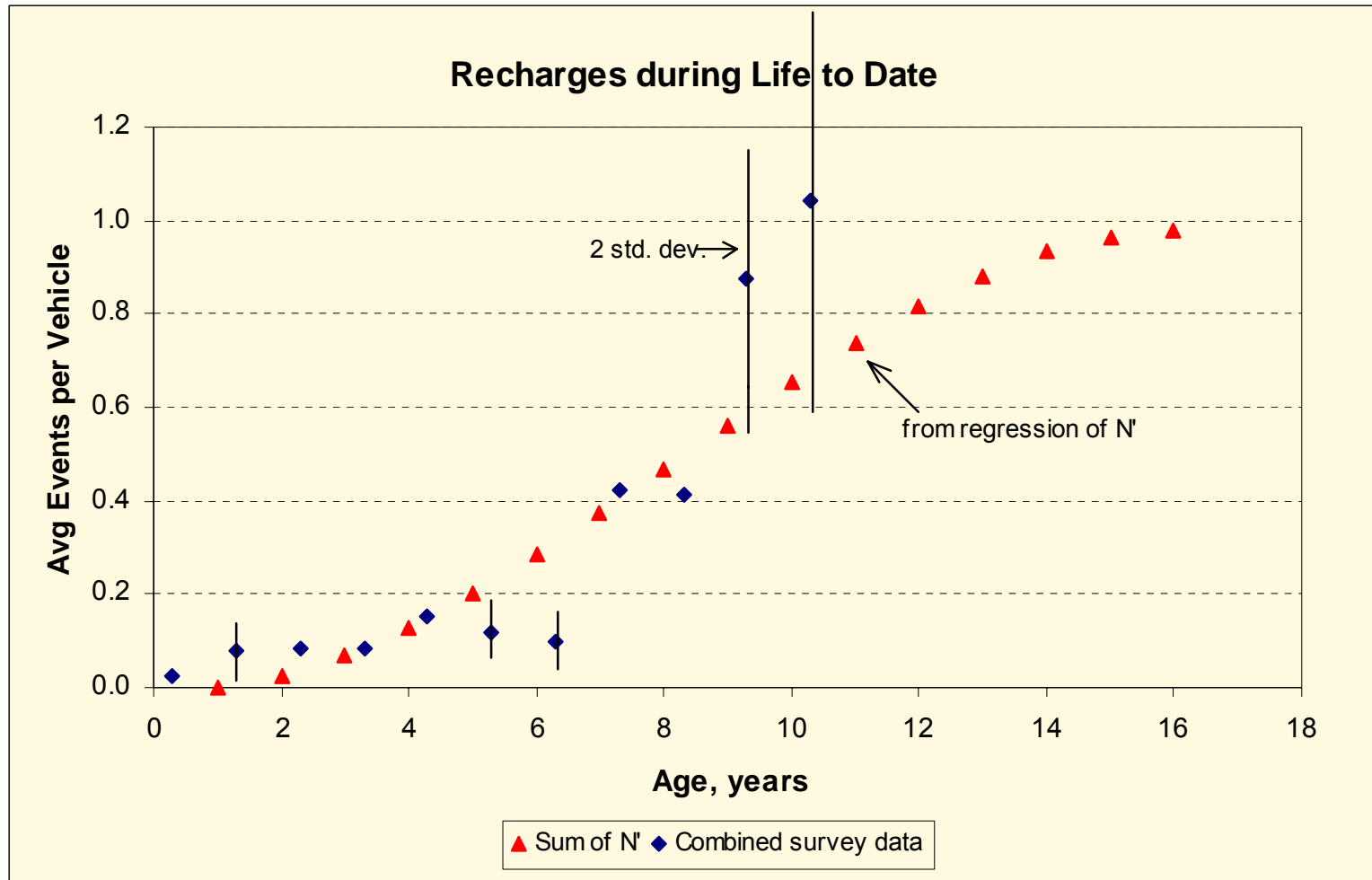
# Age Pattern



# Surveys of 966 Vehicle Owners



# Cumulative Recharges



# Average Results

N -- from 12,000 vehicles: 1 *recharge*  
*over 16 yrs*

C -- mean of 288 data: *951 grams*

f -- mean of 288 data: *.52*

g -- set to *8.5%* (50% recovery)

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$$\begin{aligned}\hat{L}E &\approx \hat{C} * (1 - \hat{g} + \hat{N} * \hat{f}) \\ &= 1.36 \text{ kg (85 g/yr)}\end{aligned}$$

# The "12-Oz. Can" Question

- Our result does not reflect:
  - excess emissions from DIY repairs (release of system contents)
  - excess from repeated top-offs w/o leak repairs (R134a & R12 systems)
- Total excess  $\leq$  50 g/yr/veh (including R134a into R12 vehicles)

# Comparisons

	<u>Loss, grams/yr</u>
Measured leak rates* (Ford)	26
Long-term loss (Öko-Recherche)^	53
Tunnel study (Swiss)	123
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ARB analysis	85

\* vehicles & AC's not operating

^ early period of vehicle life

# Summary of Analysis

- Lifetime emission estimate based on mass balance; used no data on loss rate
- Used input data from 1000's of California vehicles
- Result compatible with empirical data
- Provides sound regulatory baseline

# Limitations

- Our data are specific to the vehicle fleet of 2003; biased toward US brands
- Methodology does not allow identifying model-year effects
- Does not distinguish among loss mechanisms

# Planned Future Work

- Tunnel study in California
- Develop SHED testing
- Quantify retail sales HFC-134a (DIY emissions)
- SAE & EPA R&D projects