# Mobile A/C System Refrigerant Issues

## The State of the Mobile Air Conditioning Industry

**SAE Interior Climate Control Standards Committee Working Group**
**Ward Atkinson - James Baker - William Hill**

**SAE Congress April 19, 2007**

# Introduction

- Regulation of Refrigerant is Happening
  - Timing is Critical
- Industry Cooperation can help
  - Necessary for global refrigerant
- There are multiple alternatives
  - And no Clear choice
- HFC134a is not so bad
  - And can be improved

# Regulation of Refrigerant is Happening!!

# Background

- Regulations in Europe
- Regulations in USA
- Regulations in Asia

# Climate Change is a Growing Global Concern

- Ever-Increasing environmental and political pressure for industry to participate in mitigating the threat of climate change
- MAC industry Currently Under Pressure
  - First in the EU
  - Then in Asia
  - Soon in the USA
    - (CARB, NESCAUM, EPA)

# Climate Change is a Growing Global Concern

- MAC Industry is "On Stage"
  - With a clear opportunity to contribute to Climate Change mitigation
- Change is Inevitable Time is short
  - Meet regulations as they come
    - EU First
    - Other regions to follow-same technology?
  - Actively plan for ultimate global implementation of a single refrigerant

# Europe Refrigerant Phase out

- **European Industry written request for an extension was denied in March 2007 by Government**

EUROPEAN COMMISSION
ENTERPRISE AND INDUSTRY DIRECTORATE-GENERAL

Consumer goods
Director

Brussels, 8 March 2007

I would like to highlight that last year the European Parliament and the Council decided that the dates for the phase-out of refrigerant HFC-134a in the European Community shall be set at 1 January 2011 for new types of vehicles and 1 January 2017 for all new vehicles.

These dates are now included in Directive 2006/40/EC relating to emissions from air-conditioning systems in motor vehicles and amending Council Directive 70/156/EEC and cannot be considered as flexible and there is no intention of my services to propose any postponement of these dates.

I would therefore urge ********** companies to take the necessary measures in good time in order to be able to respect the deadlines mentioned above.

# USA EPA Refrigerant Requirements

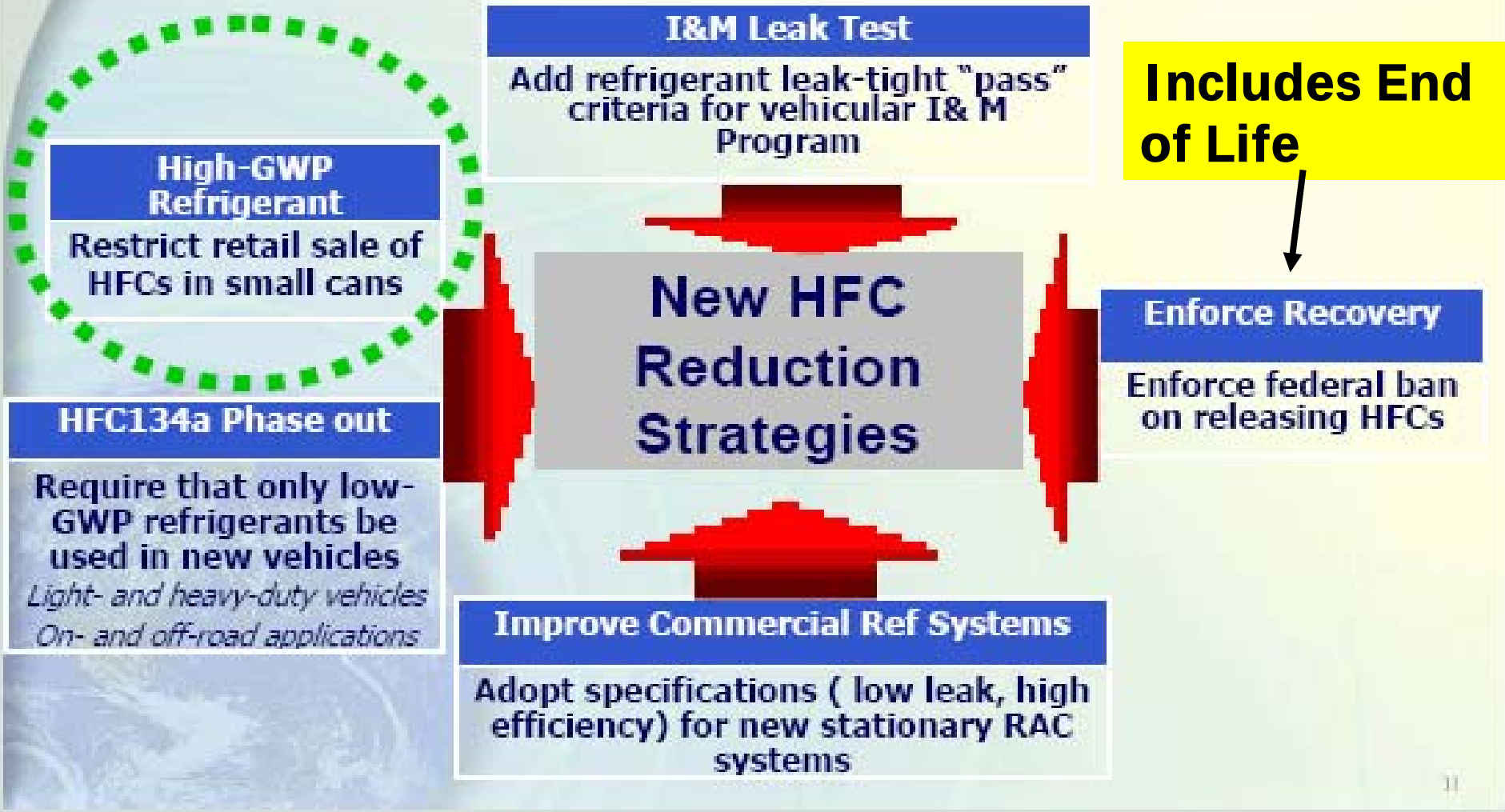
- No requirements to phase out HFC134a
- Direct expansion R744 Carbon Dioxide and HFC152a refrigerants must have safety mitigation provisions to meet new EPA (SNAP) requirements
  - SNAP rule has not been published indicating final requirements

# California

- Phase out HFC134a refrigerant for medium and Heavy Duty Truck air conditioning systems in the near term (~2015)
- Emission credits for reduced direct A/C system refrigerant emissions
  - HFC134a systems with leakage certified to SAE J2727 systems
  - Efficient components for HFC134a systems
  - R744 Carbon Dioxide systems
  - R152a systems

# Five HFC measures with potential reductions of ions in 2020

## California Future Plans



# Meeting California Requirements

- Introduce Low Emission HFC134a systems meeting SAE J2727 Standard using more efficient HFC134a components
- Future System Options
  - Spend money to commercialize R744 carbon dioxide systems

  or
  - Spend money to purchase a market-priced new blend refrigerant that is not currently a commercial product

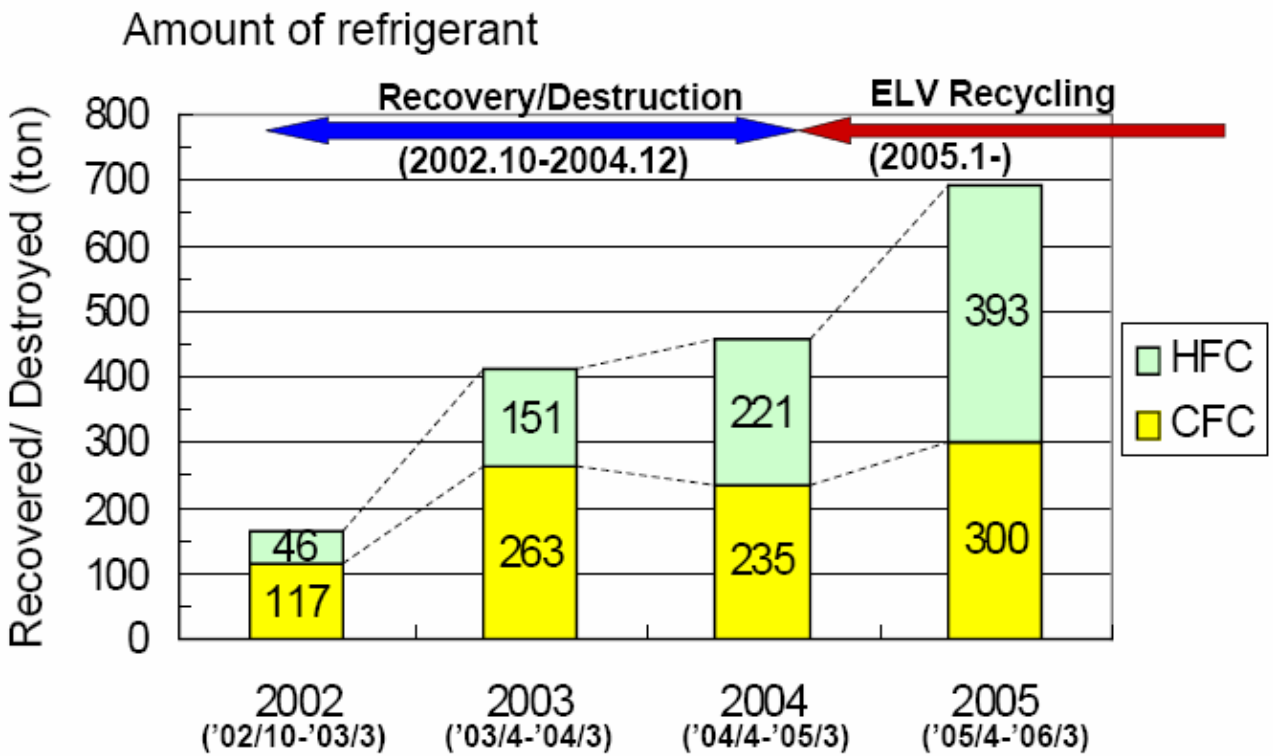
  or
  - Spend money to commercialize R152a system

# Other USA State Laws

- $CO_2$ is banned as a refrigerant in some states today
- Flammable refrigerants including R152a are banned in some states today
- Need to work to allow options
  - Waiting for responses from 10 states with known regulations

# Japan: Destruction of Recovered Refrigerant

## Achievement by Fluorocarbons Recovery and Destruction Law




- Amount of Recovery/ Destruction in 2005 is larger than 2004 by 52%.
- Amount of 2005 is reported under ELV Recycling Law.

# $Co_2$ Servicing Infrastructure: Japan

High pressure gas safety:
Registration required for stockpiling of CO2 gas cylinder, charging and sales etc.

CO2 Gas Maker (ex. Showa-tansan)

Chemical plant

Reclaiming

Compression

Recovery

Charging

CO2

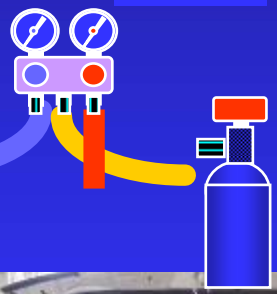
Documents should be sent to self-government office

Recycling of CO2 cylinder

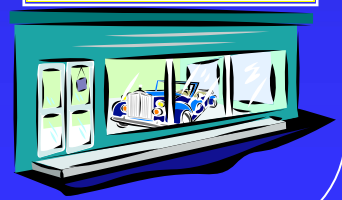
**Regular inspection (1times/5yrs by KHK)**

**Dealer**

**Charging and selling**

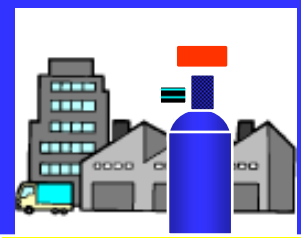


**Stocks of CO2 cylinder**



**Distribution of CO2 cylinder**

Refrigerant Vessel maker



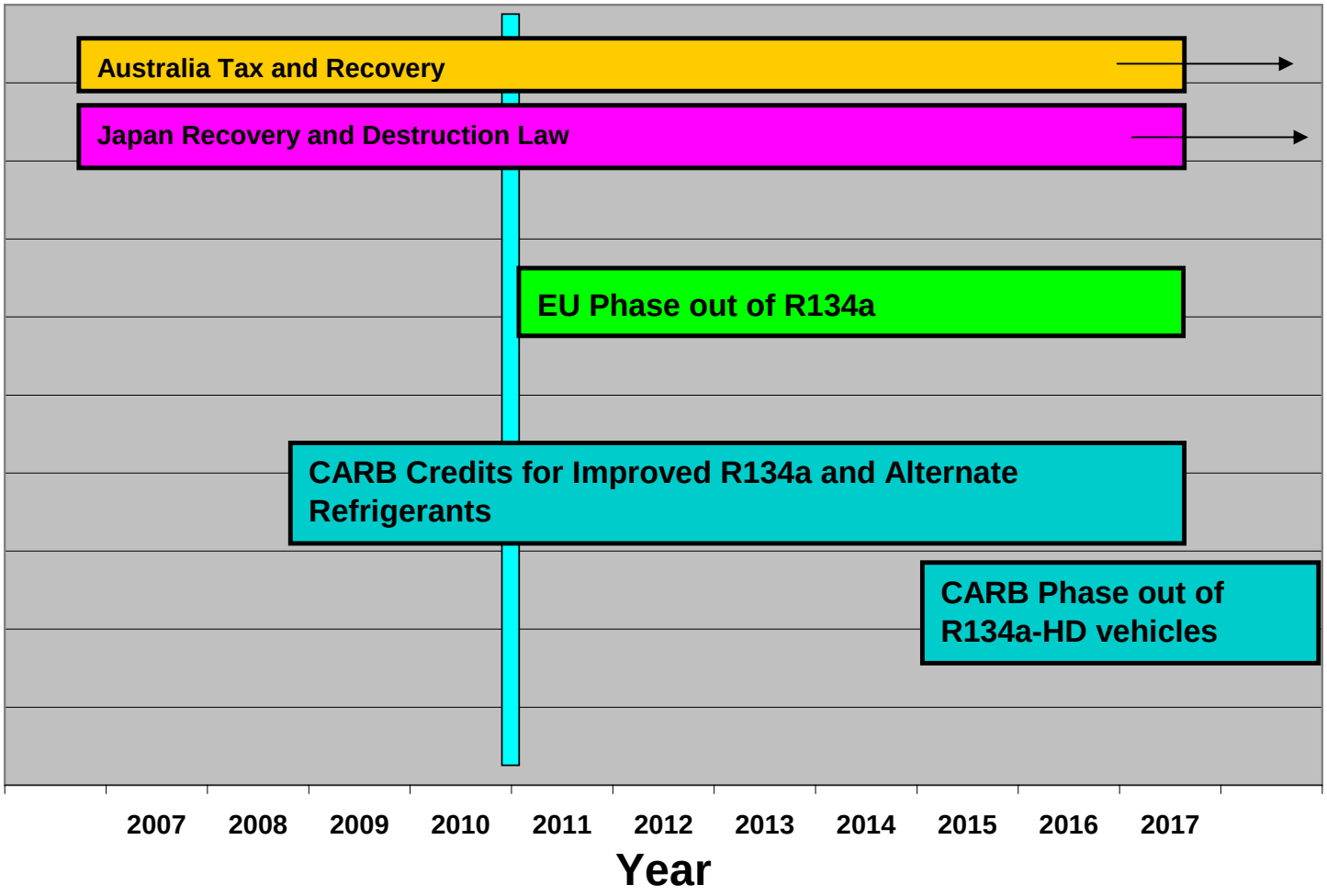
**Certification of cylinder by KHK**

**Restrictions of "HIGH PRESSURE G A S SAFETY LAW"**

KHK: Certification agent in Japan

# Refrigerant Regulations

## New Refrigerant Project Time Table



# Timing is Critical

- Timing is critical to meet EU requirements
  - Initial sourcing will occur in late 2007/early2008
- Costs will be high
  - Previous change from R12 to R134a in the early 1990's
    - World's automotive OEM cost $7 billion
    - U.S. service cost $1.5 billion
  - Total global cost of $8.5 billion for car manufacturers and the U.S. automotive service industry
  - New global industry cost(s)???

# Industry Cooperation Can Help!!!

# EPA SNAP Requirements

SAE International™

**To: Bill Wehrum, Assistant Administrator,**

**Office of Air and Radiation**

**U.S. Environmental Protection Agency**

**Subject: Significant New Alternatives Policy requirements for alternate refrigerants**

- **Assuming that these refrigerants meet the mobile air conditioning technical requirements have any of them been submitted by the chemical companies to EPA for SNAP or TSCA for environmental acceptability and toxicity considerations?**
- **When a chemical is submitted what minimum and maximum time frame is required for its acceptance?**

**December 10, 2006**

# EPA SNAP Requirements

SAE International™

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

FEB 14 2007

As stated in the original SNAP rulemaking, EPA believes that as long as class I or class II chemicals are being used, any substitute designed to replace these chemicals is subject to review under section 612 of the Clean Air Act (59 FR 13052). In addition, our experience is that manufacturers have found definitive SNAP review useful in providing safety assurance and regulatory certainty.

# US State Refrigerant Requirements


- **Alliance sent letters to10 States that reference SAE J639 Standards**

Please clarify whether new vehicles utilizing refrigerants R152a or R-744, conforming to SAE J639 and Federal Motor Vehicle Safety Standards, can be sold and operated in your state.

# US State Refrigerant Requirements

Alliance OF AUTOMOBILE MANUFACTURERS

COMMONWEALTH of VIRGINIA

DEPARTMENT OF STATE POLICE

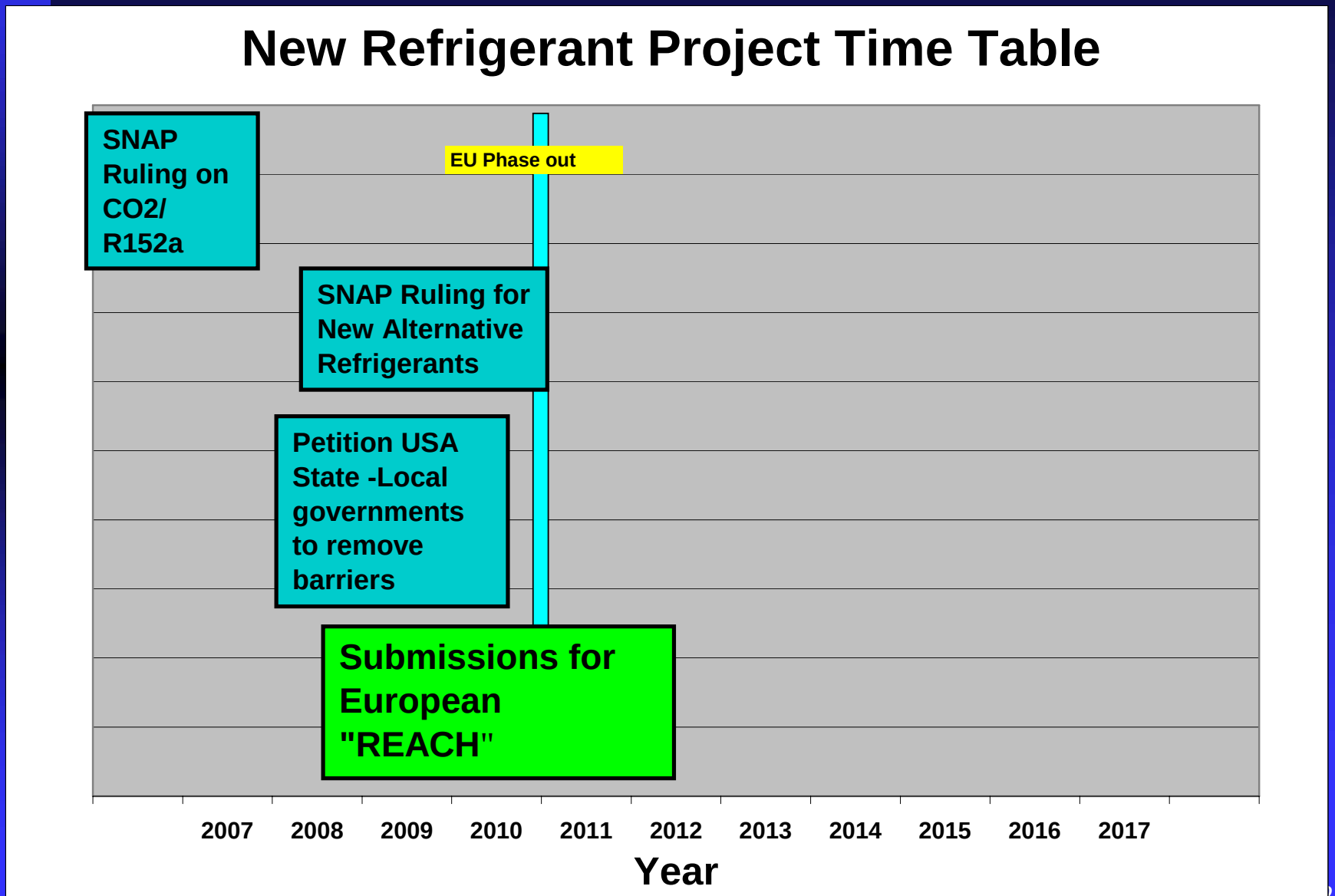
P. O. BOX 27472, RICHMOND, VA 23261-7472

February 26, 2007

Currently, Section 46.2-1088 of the Code of Virginia states that no refrigerant used in air-conditioning systems of automobiles shall be explosive, flammable, or toxic. In reviewing the information provided, it appears that R-152a, while mildly flammable, would not comply with the current language. Furthermore, R-744 contains carbon dioxide which would be considered toxic and would not be in compliance as well.

In order for these types of refrigerants to be sold or used in any vehicle in Virginia, it will be necessary to amend Section 46.2-1088 to allow their use. Further, any change to this code section will require the approval of the Virginia General Assembly.

# Use Conditions Time Table



# Need for Industry Cooperation

- Industry Cooperation is needed!
- Various industry groups are working independently now (Including SAE CRP150)
- Secrecy of refrigerant suppliers is making it difficult for cooperation
  - Proprietary refrigerant information and technology make selection more complex. Antitrust laws are a roadblock
- But a single choice for a refrigerant is best for the industry and best for the environment and customer!!!

# The Message

- Top Automotive Executives Need to Know:
  - Time to define production design A/C systems to meet the EU Law is running out
  - Selection of a replacement refrigerant for HFC134a is not complete

# There Are a Multitude of Alternatives!!

***All require more development***

# The Industry Future?

- 2008 –2010 CY
  - Potential early release requiring new car warranty servicing of R744 systems in Europe
  - HFC-134a I-MAC systems with new technologies for energy efficiency and leakage reduction
- 2011 CY Requiring new car warranty servicing of new non-HFC-134a systems in Europe
- 2011 and beyond
  - Independent repair facilities servicing multiple refrigerants globally

# New Refrigerant Requirements

- System Design issues
  - Compressor Modification
    - Capacity?
  - Hoses
    - Selective permeation
  - New Heat Exchangers
    - New Internal heat exchanger required?
  - Lubricant Compatibility
  - Material Compatibility
  - Modified Refrigerant Controls
  - Performance/Efficiency
  - Required Energy
  - Specific Service ports

# New Refrigerant Requirements

- Timing
  - Will refrigerant be available in the quantity needed?
- Costs
  - Investments
  - Refrigerant cost/kg
  - Component changes/additions
  - Service costs/recycling
- Service
  - Leak Detection Equipment
  - Recovery  Equipment
  - Charging Equipment
  - Recycle Equipment/or return to supplier for salvage
  - Technician Certification
- Toxicity / Flammability
- Life Cycle Climate Performance [LCCP]
  - Global Warming Potential

# Issues on Multiple Refrigerants

- Potential for mixing refrigerants in systems
  - Historically 8-10% of CFC12 fleet was contaminated with other refrigerants
- Major problems with SNAP listed replacements
  - Inadequate government enforcement
  - Aftermarket developed adaptor fittings
- Potential for venting at service if contaminated or wrong refrigerant installed
- New and separate service equipment needed
- Government Controls are needed
  - Regulated technician training / certification
  - Restricted access to refrigerants
  - Incentive to recover / recycle refrigerant

# New Alternative Refrigerant Issues

- Current Known Options
  - R744 Carbon dioxide
  - R152a
- New Potential Options
  - New Blend Refrigerants still under development
  - No new blend refrigerants have been submitted for EPA (SNAP) approval

# R744 Technology Impact

- Technical hurdles remain
  - Pressure is 7-10 times higher than R134a
  - All new tooling is needed
  - New internal heat exchangers are needed
  - New compressor technology has been developed
  - New expansion device technology is being developed
  - Packaging is different than R134a
  - Hose/sealing technology is still under development
  - Reliability is not proven on a variety of vehicles
    - Small vehicles are a particular challenge

# R744 Carbon Dioxide Systems

- Timing
  - Resources have been diverted to work on new alternatives
- Cost
  - Capitalizing and building component assembly plants
  - Limitations due to Patents & Sole Source Suppliers
- Service
  - New service equipment needed
  - Improved technician training needed
- Toxicity Need to meet SNAP requirements
  - Possible solution
    - Add odorant to carbon dioxide for safety to alert consumer and technician of refrigerant leak
      - Chance for service refrigerant not having odorant
- LCCP
  - Higher fuel consumption, increased vehicle emissions
  - Direct impact will be reduced

# 2. R744 Status

- DaimlerChrysler has started research on R744 for vehicle air conditioning in 1993.
- Since 1999 R744 has been considered as the substitute for R134a. With its GWP=1 it complies to the EU directive.
- Due to the thermodynamic and thermo-physical properties of R744 a complete new design of the refrigerant circuit components is required.
- The drawbacks of R744 compared to current technology are:
  - Precaution against elevated CO2 levels in confined spaces as passenger compartments and work spaces
  - Working pressures are up to 13 MPa. Staticly the system pressure is up to 9 MPa
  - Demanding joint technology and complex flexible lines
  - Additional components such as internal heat exchanger
  - Higher noise level due pulsation of compression
  - Increase of fuel consumption at specific parameters
- New service procedures and equipment have to be installed. Work on R744 air conditioning systems can only be carried out by highly trained and competent personnel.

# R152a Technology Impact

- Technical hurdles remain
  - Uses components similar to R134a system
  - Hose/sealing technology may need to be developed
  - Discharge gas temperatures are higher and may affect the compressor reliability – may be mitigated by lower discharge pressures
  - Reliability is not proven
  - Secondary loop
    - Chiller technology is not yet optimized for automotive applications
    - Requires the addition of coolant pump and reservoir
    - Can have other secondary benefits in vehicle applications with dual evaporators, hybrid vehicles and idle stop
    - Packaging is a challenge
    - Initial hot soak cool down may be delayed

# New Systems For Marketplace R152a

- **Timing**
  - EPA, Delphi, and others are working to optimize the technology needed
  - Additional manufacturing capacity is required
- **Cost**
  - Secondary loop or other safety mitigation will be required
- **Service**
  - New service equipment needed
  - Additional technician training needed
- **Toxicity**
  - Non-Toxic, but flammability issue needs to be addressed
- **LCCP**
  - Direct impact will be reduced by 95% as compared to R134a
  - Indirect will be less in direct expansion, but may be increased slightly in secondary loop

# New Systems For Marketplace Blends

Toxicity testing completion – no final answer until 2009+

On-Site Recycling or Return to Supplier

Negotiating purchasing agreements

Capitalizing and building chemical plants

Filling the supply chain

Commercial Risk is Not Insignificant

# SAE CRP 150 Blend Refrigerants Study

- Analysis of
  - Health and safety
  - Environmental impact
  - Risk assessment
- System material compatibility assessment
  - Hoses
  - Seals
  - Oils
- Quantify performance comparison to HFC-134a
  - New system component development
    - Heat exchangers
    - Compressors
- Service impact
  - New fittings
  - New standards for equipment/procedures

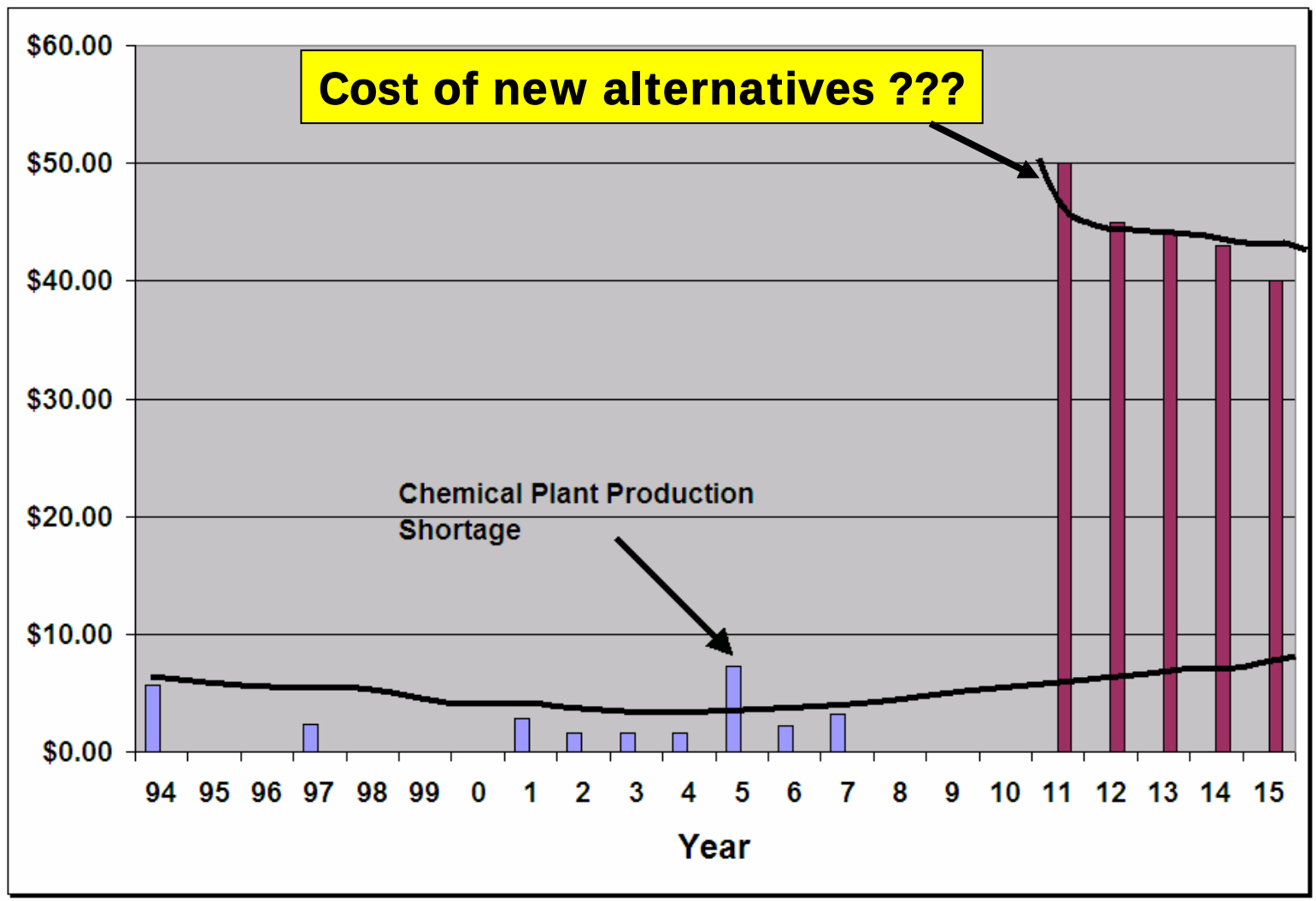
# Blend Refrigerant Technology Impact

- Technical hurdles remain
  - Uses components similar to R134a system
  - Hose/sealing technology need to be developed
  - Selective refrigerant system leakage is not fully understood
  - Reliability is not proven
  - Compatibility with all materials is unknown
  - Requirements for different systems are not defined
    - Fixed vs. variable compressors
    - External controlled vs. internal controlled compressors
    - Orifice tube versus TXV systems
    - Different heat exchanger technologies are affected differently

# New Blend Refrigerants

- **Timing**
  - New chemical plants are required
  - Sufficient supply of refrigerant is unknown
- **Cost**
  - Cost / kg will be significantly higher
  - Increased system costs for improved performance / efficiency
  - Increased service costs
    - Chemicals will likely have to be returned for reformulation
- **Service**
  - New service equipment needed
  - Additional technician training needed
  - Refrigerant recovery and Off-site recycling is likely
- **Toxicity**
  - Long-term toxicity tests will not be complete before plants need to be built
- **LCCP**
  - Indirect effects undetermined as systems have not been fully developed
  - Direct impact will be reduced by varying amounts

# Trend of R134a Service Spring Volume Purchase Price / pound



# 8. Conclusion

**Benefit**

- No large technology change in MAC is required
- Global approach should be possible

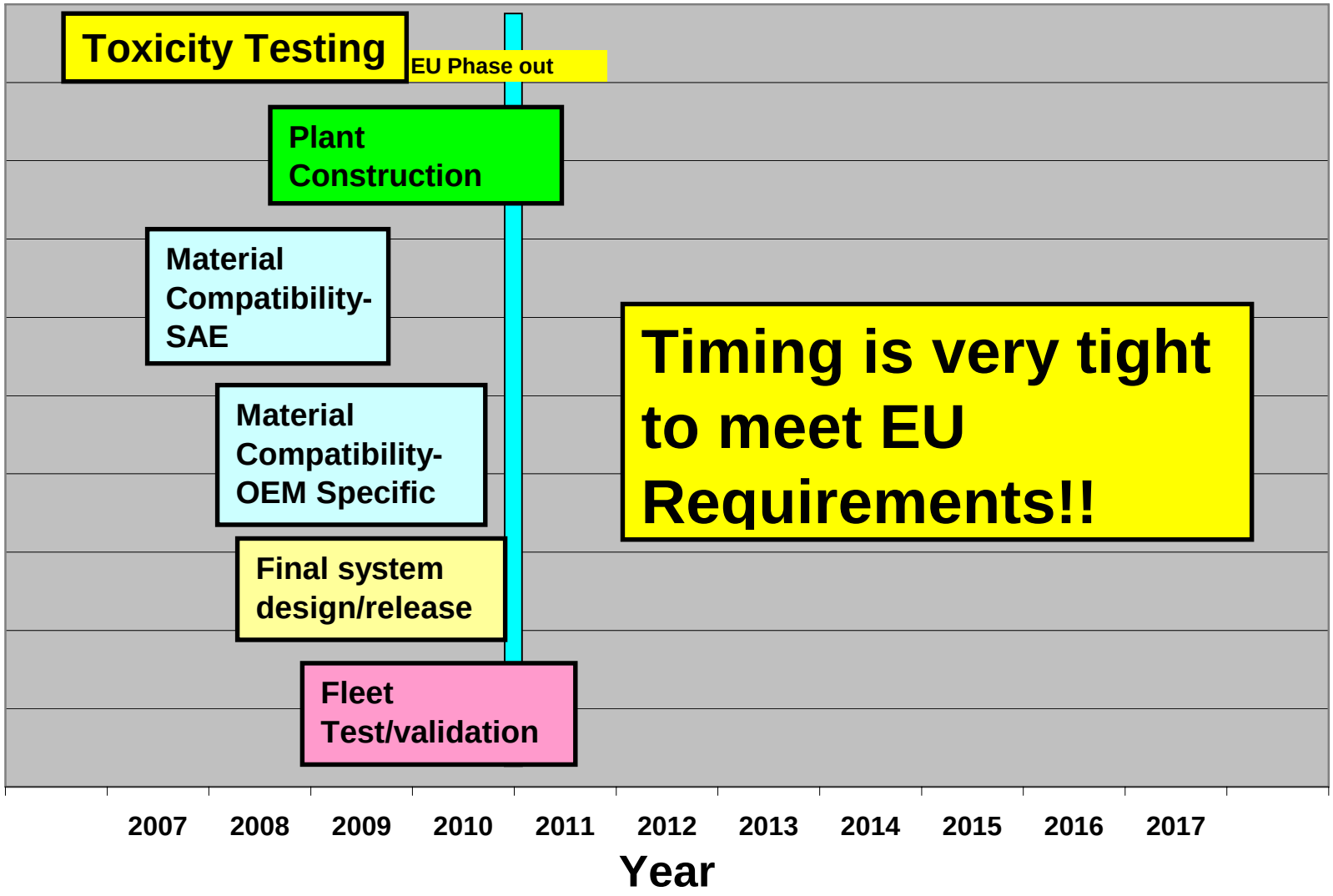
**Open Issues**

- Toxicity, Material compatibility and availability of enhanced circuit components
- The chemical industry remains very sensitive regarding confidentiality, their cooperation with the OEM and Tier 1 is not often satisfying
- Capacity and efficiency need further investigations on AC components and refrigerant circuit to close the remaining differences
- The sales price for the new refrigerants might avo a wide and fast introduction of these fluids; this becomes an even more severe disadvantage for t customer if a reliable re-use after recovery is not feasible

**The present status of our studies, technology and environmental compatibility shows the possibility to comply with the EU directive with one or more of the new synthetic refrigerants.**

# Blend Refrigerant(s) Time Table

## New Refrigerant Project Time Table



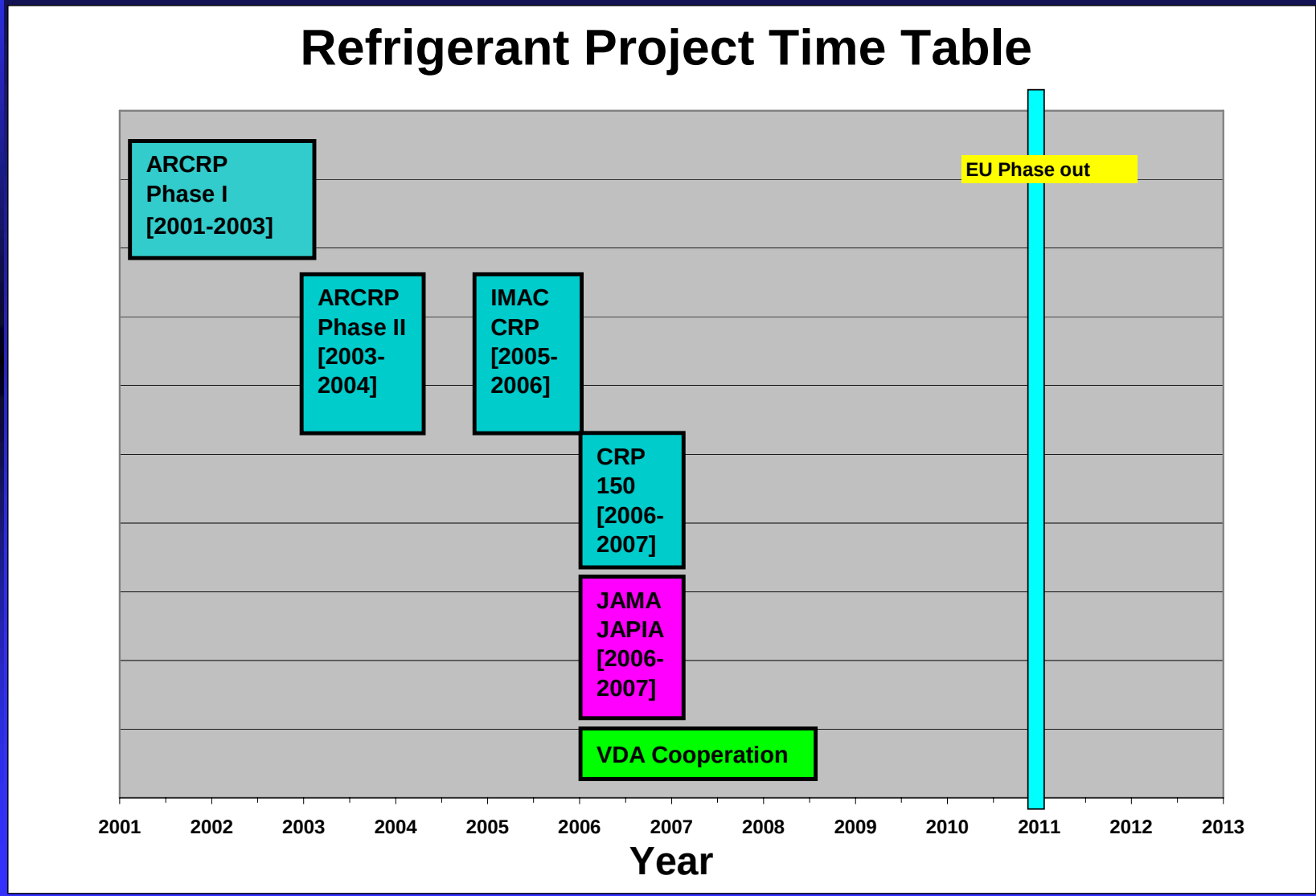
# No alternative has been chosen!

- Timing is tight
- Costs and tooling are variable
- Reliability is not fully proven on any of the alternative refrigerants with the variety of vehicles in current production
- No mechanism for choosing one single alternative
  - There may not be one global refrigerant in the future
  - Multiple refrigerants will increase costs to all regions, all refrigerant systems, all suppliers, all OEM's, and all Consumers!
- Service impact will be large
- Current resources are stretched to do a thorough evaluation of all alternatives
  - Risks are high that there may be more issues that are still unknown

# R134a is not so bad for the Environment !!

## Industry Cooperation Works!

# Industry Activity Time Table



# SAE Cooperative Research Programs

- Alternate Refrigerant Cooperative Research Program Phase I
  - Study of R134a system as compared to R744 and R290 [Secondary loop]
- Alternate Refrigerant Cooperative Research Program Phase II
  - Study of R134a and R152a systems as compared to R744
- Improved Mobile Air Conditioning
  - Study of improved R134a technologies
- Cooperative Research Program 150
  - Study of systems and components for use with use of refrigerants < 150 GWP
  - JAMA/VDA Efforts Parallel this

# New HFC-134a Systems For Marketplace

- Improved HFC-134a systems
  - Have less refrigerant leakage
  - Use less refrigerant
  - Are more efficient
- Reduced refrigerant loss at service requires:
  - New service equipment
  - Improved technician training
- Added costs could be rewarded with proposed emission credits (California,et al)

# R134a can be improved!

- Leakage has been improved over the last five years
  - Further improvements have been demonstrated in the SAE IMAC CRP
- Efficiency improvements are being introduced on new vehicles to reduce the fuel economy impact of AC
  - IMAC has demonstrated further improvements are possible
- Improved service equipment is being introduced in the USA
  - Need to do this globally
- Benefit Cost of improved R134a systems is much greater than any of the proposed alternatives

# Life Cycle Climate Performance

## Cradle-to-Grave Emissions For A Mobile A/C System

- Production Energy - All Materials
- Refrigerant Emissions
  - Refrigerant Mfg and Transportation Losses
  - Vehicle System Leakage
  - Vehicle Service & End - of - Life Losses
- Energy to Carry A/C System Mass
- Energy to Operate A/C System
  - Vehicle Tail Pipe Emissions
- Energy Required for re-claim and re-cycle all A/C system materials including end of life and manufacturing of refrigerant

# The Questions ???

- Does the new refrigerant really lower total GHG emissions?
  - Is the advantage reduced / loss due to lower energy efficiency?
- Is the refrigerant recyclable (reusable) on-site in service shops?
  - Or is a new collection and offsite reclamation industry required?

# The Questions ???

- Consumer cost of service adds to cost of ownership
  - High cost refrigerant will drive some consumers to use a lower cost refrigerant – likely propane
  - Cost-effective refrigerant will be the most successful for global application.
  - High cost refrigerants will prolong the use of HFC-134a indefinitely.
- Bang for the Buck
  - How can industry/consumer money best be spent to improve the environment?
    - Improve R134a systems or replace them?

# Questions???

**Which alternative can best make it to production in time to meet the law?**

**Commercial Uncertainty – what stands in the way?**

**Will there be just one global refrigerant in the future??**

# New Refrigerants?

- Development expense of multiple refrigerants
- Manufacturing complexity of multiple refrigerants
- Packaging issues of multiple refrigerants
- Piece costs increases caused by multiple refrigerants
- Uncertainty of Supply for new chemicals
- Chemical Plant Capitalization, Distribution & Timing
- Recovery time for capital investment

# 2007 Phoenix ARSS


**In July more of the story will be told !!**