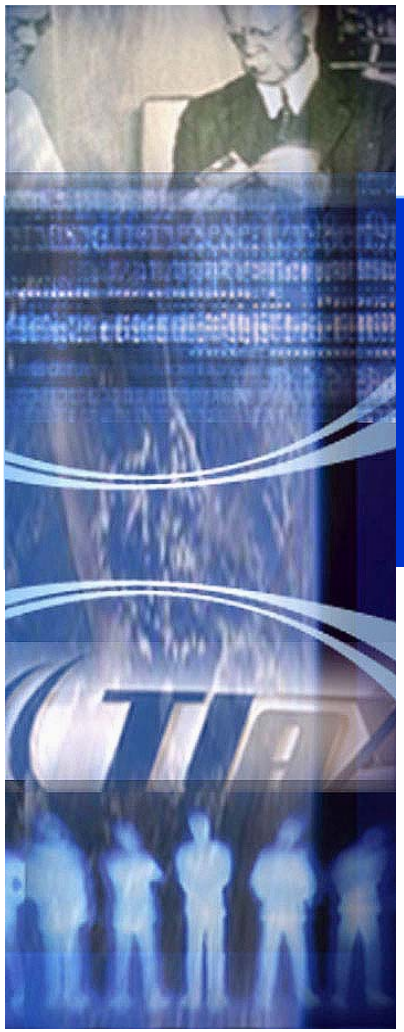

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Distributing Urea for the On-Road Vehicle Market

Presented
at

DEER 2006
August 20-24, 2006
Detroit, Michigan

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Agenda

1. Introduction
2. Estimated Urea Consumption
3. Urea Distribution Pathways
4. Estimated Urea Costs/Prices
5. Infrastructure Requirements
6. Operating Costs
7. Concluding Remarks

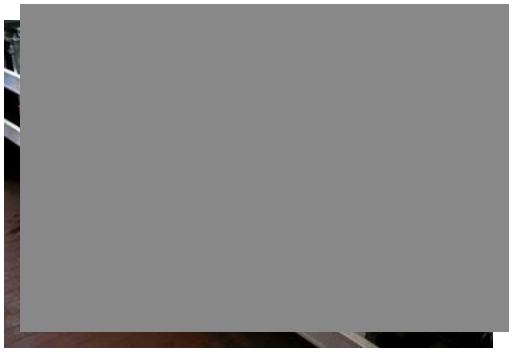
Will an Urea Infrastructure Developed if Engine Manufacturers Chose SCR for 2010 NOx Control?

- What vehicle applications will use SCR Urea?
- How much urea will be required for these applications?
  - NOx reduction needed
- How will urea be manufactured and supplied for the on-road market?
  - Urea specification
  - Aqueous urea: 32.5 % (vol) with deionized water
  - Trucked to large station users
  - Packaged/bottle and shipped to retail outlets
    - Totes
    - Barrels
    - Bottles
- What's the cost and possible business case for manufacturing and distributing urea?

Several Light- and Heavy-Duty Engine/Vehicle Manufacturers Have Selected SCR as Their NOx Control Strategy

- On road SCR systems will use aqueous urea—on road specification at 32.5% mixed with deionized water
- For light-duty vehicles to meet Tier 2, Bin 5 NOx standards urea will require 2% aqueous urea (urea volume to diesel volume)
- For heavy-duty vehicles to reduce engine out NOx emissions from 1.2 g/bhp-hr to 0.2 g/bhp-hr will require 1% aqueous urea
- On-board urea storage depends on vehicle packaging, weight, and range considerations

SCR Catalyst



Urea dosing Unit and Integrated Urea/Diesel Tank

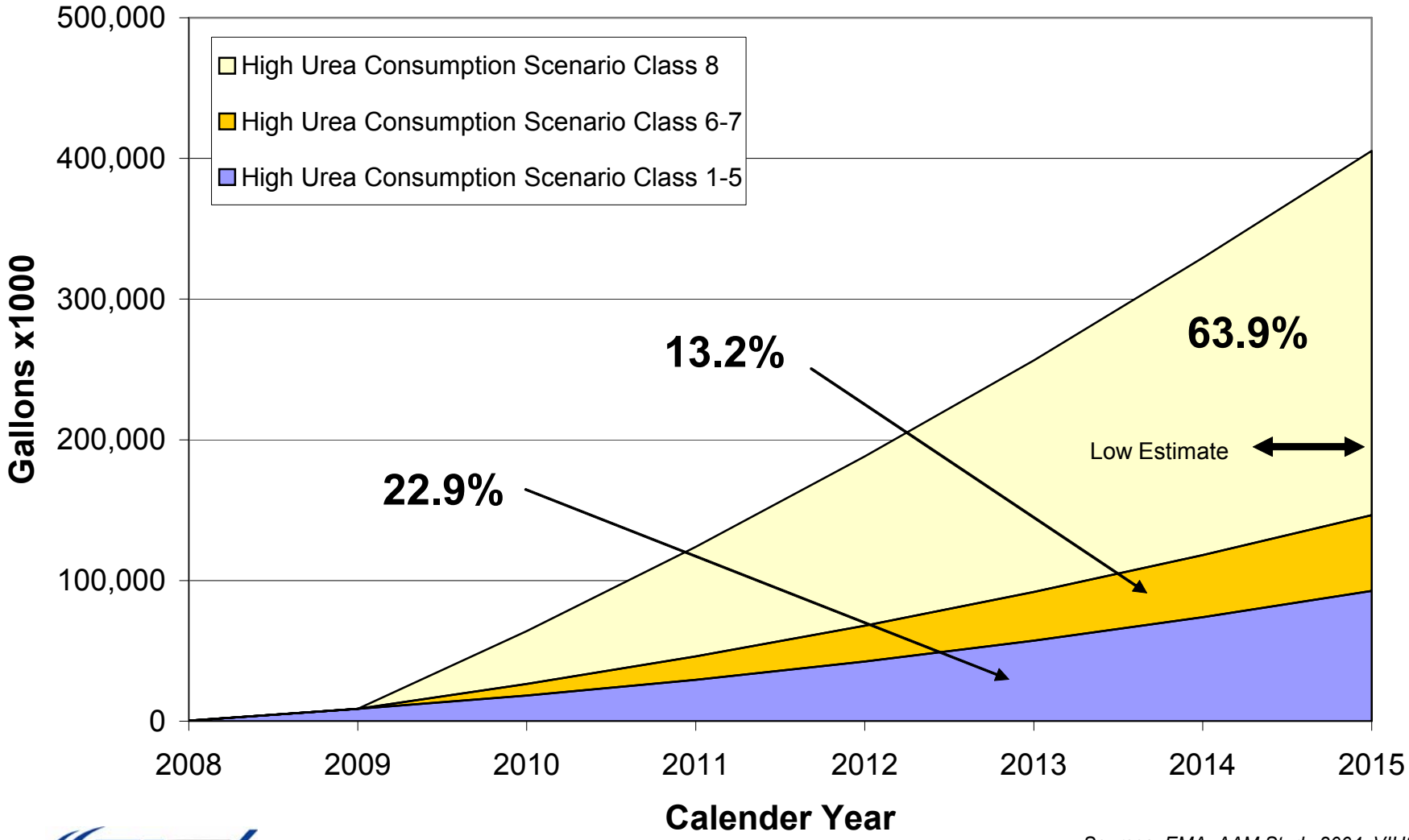
Sources: NREL Study 2002

Urea consumption = (sales estimate x VMT x urea consumption %) / FE

- Consumption estimates were calculated for each vehicle class: LDV (1-5) and HDV (6,7) and HHDV (8)
- VIUS 2002 data was segmented in order to provide a reasonable outlook
  - All diesel vehicles on the road are used to determine annual VMT
  - Trucks that were less than 1 year old were used to determine fuel economy
- Sales estimates obtained from
  - Alliance of Auto Manufactures and EMA for LDVs (13.4% to 4.4%)
  - EMA for HDVs (consistent with Wards Sales data)
- Urea Consumption varying sales estimates and urea consumption used to provide range of estimates
  - Low range: 4.4% LDD sales (with 2% urea) and 1% urea in HDVs
  - High range: 13.4% AAM LDD sales and 2% urea in HDVs

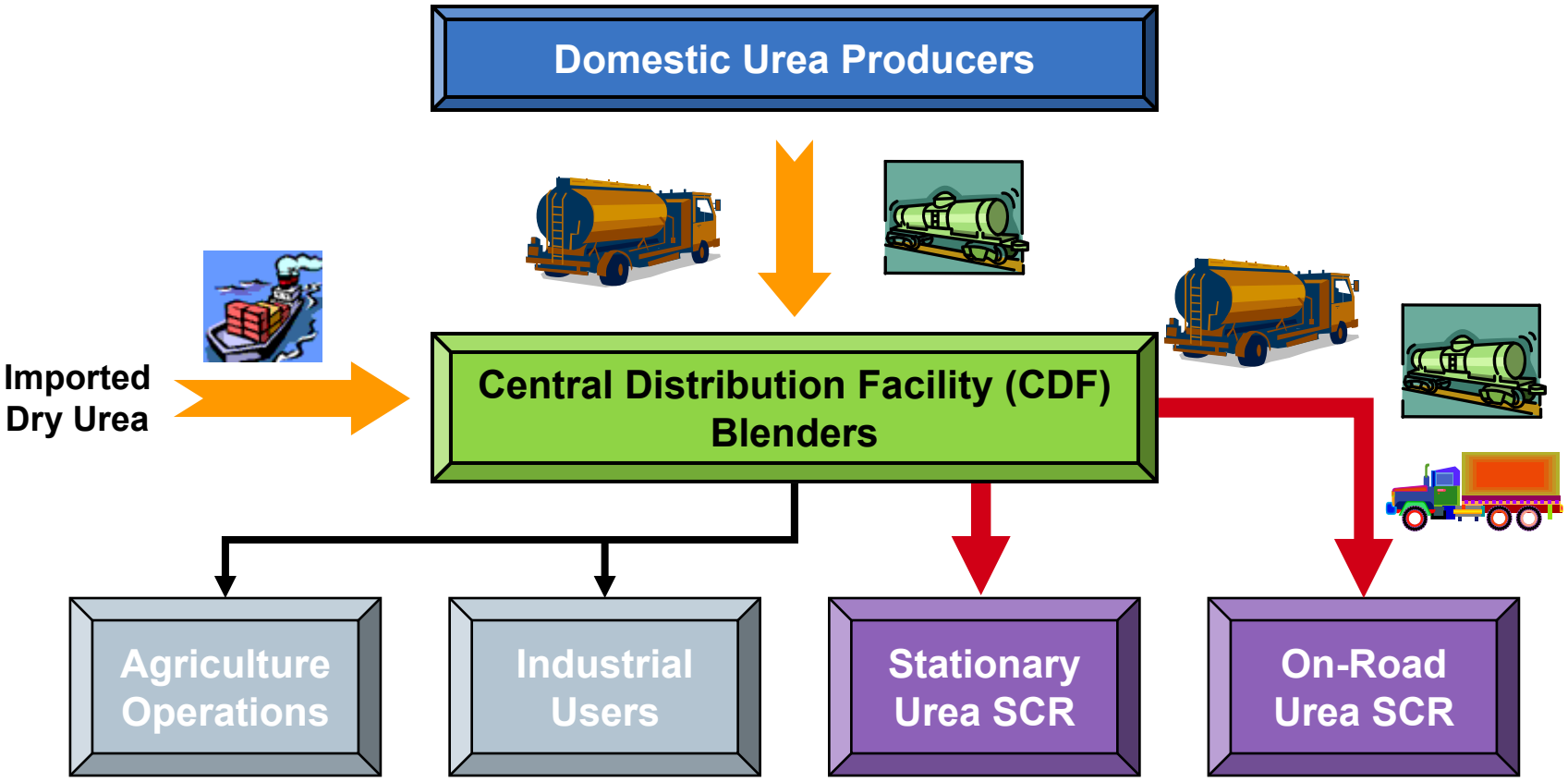
Source: VIUS 2002

Urea Consumption Estimates



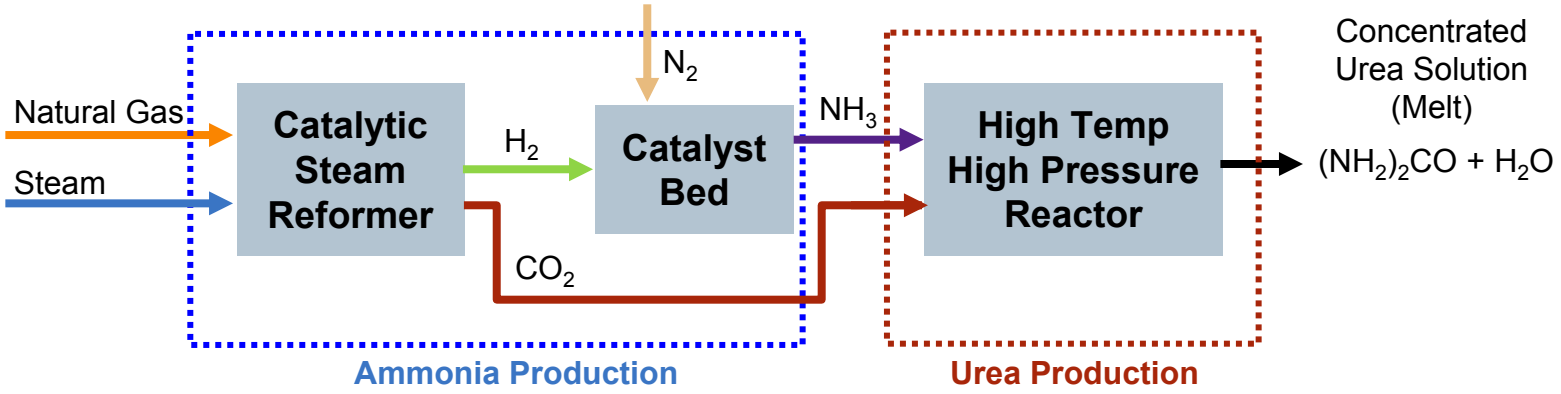
Sources: EMA, AAM Study 2004, VIUS 2002

Domestic and Imported Urea is Shipped to a Central Distribution Facility, Blended and Transported to the Retailer



- Truck Stops
- Fleet Refueling
- Retail Stations
- Other Retail

Urea Manufacturing and Specification



Urea Classifications		
Agency Listing	**Hazardous**	**Carcinogenic**
EPA	No	No
OSHA	Yes[2]	No
DOT	No	
Federal Hazardous Waste Regulations[1]	No	

1. 40 CFR 261
2. Some of the MSDS' surveyed indicate that urea is not hazardous under OSHA Hazard Communication Standard 22CFR 1910.1000

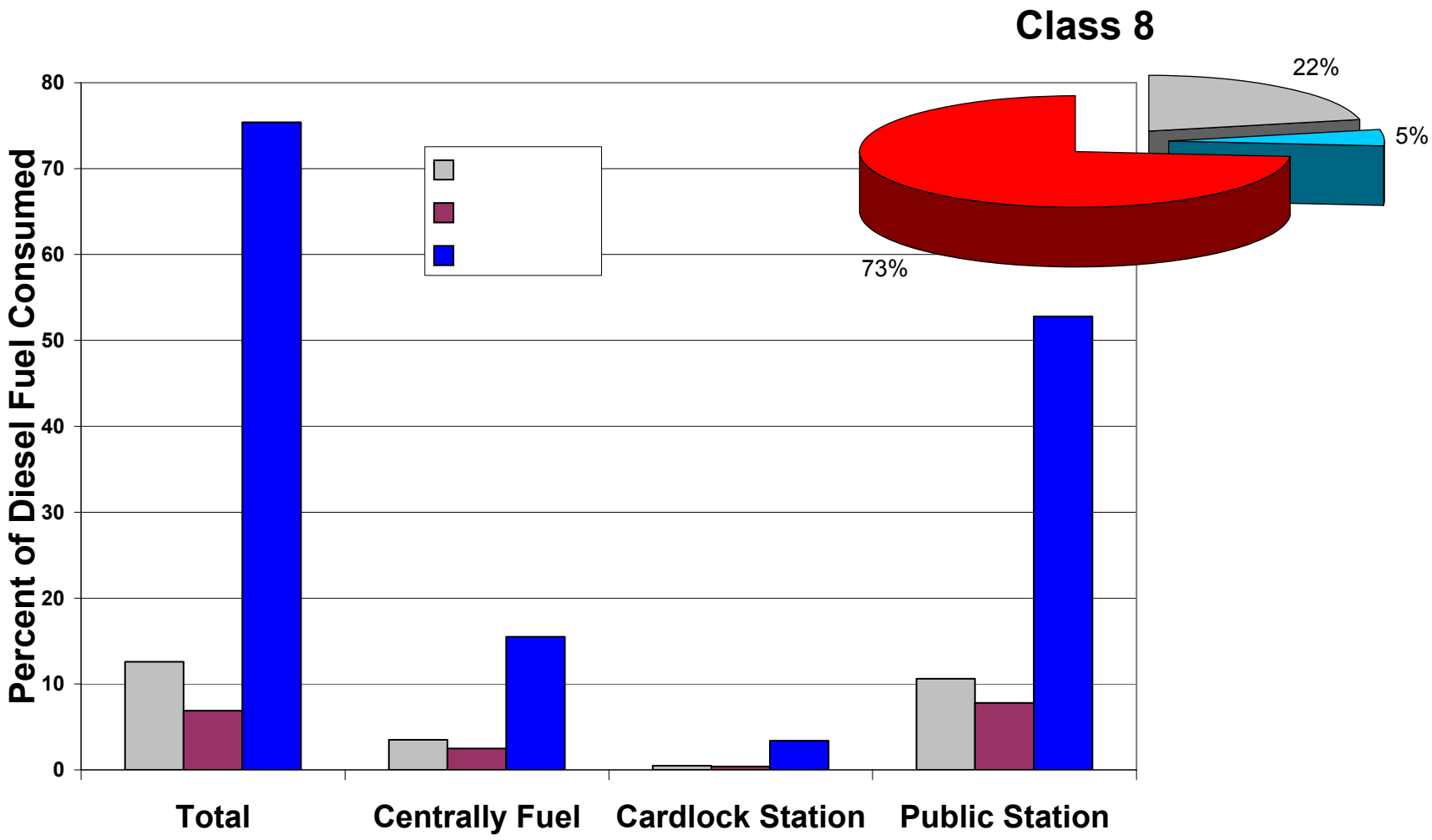
SCR Urea DIN 70070 as of 2005			
	Unit	Min	Max
Urea Concentration	wt%	31.8	33.2
Density at 20°C	kg/cm3	1087	1093
Refractive Index at 20°C		1.3814	1.3843
Alkalinity as NH3	wt%		0.2
Biuret	wt%		0.3
Aldehyde	mg/kg		5
Insolubles	mg/kg		20
Phosphate	mg/kg		0.5
Calcium	mg/kg		0.5
Iron	mg/kg		0.5
Copper	mg/kg		0.2
Zinc	mg/kg		0.2
Chromium	mg/kg		0.2
Nickel	mg/kg		0.2
Aluminum	mg/kg		0.5
Magnesium	mg/kg		0.5
Sodium	mg/kg		0.5
Potassium	mg/kg		0.5

Sources: NREL Study 2002

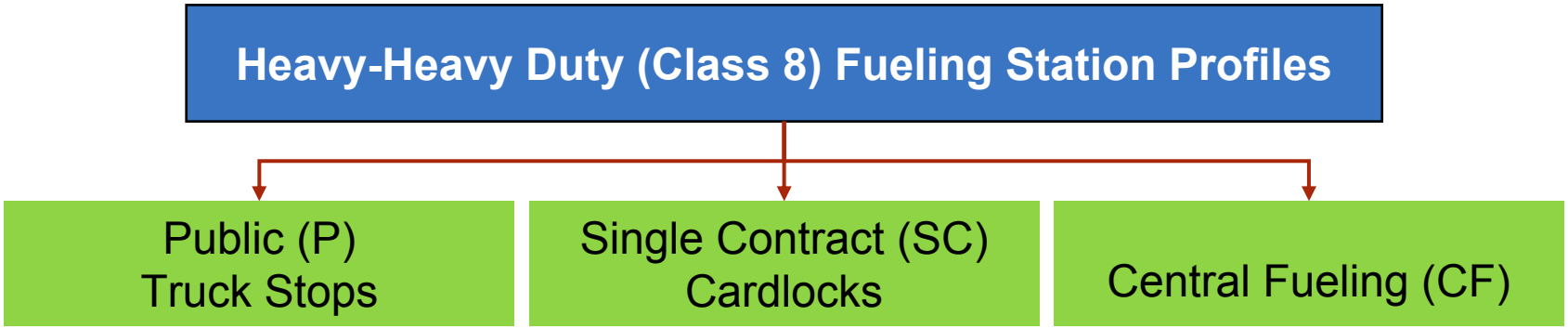
Urea Gallons Needed Between Maintenance or Fueling Intervals for Various Vehicle Classes

	Urea Tank Range Analysis		
	Light-duty Car; Class 1	Light heavy-duty Truck; Class 6-7	Heavy heavy-duty Truck; Class 8
	< 10,000 lb	19,501 - 33,000 lb	> 33,000 lb
Fuel Economy, mpg	29.60	8.45	6.51
Average Miles/Yr	12,227	12,974	41,500
Urea Consumption %	2.0%	1.0%	1.0%
Urea Tank Size (gal)	7.5	20	20
Urea Tank Range (mi)	11,100	16,901	13,025
Diesel Tank Size (gal)	13	100	300
Diesel Tank Range (mi)	385	845	1,954
Diesel Fills/Urea Fills	28.85	20.00	6.67
Long Maint. Interval (mi)	7,500	15,000	25,000
Miles Short for Maint.(mi)	0	0	11,975
Urea Gallons Needed between Maintenance Intervals (gal)	0.00	0.00	18.39

Characteristics of Private and Commercial Truck Fueling



Heavy Duty Truck Fueling Occurs at Truck Stops, Cardlocks, and Central or Fleet Fueling



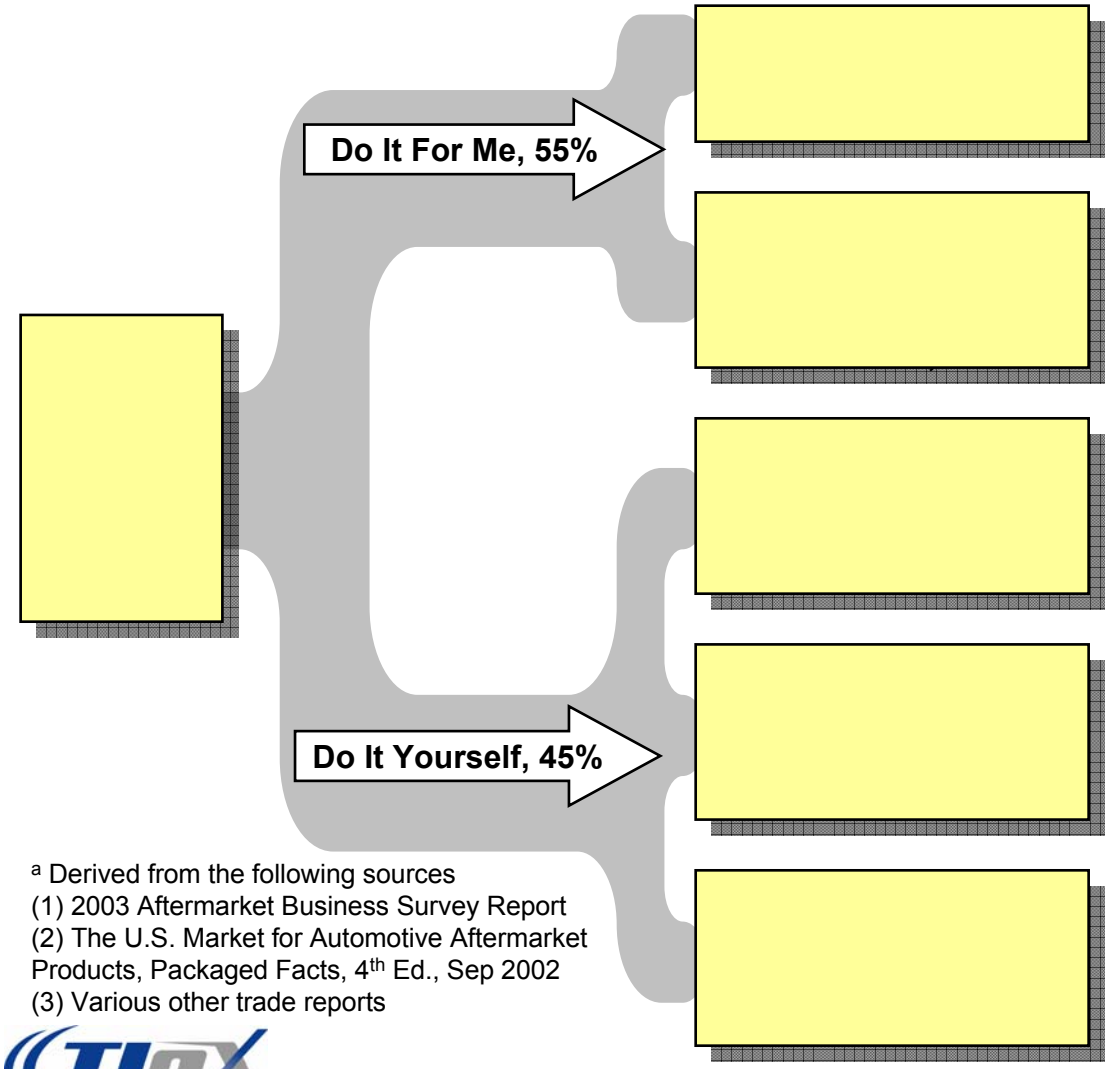
- 5,000 truck stops in the U.S.
- Distributed throughout the country. Tracks regional on-road diesel consumption.
- Avg. fuel throughput 200,000 gal/mo
- 78% have below-average throughput
- High: 750,000 to 1,000,000 gal/mo
- Low: 10,000 gal/mo
- 54% of all on-road diesel consumption

- 2,500 cardlocks serving HD truck diesel
- Distributed throughout the country. Skewed towards urban centers.
- 4% of all on-road diesel consumption
- Average fuel throughput estimated based on the VIUS database (DB) = 80,000 gal/mo

- 25,000 central fleet fueling stations for HD trucks
- Assumed distributed throughout the country. Profile under investigation.
- 16% of all on-road diesel consumption
- Average fuel throughput estimated based on the VIUS DB = 25,000 gal/mo

Sources: EMA Study 2003: NATSO, EPA, CFN, Waste Management, BP, VIUS97

Urea Distribution for Light Duty Diesel Vehicles Will Follow the Existing Automotive Maintenance Market

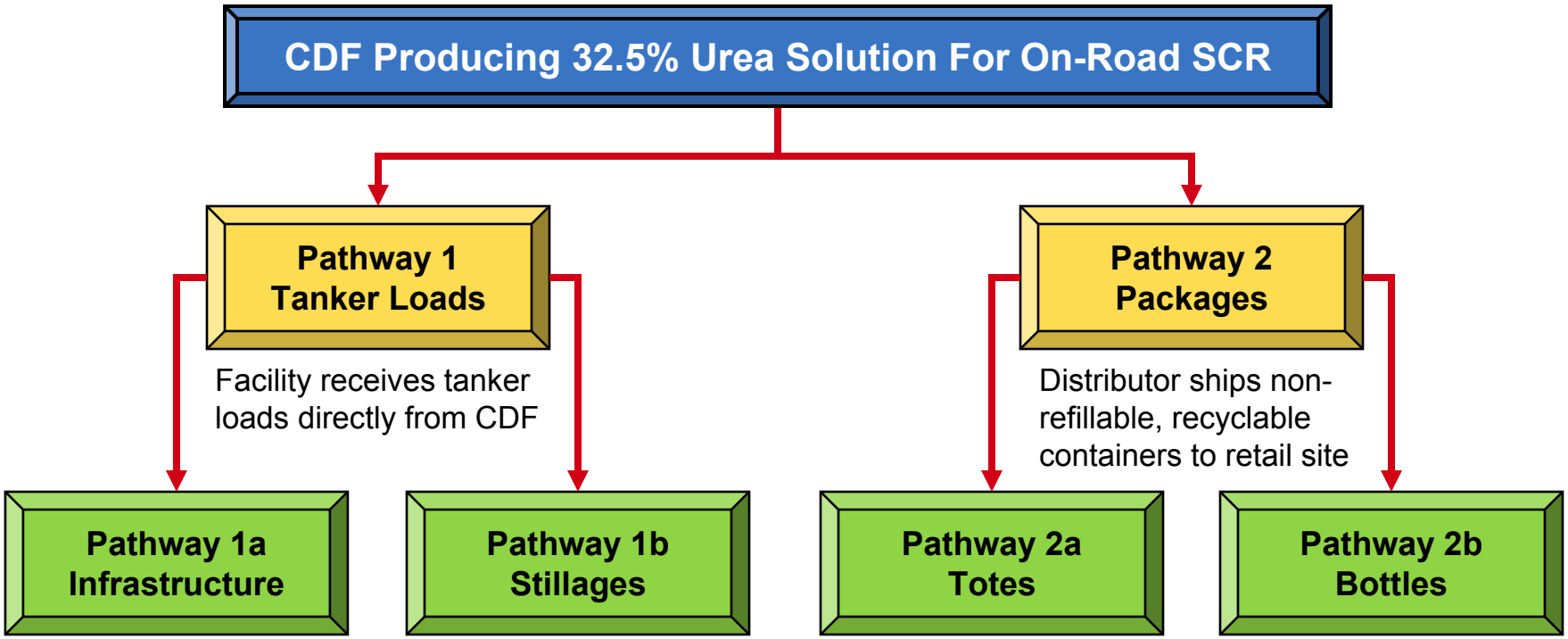


- On average, the existing automotive maintenance market share is also applicable to motor oil change
- It can be expected that any new automotive aftermarket functional fluid will exhibit similar retail characteristics on maturity
- SCR-urea is likely to have a price point that is similar to that of key automotive functional fluids such as motor oil, coolant, brake fluid, etc.
- Further, depending on the ease and frequency of urea refill, the urea market share will also **"naturally"** mature to resemble the market shown in the figure on the left

[a] Derived from the following sources
(1) 2003 Aftermarket Business Survey Report
(2) The U.S. Market for Automotive Aftermarket Products, Packaged Facts, 4th Ed., Sep 2002
(3) Various other trade reports

Sources: AAM Study 2004

Two Main Pathways for Urea Delivery are Tanker Loads and Packages



- Sales > 2500 gal/month
- Facility installs permanent UST/AST and dispensing system

- Sales 500-7,500 gal/month
- Facility utilizes purchased, refillable dispensing systems

- Sales < 1000 gal/month
- Retail site uses totes that are dropped off full, replaced when empty

- Sales < 500 gal/month
- Retail site uses bottles or sells bottles to customers

The European SCR-Urea Market is Currently Selling AdBlue, a 32.5% weight by Volume Aqueous Urea Solution, in a Variety of Volumes

Stillages[a]

Totes[a]

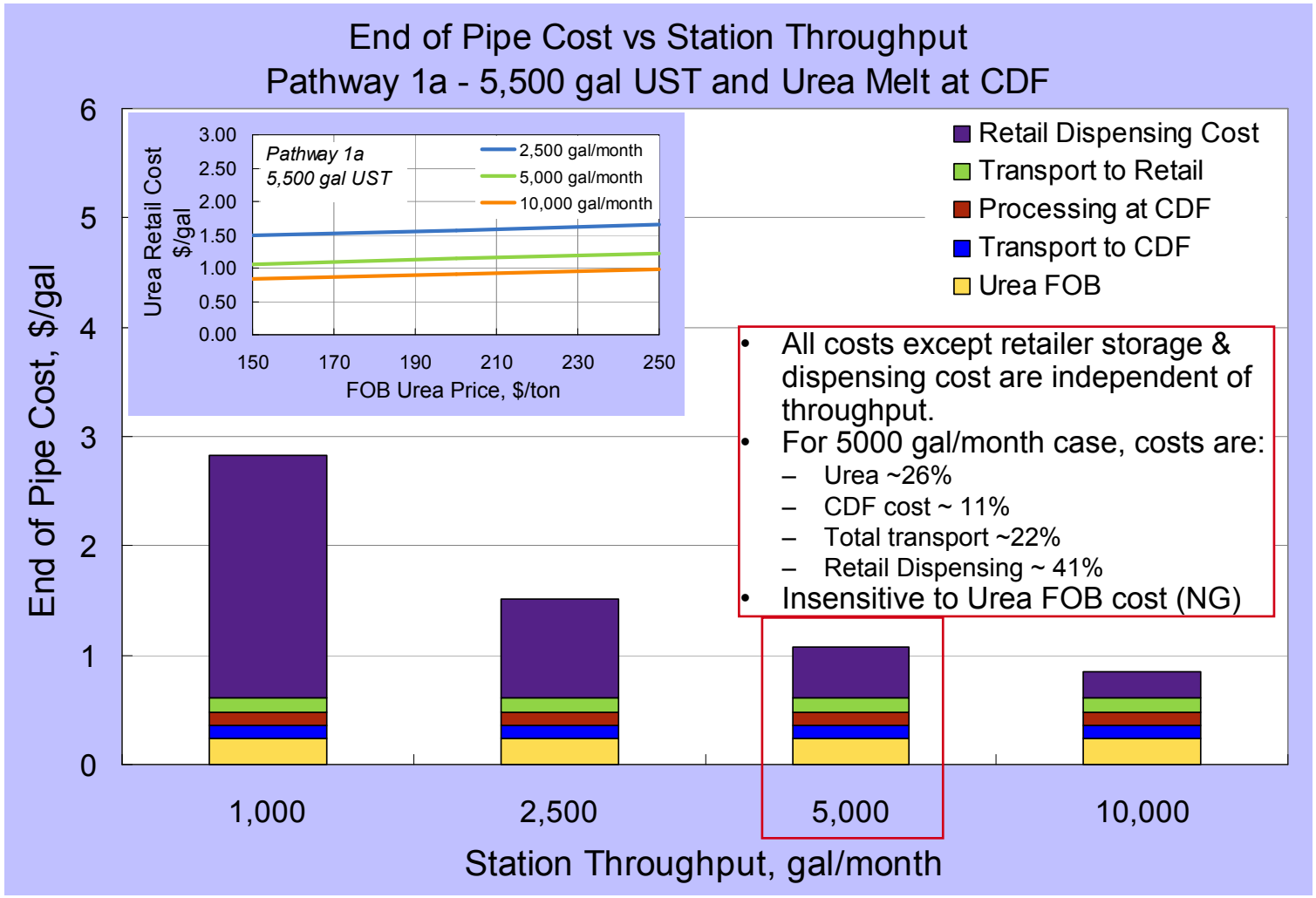
Bottles[a]

AdBlue Retail Containers	Container Volume	Price of AdBlue ($/gal)[c]
Stillages[b]	15,000-L (3,963-gal) 3,000-L (793-gal)	2.12 2.52
Totes	1,000-L (264-gal)	2.78
Bottles	18-L (4.8-gal) 10-L (2.6-gal) 5-L (1.3-gal)	4.30 4.63 5.30

[a] Pictures of Air1 are shown as an example and do not imply an endorsement of the product
[b] Stillages are covered under Pathway 1 in this analysis
[c] Prices are shown without applicable taxes.

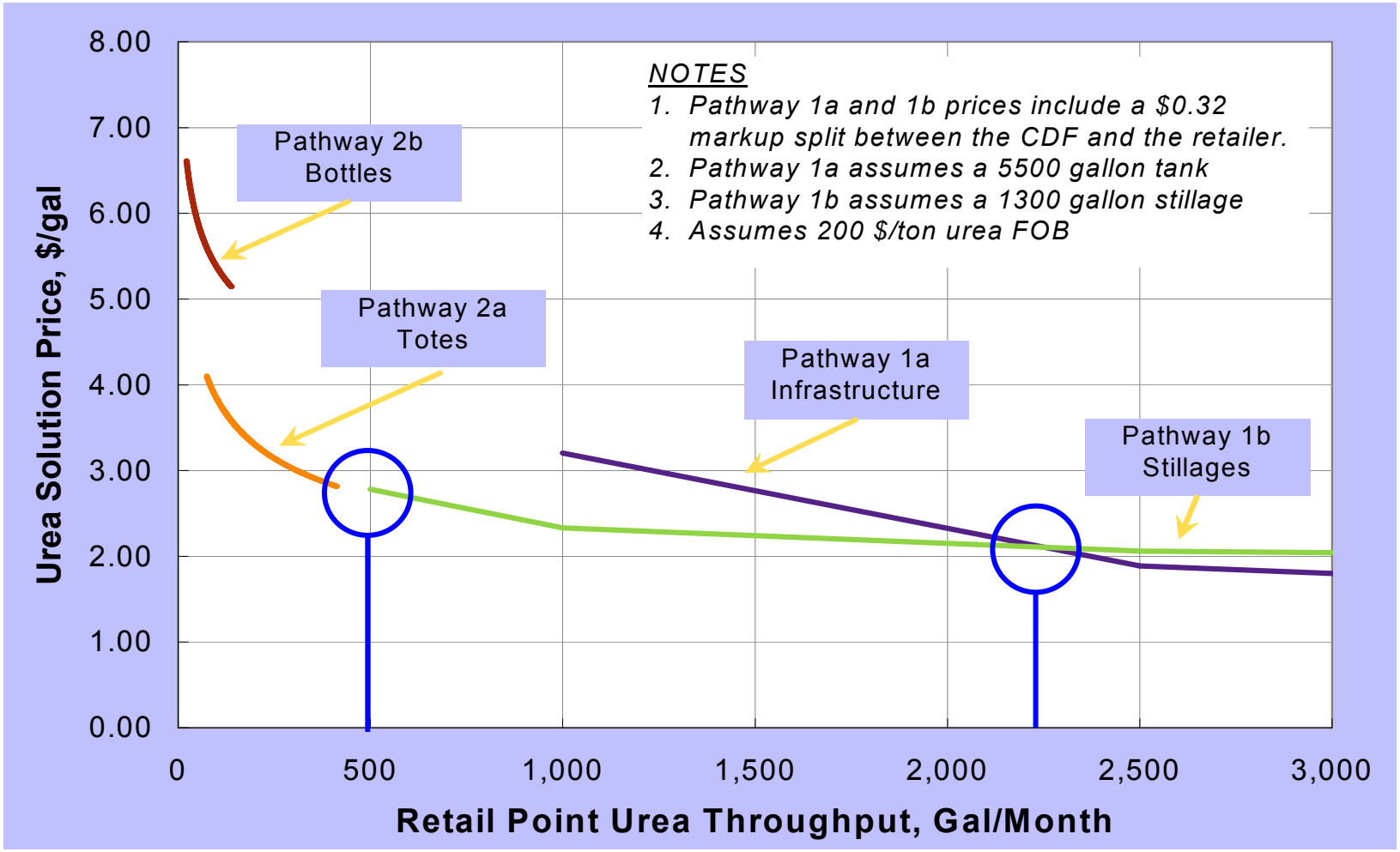
Sources: AAM Study 2004

Retailer Costs Dominate Urea Costs for Underground Tanks Selling Less Than 10,000 gal/month*



* For 2010-2015, TIAX projects all stations will be less than 10,000 gal/month.

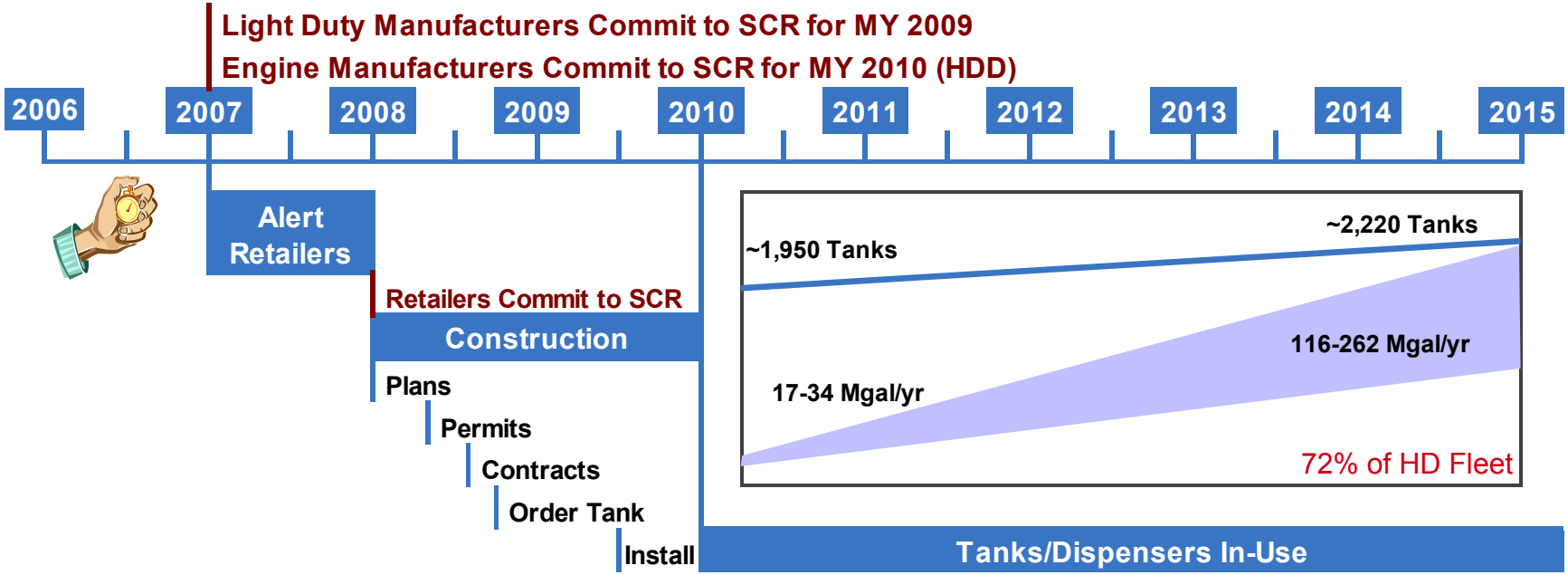
Projected Urea Prices for Various Retail Distribution Strategies



Methodology for Estimating Urea Infrastructure

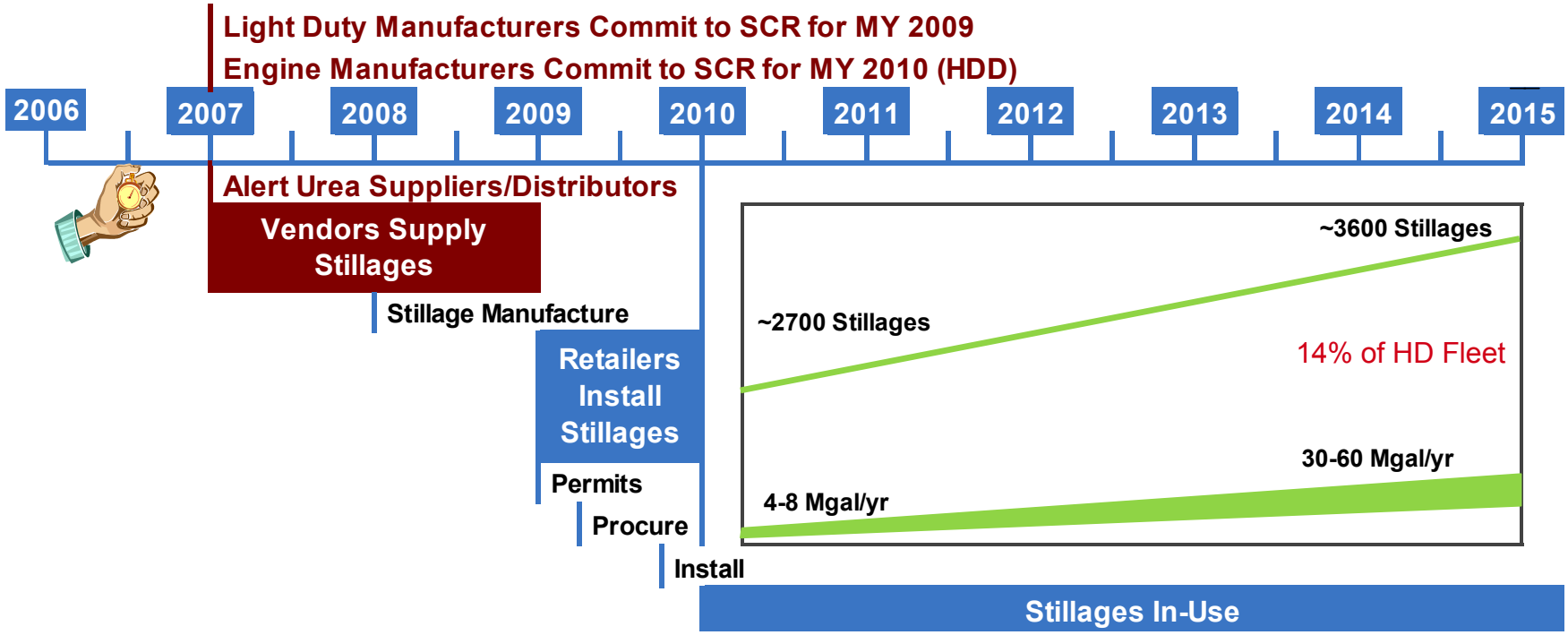
- For pathway 1 segmented diesel fueling into station sizes and then assigned urea volume
  - Station size, number of stations, and percentage of diesel throughput
  - For each station size determined urea throughput based on percentage of diesel throughput
  - Determine type and number of urea dispensing systems needed to meet urea demand
    - Type based on infrastructure costs (function of urea throughput)
    - Above ground or underground tank systems for large throughputs, stillages for medium, and totes for small throughputs
- For pathway 2 assigned remaining urea demand among a widely distributed supply system that provides coverage within 20 miles to a high percent of U.S. population
  - Dealers, service stations, fueling stations, auto parts stores, and mass merchants (~30,000 sites throughout the U.S.)
  - Barrels and totes, and bottles

Need 2 Years to Install 1,950 Tank-Dispenser Systems (Pathway 1A). Construction Should Begin Jan 2008



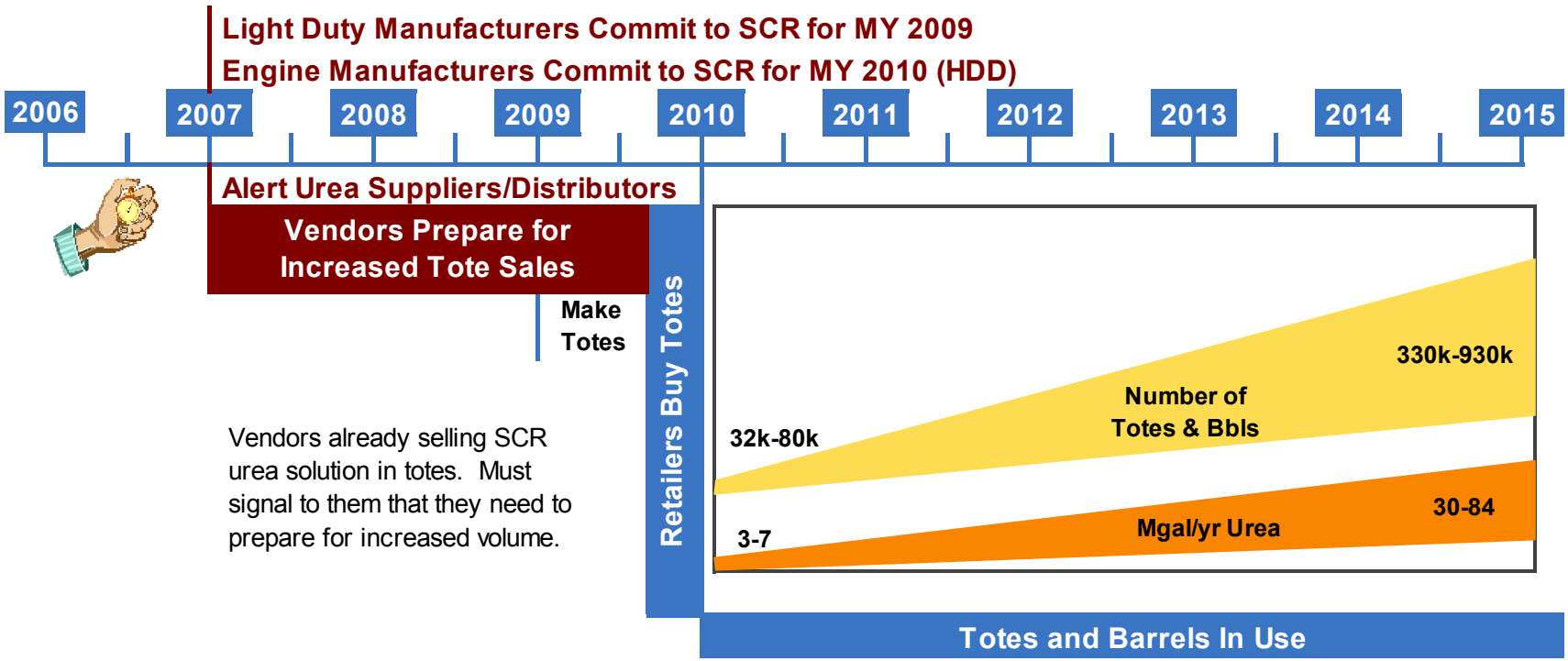
5,500 gal UST throughput range: 500 to 10,000 gal/month

Need 1 Year for Retailers to Site and Install 2,700 Stillages by 2010 (Pathway 1B)



1,300 gal Stillage throughput range: 100 to 2,000 gal/month

For Pathway 2A, Vendors Already Sell Urea in Totes for Stationary SCR Use but Will Need Significant Jump in Volume by 2010



264 gal totes or barrels throughput range: 60 to 240 gal/month

Services both HD and LD Market

Vendors will need to set up bottling production to handle projected bottled urea demand

Light Duty Manufacturers Commit to SCR for MY 2009
Engine Manufacturers Commit to SCR for MY 2010 (HDD)

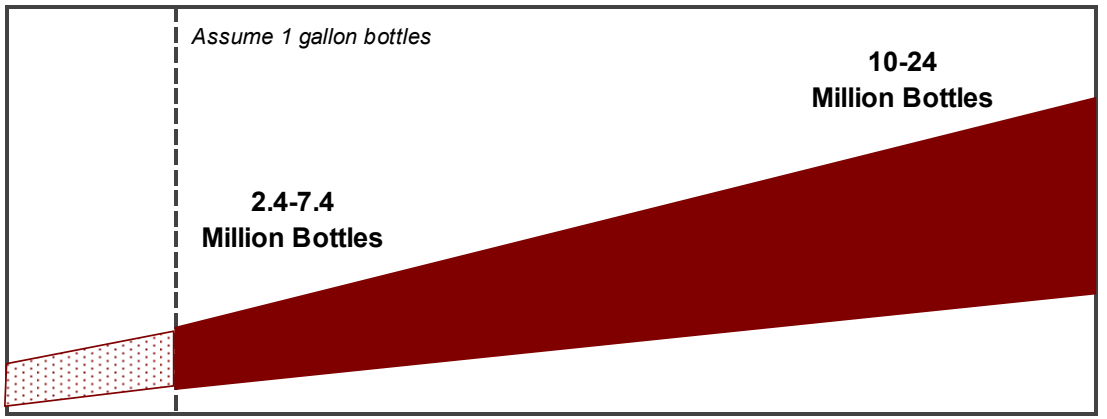
2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015

Alert Urea Suppliers/Distributors

Distributors Bottle SCR Urea

Setup Bottling

Must signal to vendors they need to either make agreement with bottlers or set up bottling lines.



Bottles In-Use

Distributing 1 gallon bottles in 2010 to ~30,000 retail sites

Dealers	21%
Service Stations	19%
Fueling Stations	8%
Auto Parts Stores	1%
Mass Merchants	1%

Operating Costs for Urea are Lower than Fuel Penalty Costs of Other Alternatives for 2010 NOx Compliance

- Range of urea consumption identified to be between 1 and 2%
- Urea price for Classes 1-5 average of Pathway 2 prices, Pathway 1 average for Classes 6-8
- Diesel cost per gallon range uses EIA AEO2006 projected diesel price for the low, today's diesel price for the high
- 5% Fuel Economy Penalty is compared to urea costs
- All prices and costs shown in 2006 $

	Light Duty Class 1-2			Heavy Duty Class 8		
	Local <200 miles	Medium 200-500 miles	Long >500 miles	Local <200 miles	Medium 200-500 miles	Long >500 miles
Fuel Economy (mpg)	17.6			6.5		
VMT (mi/yr)	13,100	25,000	50,000	15,000	50,000	125,000
Urea Consumption	1% to 2%					
Urea Price ($/gal)	4.97			1.99		
Diesel Price ($/gal)	$1.82 to $2.94					
5% FE Penalty ($/yr)	$68 - $109	$129 - $208	$258 - $417	$210 - $339	$699 - $1,129	$1,747 - $2,821
Urea Costs ($/yr)	$37 - $74	$70 - $141	$141 - $282	$46 - $92	$153 - $306	$382 - $764

Full Range of Urea Infrastructure from Underground Tanks to Bottles can Develop in Time to Meet the Needs of Light- and Heavy-Duty Diesel Vehicles Using SCR

- Clear signal from vehicle manufacturers is needed by 2007
  - Urea manufacturers
  - Urea distributors (CDFs)--some construction lead time
  - Urea Retailers--permitting and construction lead times
  - Equipment and system manufacturers—manufacturing lead times
- European experience will help U.S. infrastructure development
  - Vendors with product already developed for stillages, totes, and bottles
  - U.S. numbers not overwhelming according suppliers of dispensing equipment
- Margins make a reasonable business case based on “averages”, but detail planning will be required to achieve these margins
  - Need to meet urea demand but not strand infrastructure investment
  - Easiest for large volume stations harder for small volume stations

Thank You For Your Attention

TIAX Final Report Available on Engine Manufacturers Association (EMA) Web Site:

http://www.enginemanufacturers.org/admin/content/upload/186.pdf

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