Executive Summary for:
SCR-Urea Implementation Strategies Update
Final Report

Engine Manufacturers Association

June 29, 2006

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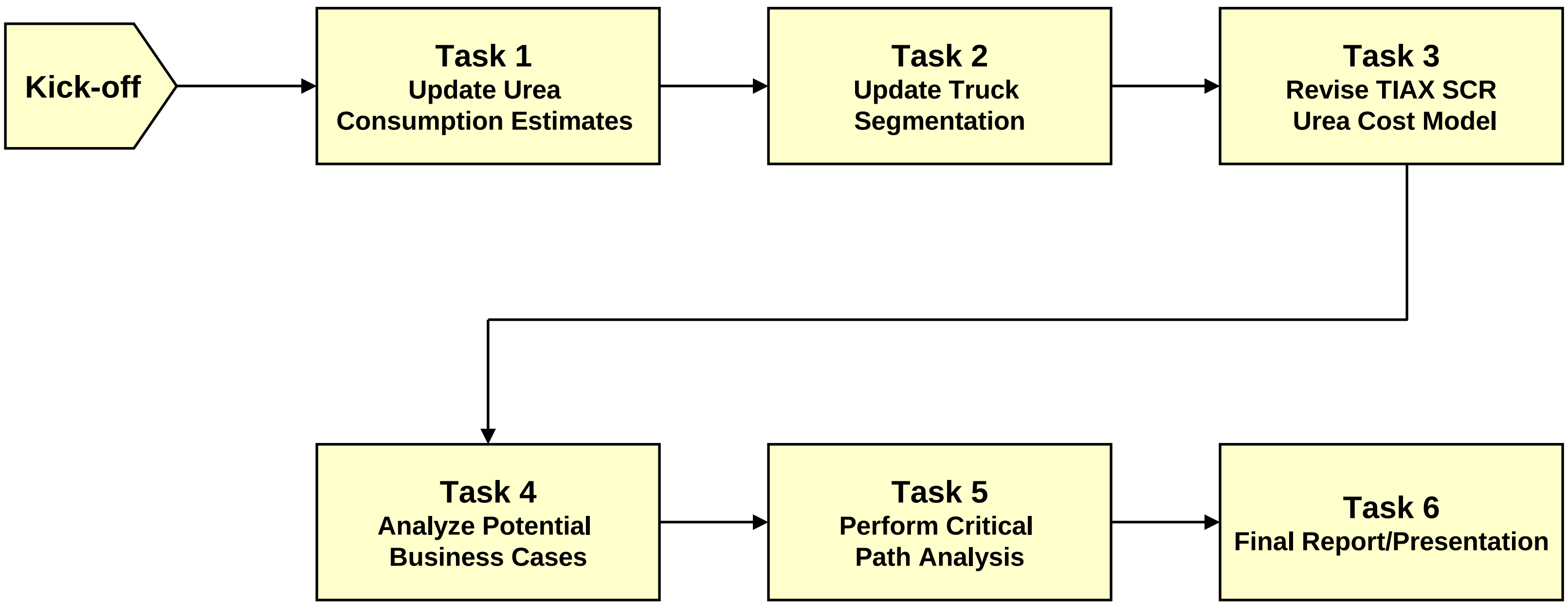
Reference:D.5498

The Engine Manufacturers Association commissioned an update to the 2003 “SCR*-Urea Infrastructure Implementation Study” because several influences had changed and their impact was unknown

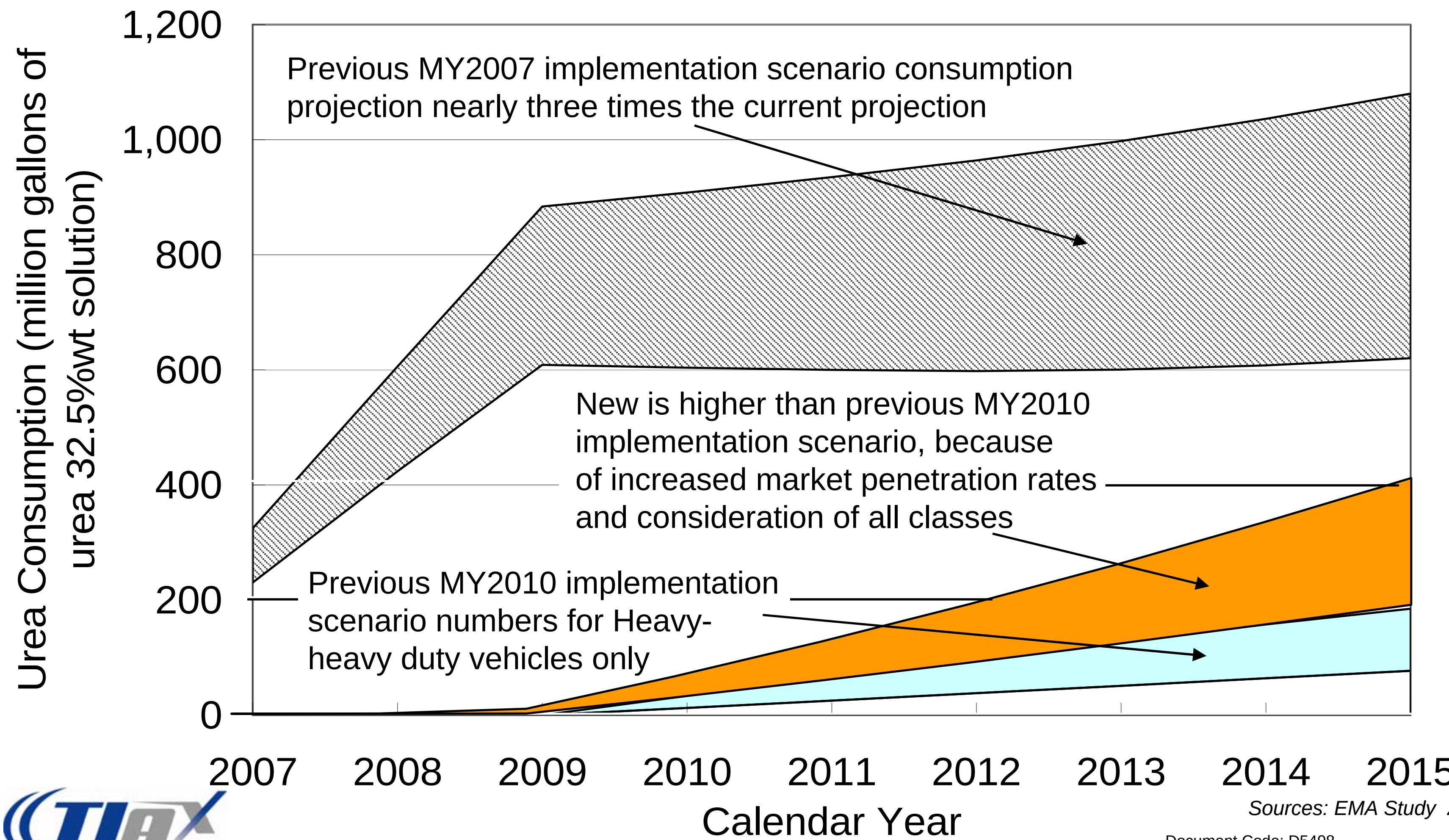
- MY2007 implementation no longer a possible scenario
  - Changes key timelines in the implementation of a future infrastructure
  - Consumption ratio would change to match 2010 engine technology
  - Slow growth rate of market could inhibit the economic feasibility of urea infrastructure
- Projected sales volumes of SCR-urea vehicles increased
  - SCR-urea systems expected for all classes, not just Heavy-heavy duty
  - Light-duty diesel vehicles are expected to gain market share
- Interaction between Light-duty urea market and Heavy-duty urea market was unknown
- Other factors that influence transportation sector have changed
  - Petroleum price increase and projected prices of fuel
  - Effect of higher NG prices on the cost of urea to the on-road market
  - Market needs for SCR-urea in the stationary sector are growing

* Please see a full list of acronyms at the end of this report

TIAX completed the following tasks in order to update the SCR-urea implementation strategies



New estimated urea consumption (~400Mgal/year in 2015) is significantly lower than the MY2007 implementation scenario values (~800Mgal/year in 2015) that were previously used to project urea station throughput…



Sources: EMA Study 2003

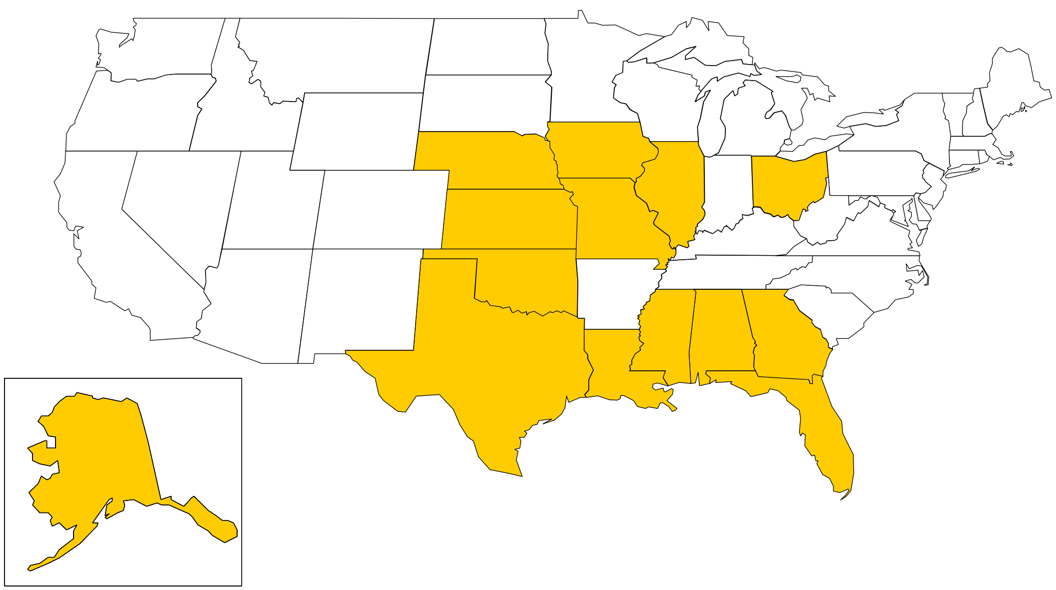
…However, the estimated urea consumption in the United States is projected to be greater than the previous MY2010 implementation estimates

- Urea consumption ratios of 4.0% to 5.6% were analyzed for the MY2007 introduction case because of the higher engine-out NOx expected from 2007 engines
- 2007 consumption estimates were predominately used through the previous study to identify the needs of the infrastructure
- 2010 engines are projected to have much lower engine-out NOx levels, but this could vary from manufacturer to manufacturer
- There are three main reasons that the new projection for MY2010 implementation is higher than the previous study
  - All classes of vehicles were included in this study, previous study concentrated on Heavy-heavy duty trucks
  - Projected increase in LDD passenger car sales
  - Urea consumption ratio is assumed to be between 1% and 2%, rather than 0.8% and 1.2%

The current major urea-producing states are in close proximity to abundant natural gas sources, like the Gulf of Mexico and Alaska

Major Urea* Producing States in the United States

* Includes both urea and urea ammonium nitrate



Key Urea Manufacturing Companies in the U.S.	Capacity	
	2002[1]	2005[2]
	Million TPY	Million TPY
Agrium	1.2	0.9
CF Industries	2.4	3.3
PCS Nitrogen	1.9	1.0
Terra Industries	1.4	1.3
Other	3.1	1.7
Total	**10.1**	**8.2**

1. www.the-innovation-group.com
2. British Sulphur Consultants, CRU Group for 2005

U.S. Capacity has decreased over the past 3 years from 10 to 8 Million TPY

Sources: The Innovation Group, British Sulphur Consultants

U.S. urea consumption is supported by domestic and world urea producers

- Urea production and import levels are heavily influenced by the price of natural gas, the main feedstock for urea production
- Rise in domestic natural gas prices leads to increased urea imports
- Roughly one-half of current domestic consumption is foreign urea imported by domestic distributors
- SCR urea will likely come from domestic suppliers of concentrated solution rather than imported granular urea
- Total on-road SCR-urea demand is projected to be 0.6 Mtons/yr by 2015
- Total Stationary demand projected to be ~0.5 Mtons/yr by 2010
- Sufficient worldwide urea production capacity exists to meet U.S. on-road SCR-urea demand

Urea Production and Distribution

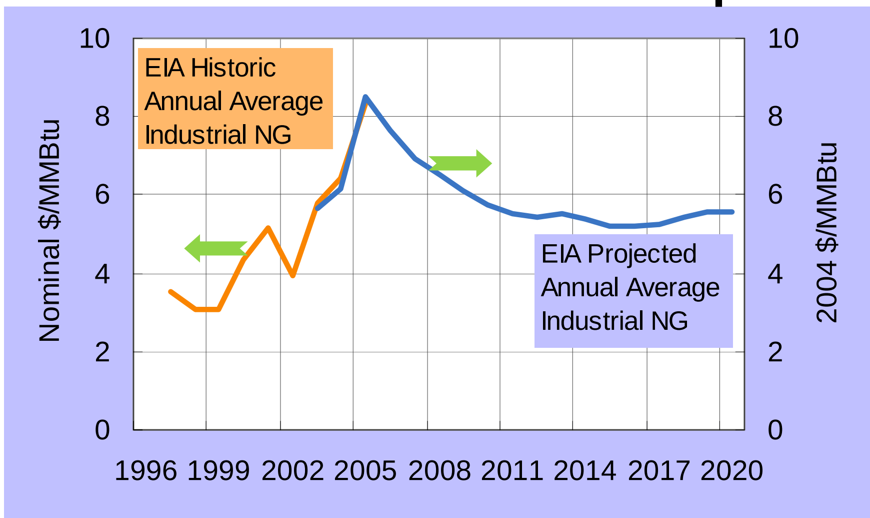
All Urea Grades		Million short tons/year
WORLD[1]	Demand	137
	Production	138
	Capacity	162
DOMESTIC (U.S.)[1]	Demand	12.4
	Production	6.0
	Capacity	8.2
Projected 2015 U.S. On Road Diesel Vehicle	Urea Demand	0.6[2]

1 British Sulphur Consultants, CRU Group for 2005

2. Equivalent to 400 Million gallons 32.5% soln

Sources: British Sulphur Consultants

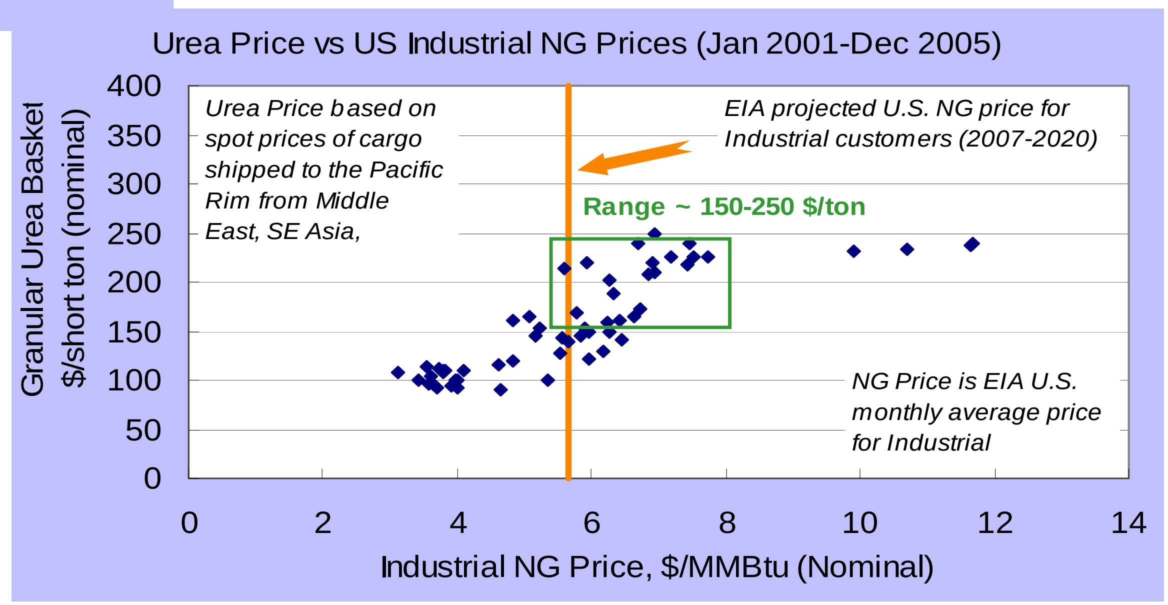
The model assumes a urea price based on predicted future NG prices



Selected Nominal price of 200 $/ton

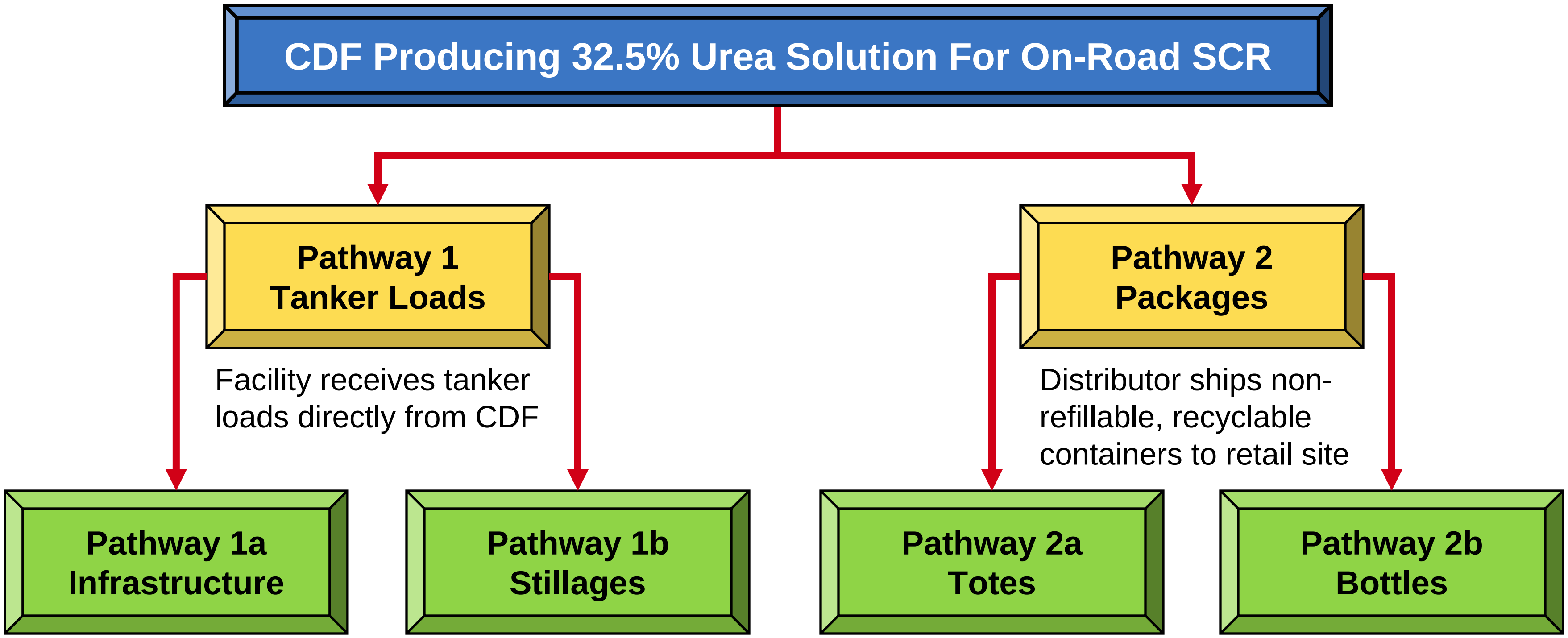
Evaluated cost impact over range 150-250 $/ton

- Urea price dependent on natural gas prices
- EIA predicts stable NG prices for US industrial customers ~ $5.7 per MMBtu for 2007-2020 period
- NG prices > 7 $/MMBtu has minimal impact on urea price due to increased imports



Sources: EIA AEO2006, Henry Hub

Two main pathways for urea delivery are tanker loads and packages



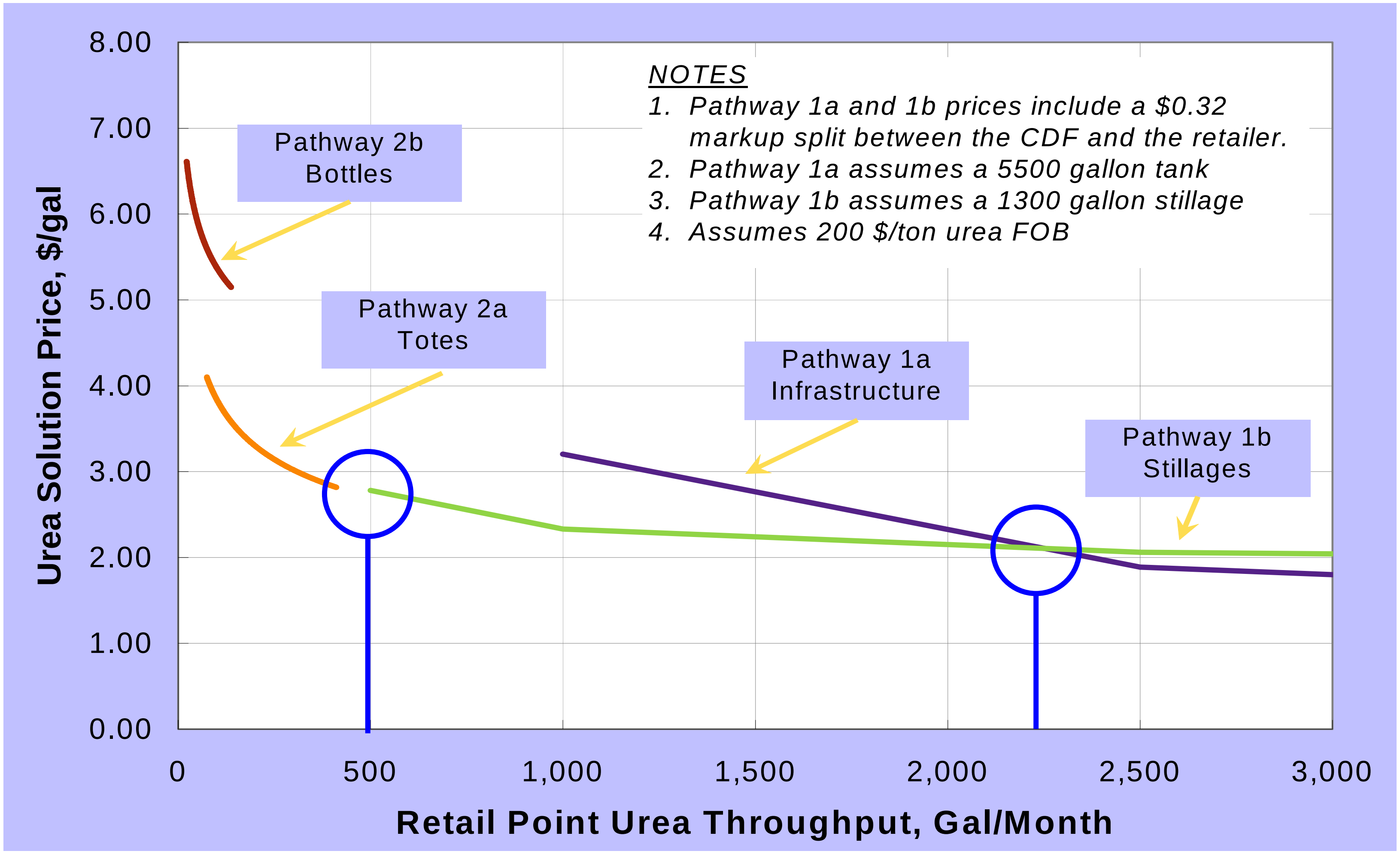
Pathway 1a – Infrastructure
- Sales > 2500 gal/month
- Facility installs permanent UST/AST and dispensing system

Pathway 1b – Stillages
- Sales 500-7,500 gal/month
- Facility utilizes purchased, refillable dispensing systems

Pathway 2a – Totes
- Sales < 1000 gal/month
- Retail site uses totes that are dropped off full, replaced when empty

Pathway 2b – Bottles
- Sales < 500 gal/month
- Retail site uses bottles or sells bottles to customers

Projected prices with cross-over points and separations are identified in order to assign distribution strategies to retail locations



Example Scenario:
2,500 gal/month retail station with a 1300 gal stillage buying 32.5% aqueous solution from a CDF utilizing urea melt.

Urea Melt

- The model assumes 200 $/ton urea FOB discounted 20% for melt.
- **Cost = $0.24/gal** product urea **(A)**

Transportation To Central Distribution Facility (CDF)

- Transportation of urea melt to CDF from plant
- Assume 800 miles from plant to CDF 75% by rail, 25% by truck.
- **Cost = $0.12/gal** product urea **(B)**

Processing @ CDF to 32.5 wt%

- Blending, storage and distribution of 32.5% urea at CDF with 2 million gal/yr throughput
- Capital investment = $470K with $16k/yr operating costs, 12% interest over 2.5 yrs.
- **Cost = $0.13/gal** product urea **(C)**
- **Expected CDF profit mark-up = $ 0.09 to $0.24 per gal product urea (D)**

Transport To Retail

- Transportation of 32.5% urea solution 350 miles from CDF to retailer
- Less than load transport cost is $3.33/mile plus 20% surcharge
- **Cost = $1.00/gal** product urea **(E)**

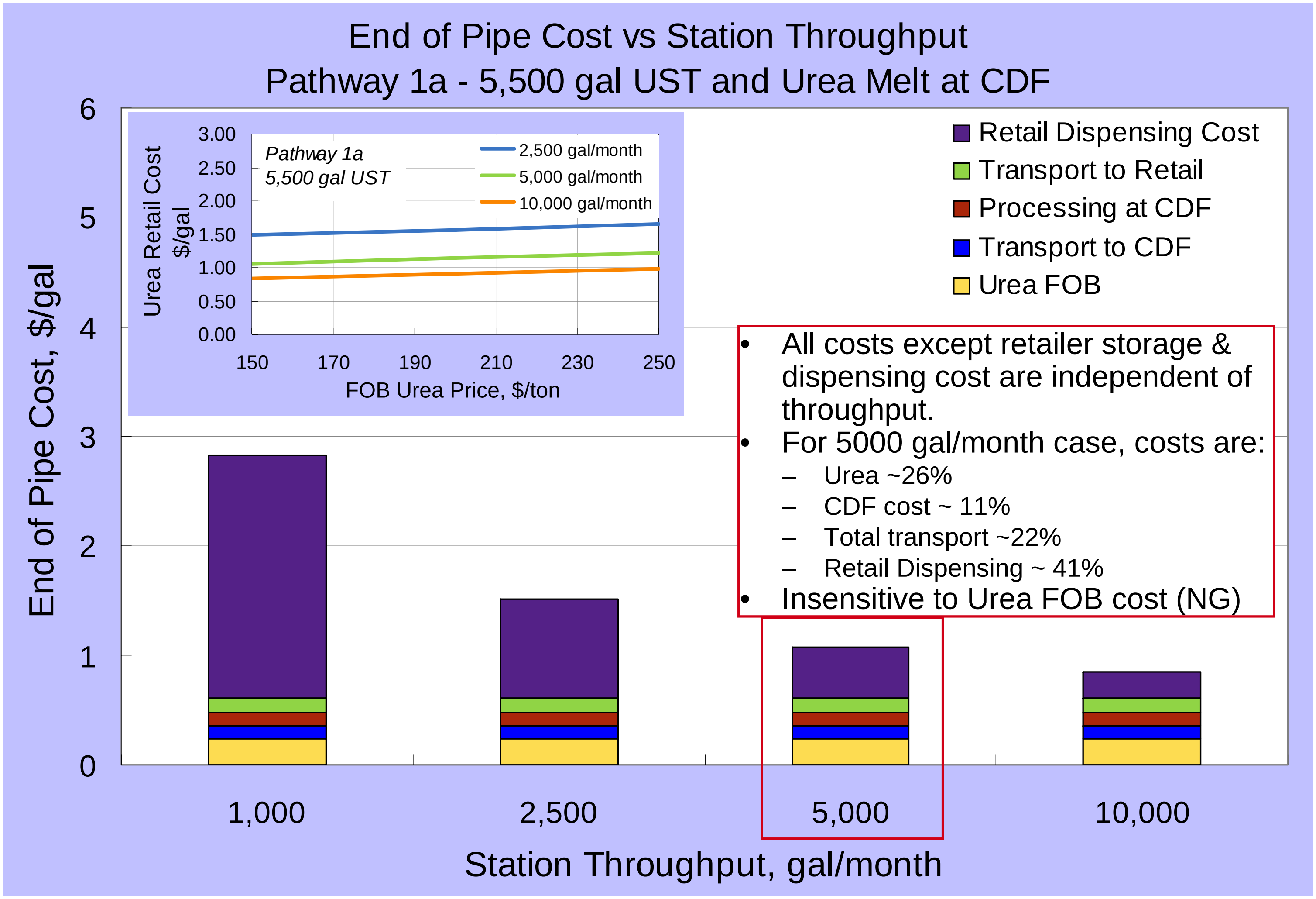
Retail Station Storage & Dispensing

- Storage & dispensing at a 2,500 gal/month station with 1300 gal capacity
- Capital investment = $10K at 12% over 3 yrs with $1.7k/yr operating costs
- **Average cost = $0.20/gal** product urea **(F)**
- **Expected retail profit mark-up = $ 0.07 to $0.12 per gal (G)**

The cost model does not include mark-ups; mark-ups were added here for illustration

Average Expected Price = (A) + (B) + (C) + (D) + (E) + (F) + (G) = 1.85 to 2.05 $/gal

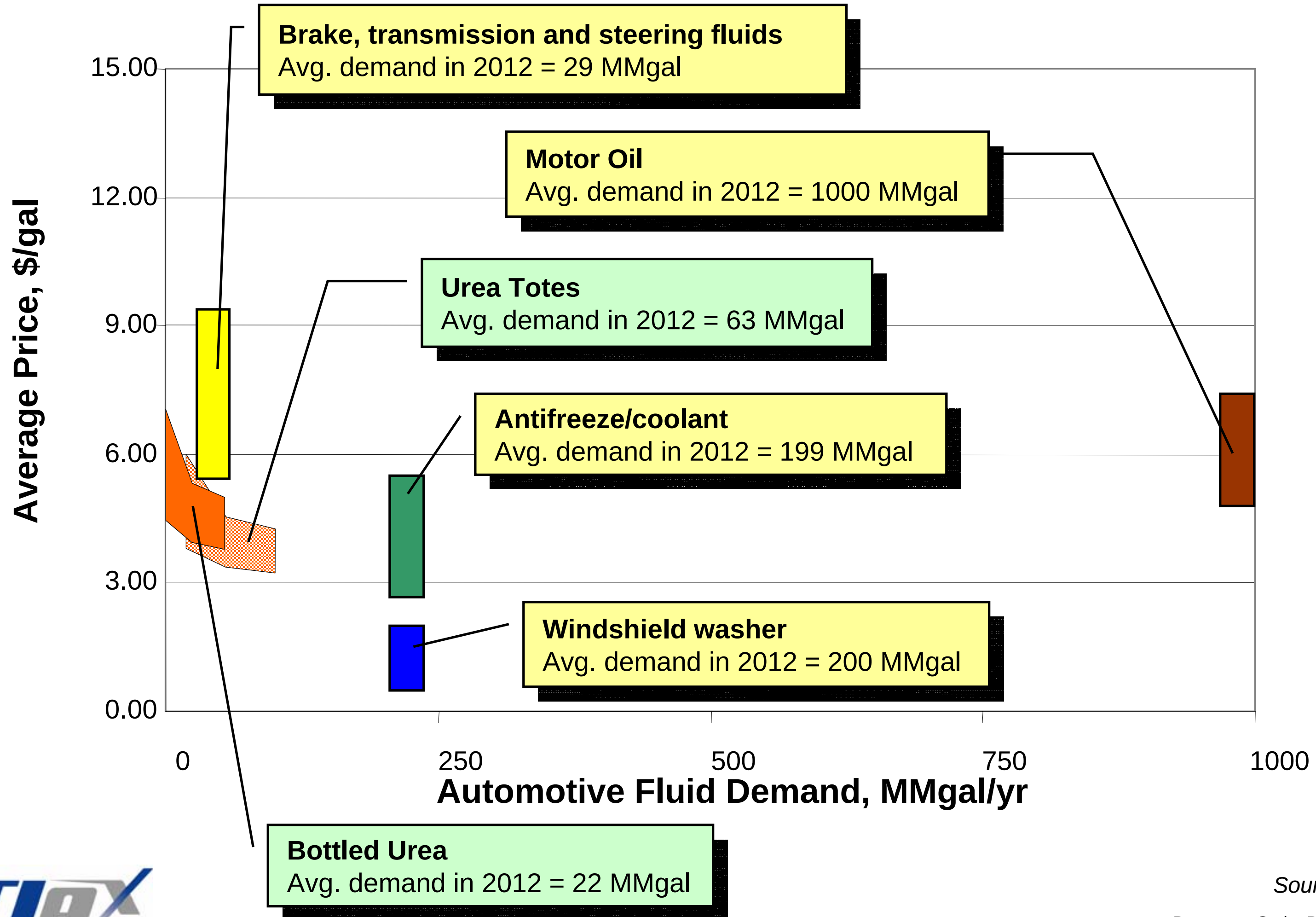
For stations selling less than 10,000 gal/month, retailer costs dominate the end of pipe urea cost…



…In 2010-2015, TIAX projects throughput at all stations to be less than 10,000 gal/month

- The retail cost of urea is highly dependent on station throughput
- All urea retail costs on a $/gal basis are independent of station throughput and storage capacity except for:
  - Retailer storage and dispensing costs
    - Retailer cost represents ~ $2 per gal or 2/3 of total cost at a 1,000 gal/month station
    - Retailer cost represents ~ $0.1 per gal or 1/8 of total cost at 20,000 gal/month station
  - Transport cost from CDF to retailer with storage capacity less than 5500 gal
    - LTL delivery costs on $/gal basis can be significant
    - For 1300 gal stillage case with 2500 gal/month throughput, delivery cost is $1.00/gal, nearly 60% of retailer cost.
- Urea solution retail cost is insensitive to variability in natural gas price
  - As urea FOB price varies from $150 to $250 per ton, the retail price only increases $0.15 per gal for the 5,000 gal/month throughput case
- Costs to install tanks with capacities greater than 5500 gallons (full tanker load) are not justified for any stations at projected urea throughput levels

A comparison of urea market price and size with the automotive fluids market indicates that the LDD distribution of urea would be generally similar in price and demand to most automotive fluids



Sources: AAM Study 2004

Two distinctly different distribution strategies were investigated for the heavy-duty and light-duty markets

- Heavy-duty urea distribution is assumed to follow diesel fuel
  - This results in Pathway 1 for the majority of HDD fueling stations and a significant percentage of the overall on-road urea throughput
  - Urea tank size on the vehicles will impact this assumption
- Light-duty urea tank fills are assumed to correspond with regular maintenance, like oil change intervals
  - This results in Pathway 2 for the majority of LDD retail locations
  - Again, urea fill intervals will be dependent on the urea tank size
- Some overlap will occur in distribution strategies
  - HDD fueling stations could provide downward price pressure on the LDD distribution
  - LDD retail locations would provide the HDD vehicles emergency urea infrastructure

Using average throughput numbers for similar retail sites we identified the number of retail outlets by distribution type in 2010

Heavy-duty Station Size Designation	Number of Stations	% of Urea Sales in HD Vehicles
XXL	310	17%
XL	1,128	44%
L	515	11%
ML	262	2%
M	2,436	14%
MS	1,115	4%
S	2,491	4%
XS	24,251	4%

Light-duty Retail Location	Number of Retail Sites	% of Urea Sales in LD Vehicles
Dealers (D)	17,252	21%
Service Stations (SS)	1,400	19%
Fueling Stations (FS)	6,000	8%
Auto Parts Stores (AP)	2,696	1%
Mass Merchants (MM)	3,978	1%

Urea Throughput (gal/month)	2010			
	Bottles	Barrels & Totes	Stillages	Tanks
10,000 - 5,000				
5,000 - 2,500				310 XXL
2,500 - 1,000				1,128 XL
1,000 - 500				515 L
500 - 250			262 ML	
250 - 100		1,400 SS	2,436 M	
< 100	17,252 D 6,000 FS 2,696 AP 3,978 MM	1,115 MS 2,491 S		
Total Retail Sites	29,926	5,006	2,698	1,953

- **24,251 XS Heavy-duty fueling stations are not categorized because urea distribution at 6,000 public fueling stations give coverage within 20 miles to >80% of US population***

**Source: Air Improvement Inc. Study 2005*

In most cases, infrastructure decisions made for 2010 urea volumes allow for the increased throughput projected in 2015

Heavy-duty Station Size Designation	Number of Stations	% of Urea Sales in HD Vehicles
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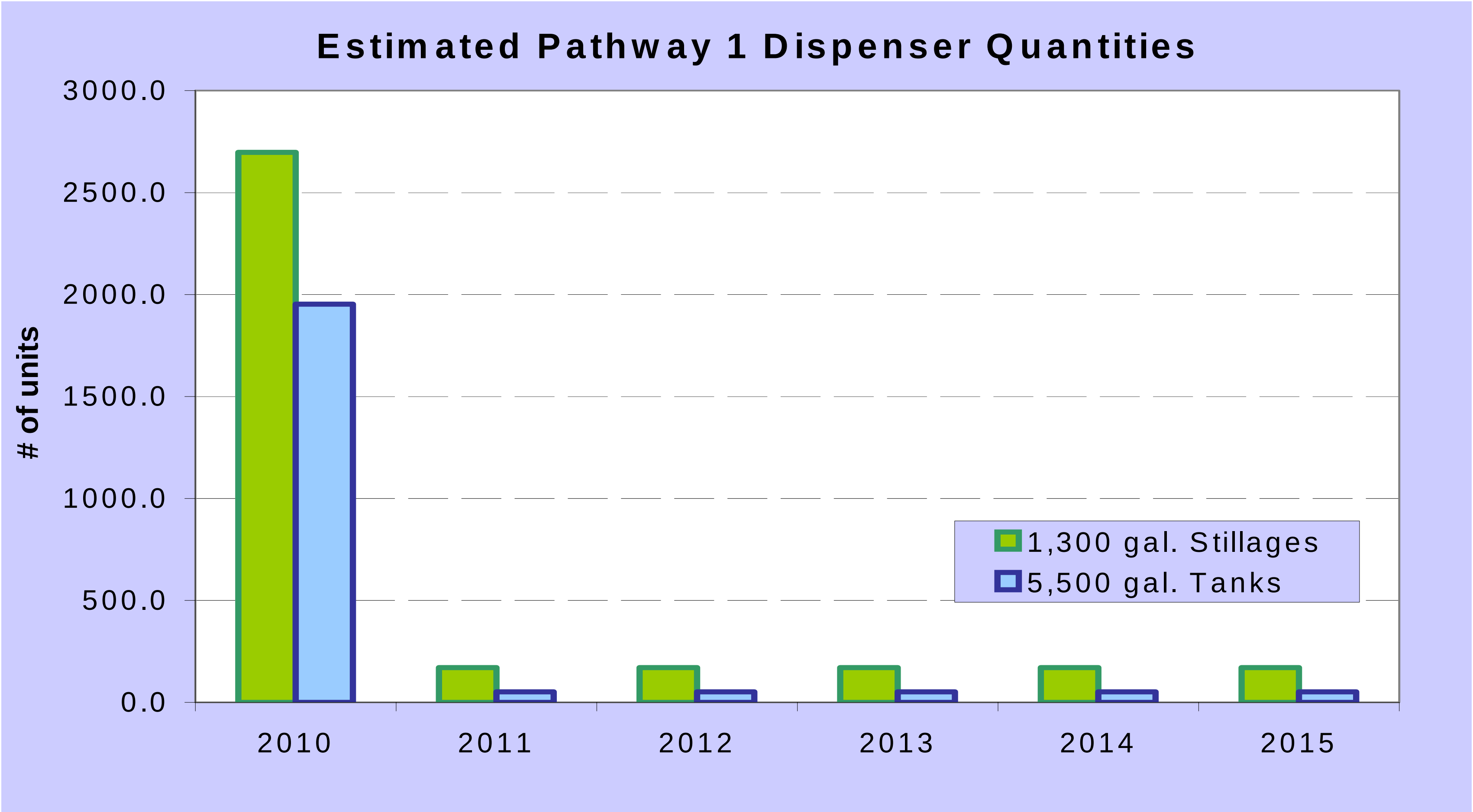
Light-duty Retail Designation	Number of Retail Sites	% of Urea Sales in LD Vehicles
Dealers (D)	18,714	31%
Service Stations (SS)	7,000	30%
Fueling Stations (FS)	12,000	17%
Auto Parts Stores (AP)	10,784	6%
Mass Merchants (MM)	15,910	6%

Urea Throughput (gal/month)	2015			
	Bottles	Barrels & Totes	Stillages	Tanks
10,000 - 5,000				310 XXL 1,128 XL
5,000 - 2,500				515 L
2,500 - 1,000			2,436 M	262 ML
1,000 - 500			1,115 MS	
500 - 250		2,491 S		
250 - 100		7,000 SS		
< 100	10,784 AP 15,910 MM	18,714 D 12,000 FS		
Total Retail Sites	26,694	40,205	3,551	2,215

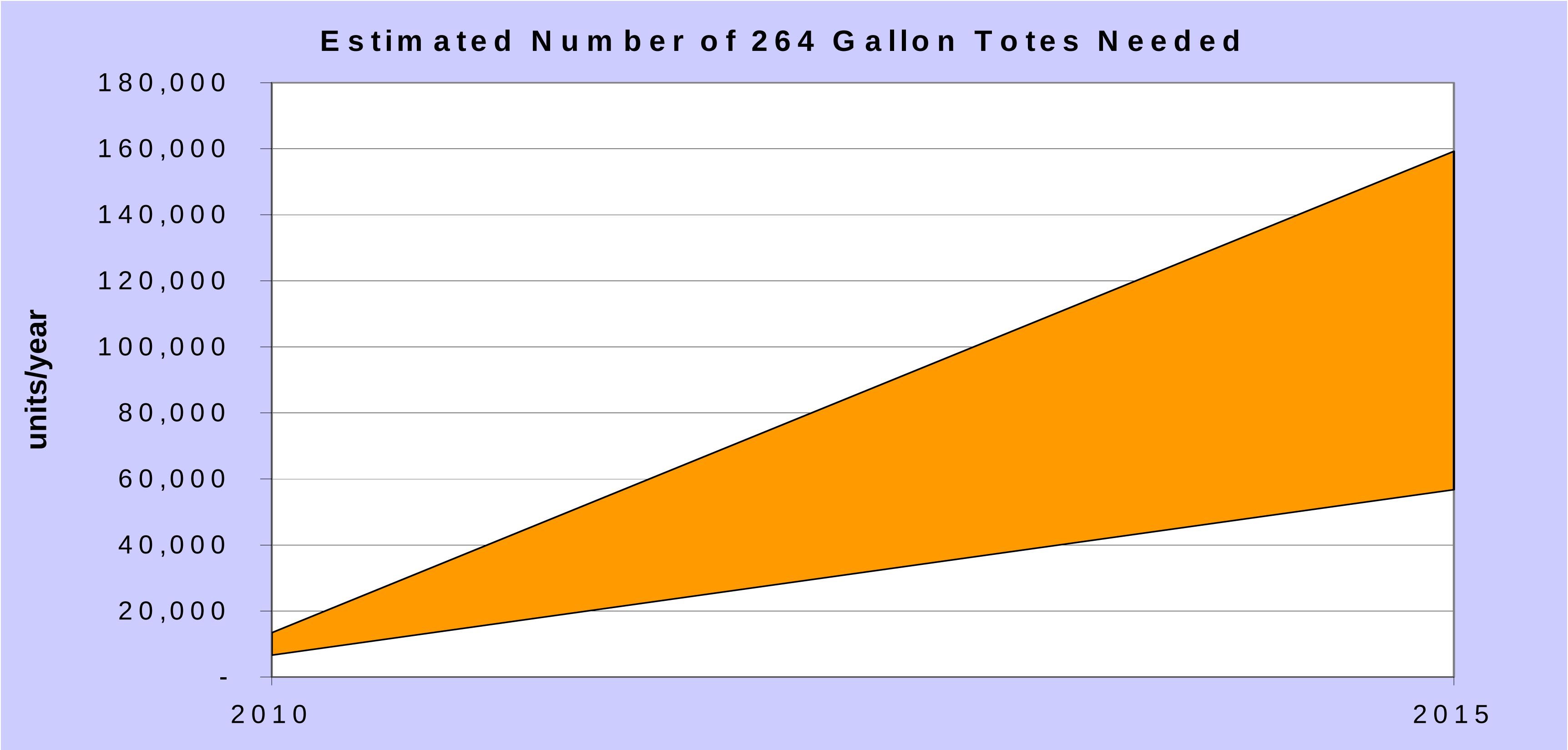
- **24,251 XS Heavy-duty fueling stations are not categorized because urea distribution at 12,000 public fueling stations give coverage within 20 miles to >90% of US population***

**Source: Air Improvement Inc. Study 2005*

Bulk of Pathway 1 installations are needed for 2010, number of additional tanks and stillages between 2010 and 2015 is small



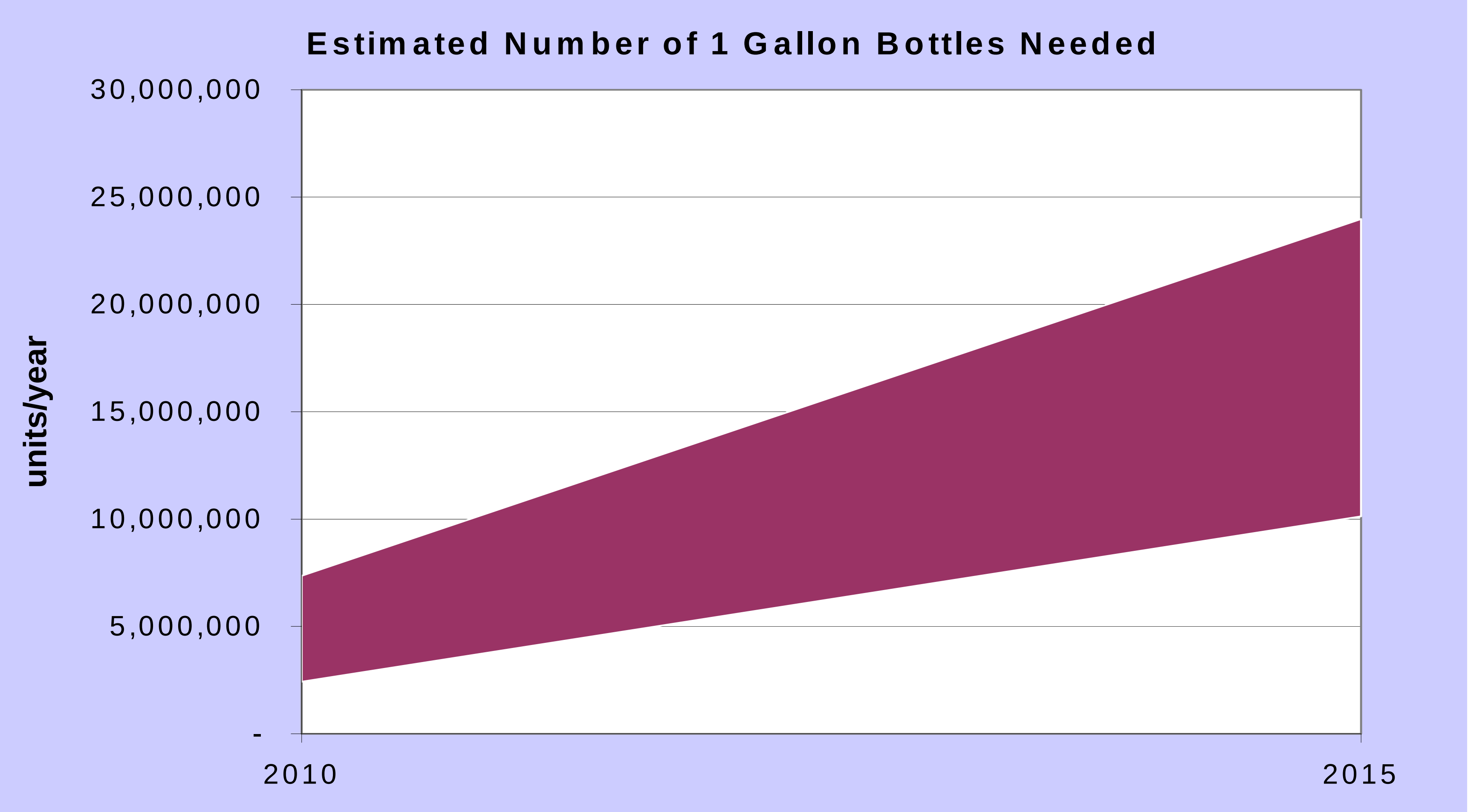
The number of totes is estimated by assuming a 50-50 split with barrels for Pathway 2a and is a function of both urea throughput in the pathway and the number of retail locations



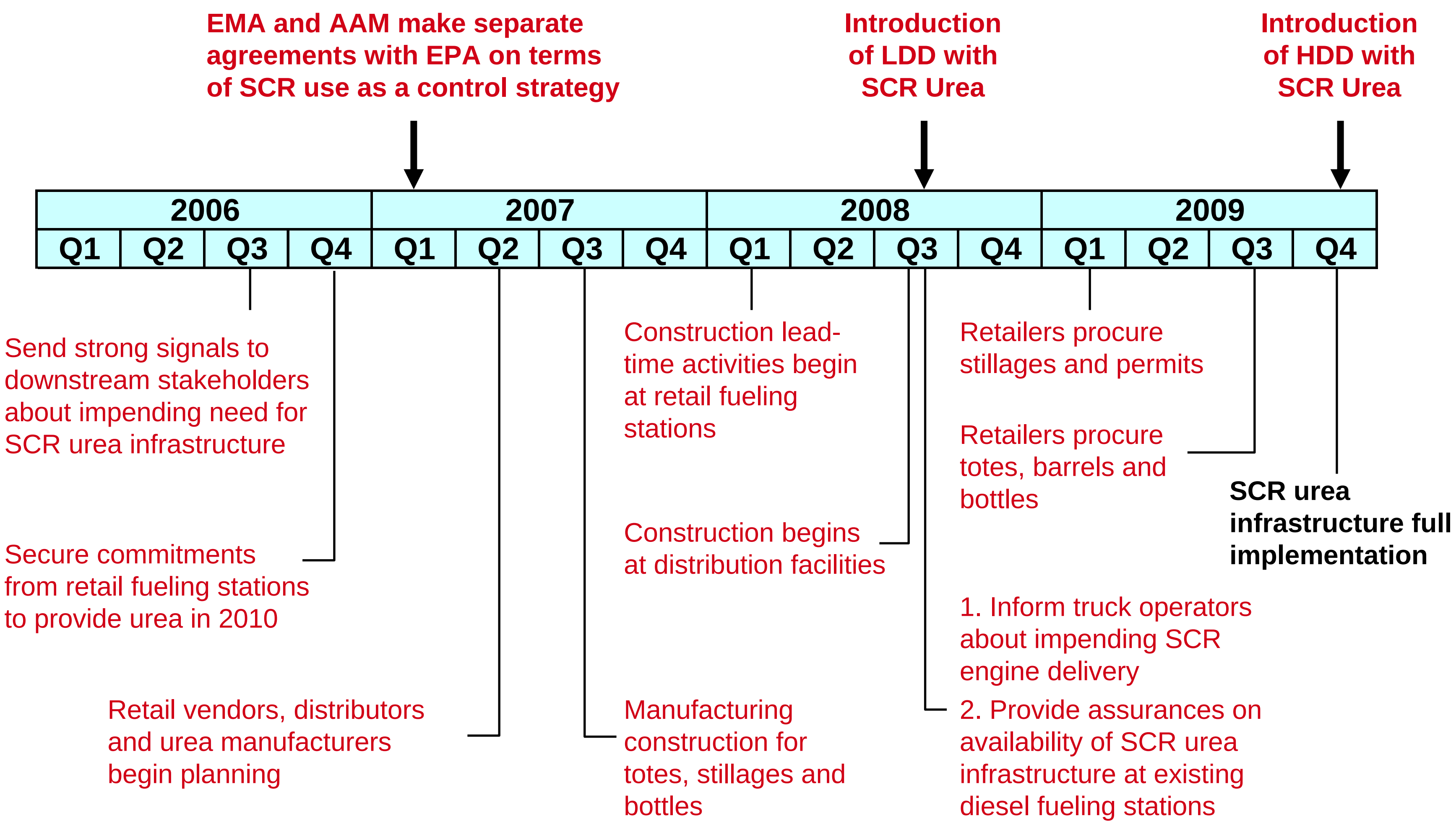
- **Barrels not shown in the executive summary, with 50-50 split the volume of barrels needed is 264/55 or roughly 5x the number of totes needed**

Note: 264 gallon (1000L) tote was used as estimate based on European experience, other sizes may be applicable to NA market

The estimated number of bottles needed is a function of both urea throughput and bottle size. Bottling lines exist today to handle projected 2015 volume.



Milestones along the path to an on-road SCR-urea infrastructure



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3	Task 2 – Update Truck Segmentation
4	Task 3 – Revise TIAX SCR-Urea Cost Model
5	Task 4 – Analyze Potential Business Cases
6	Task 5 – Perform Critical Path Analysis

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TIAX, LLC's three previous studies on the feasibility of an SCR-urea infrastructure were used as the starting point in the development of a market for all on-road diesel vehicles

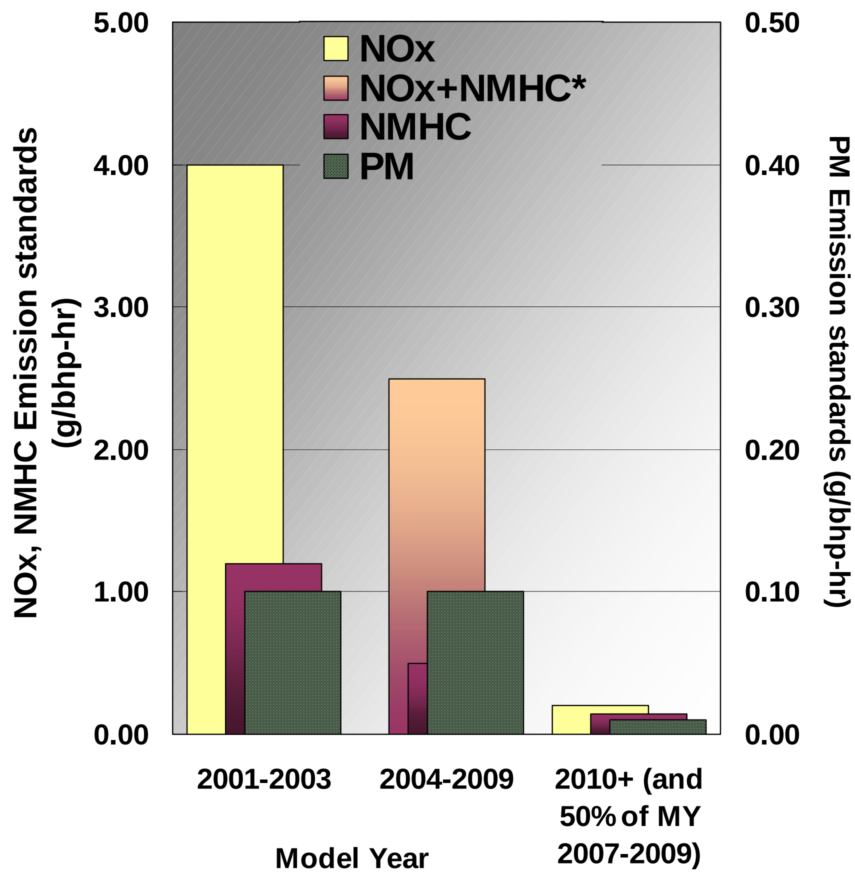
- "Selective Catalytic Reduction Urea Infrastructure Study," July 2002 – National Renewable Energy Laboratories Contract No. ACL1-31038-01 (NREL Study 2002)
- "SCR-Urea Infrastructure Implementation Study," July 2003 for the Engine Manufacturers Association (EMA Study 2003)
- "Light-duty Vehicle SCR-urea Supply Study," November 2004 for the Alliance of Automotive Manufacturers (AAM Study 2004)

Main data sources used in to complete the update to the analysis of the potential urea infrastructure include:

- "Transportation Energy Data Book, Edition 24," U.S. Department of Energy, Energy Efficiency and Renewable Energy, December 2004
- "Vehicle Inventory and Use Survey (VIUS) 2002," U.S. Census Bureau, Issued December 2004
- U.S. Department of Energy, Energy Information Annual Energy Outlook 2006 (EIA AEO2006), Report #:DOE/EIA-0383(2006) Released February 2006
- Urea Basket Price Report, www.fertilizerworks.com
- "Overview of U.S. Freight Railroads", Association of American Railroads, Jan 2006
- Air Improvement Resources Inc. Study to the Alliance of Automotive Manufacturers, 2005 (Air Improvement Res. Inc. Study 2005)

Meeting Federal emissions standards for MY2010 heavy-duty on-road diesel vehicles will require significant NOx, NMHC, and PM reductions

- Emission standards will be reduced by 90% by MY2010
  - Major engine manufacturers have met MY2004 standards starting October 2002
  - MY2010 low-emission standards applies to 50% of MY2007-2009 sales, or a corporate average of 1.2 g/bhp-hr, and all of MY2010+ sales
- Potential technologies to meet new requirements:
  - Exhaust Gas Recirculation (EGR)
  - Diesel Particulate Filters (DPF)
  - SCR systems



*Engine manufacturers may substitute a NOx+NMHC engine certification standard of 2.4 g/bhp-hr in place of the MY 2004-2009 independent NOx+NMHC and NMHC standards.

Sources: NREL Study 2002

Urea as reductant choice for SCR

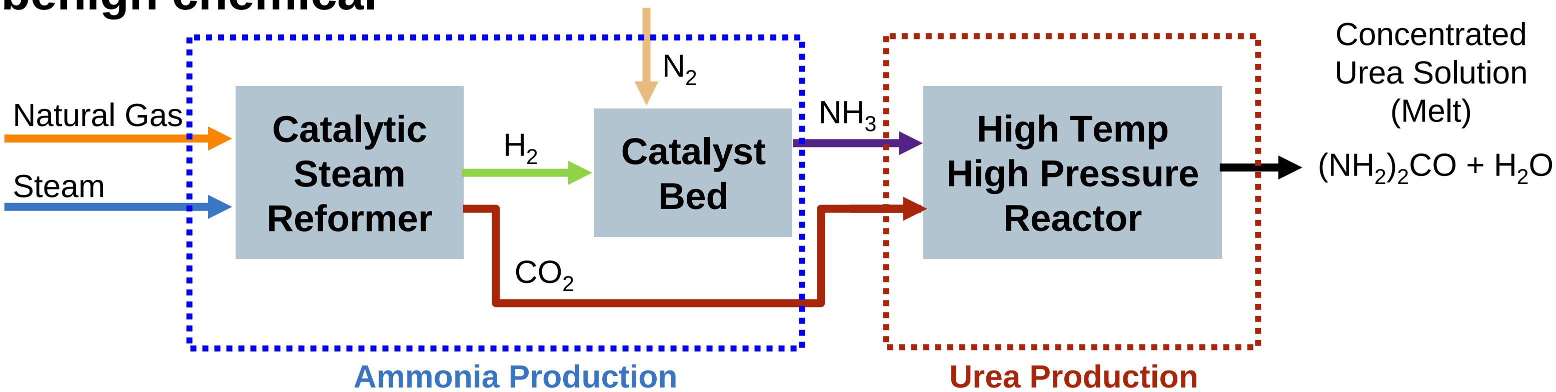
- SCR systems require an on-board supply of ammonia or other nitrogen-containing chemicals that decompose into ammonia in the engine exhaust stream.
- Storing ammonia on-board may pose several challenges since it is corrosive and can present a health hazard if spilled or vented.
- Using urea as a reductant offers a means for generating ammonia for the SCR system, while posing minimal heath and corrosion issues.
- Urea is widely used in agriculture as a fertilizer, and is available in large quantities.
- Driving forces for urea use in transportation: low health hazard, produced in large quantities, stationary SCR and SNCR experience

SCR Catalyst

Urea dosing Unit and Integrated Urea/Diesel Tank

Sources: NREL Study 2002

A two-step process is utilized to manufacture urea, an environmentally benign chemical

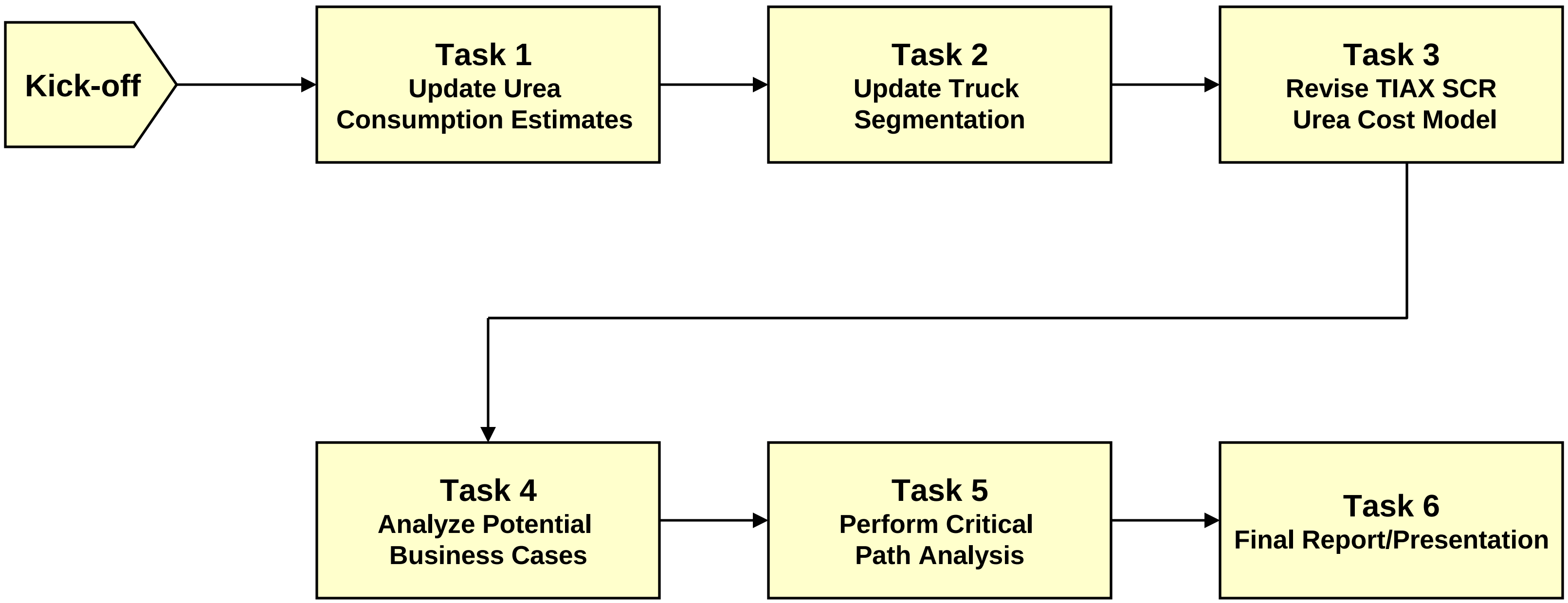


Urea Classifications		
Agency Listing	**Hazardous**	**Carcinogenic**
EPA	No	No
OSHA	Yes[2]	No
DOT	No	
Federal Hazardous Waste Regulations[1]	No	

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


Kick-off
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Task 6
Final Report/Presentation

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TASK 1
Update Urea Consumption Estimates

Inputs

Previous SCR-urea TS&D cost analysis TIAX Reports
- NREL Study 2002
- EMA Study 2003
- AAM Study 2004

VIUS 2002 Database

Trans. Energy Data Book (2004)

Task 1 activities

Verify light- and medium-duty urea consumption estimates
(Source: EMA, AAM)

Obtain data for projected engine sales for use in SCR-equipped vehicles in 2009+ time frame
(Source: EMA, AAM)

Estimate VMT and Fuel economy by vehicle class
(Source: VIUS)

Determine projected SCR-urea consumption ratio by class using engine sales and fuel consumption information

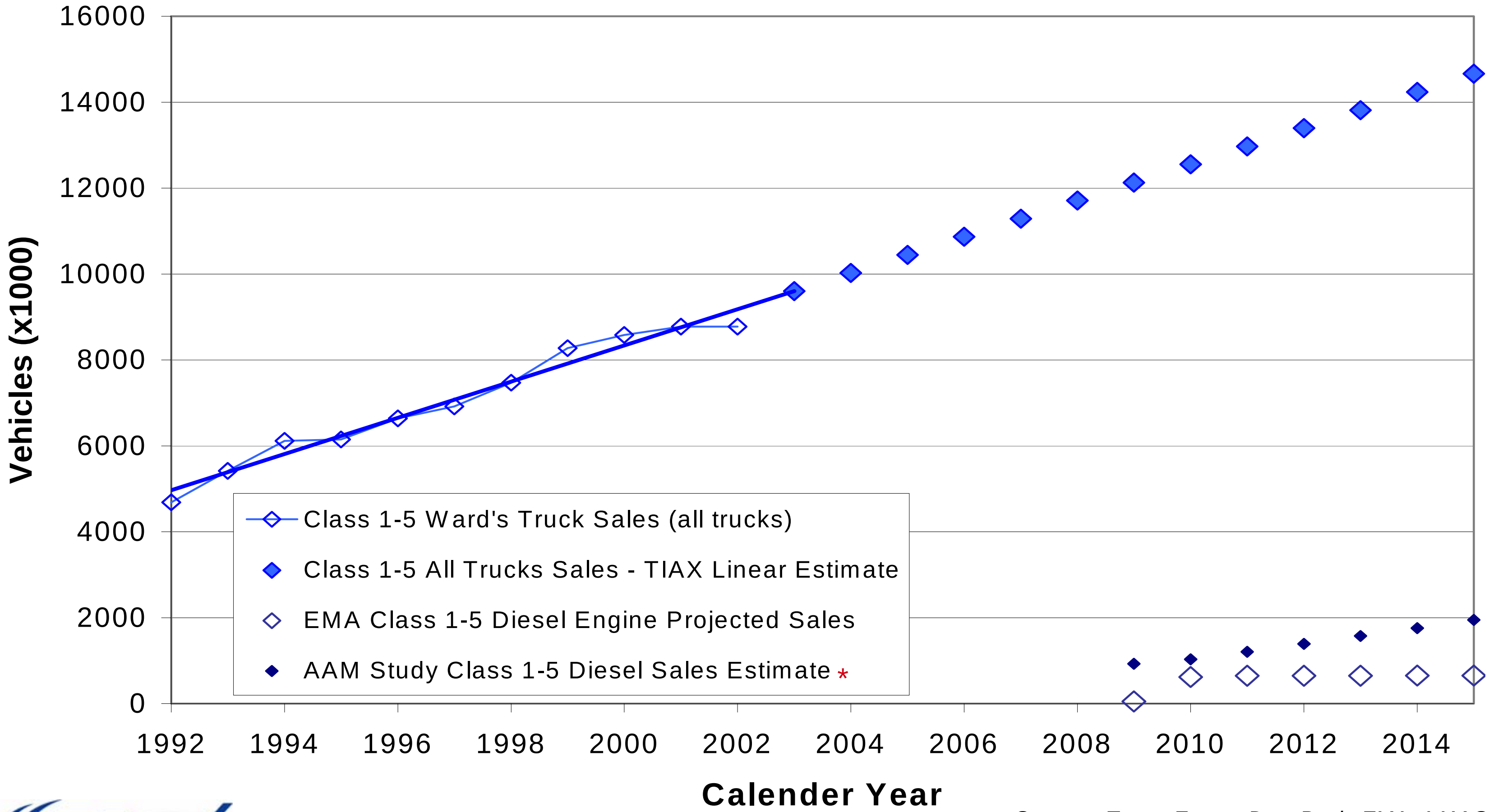
Determine urea consumption from 2009-2015, estimate 2020 if data available

Combine light-, medium-, and heavy-duty consumption estimates

Outputs

- Projected annual SCR-urea consumption (gallons) 2009-2015

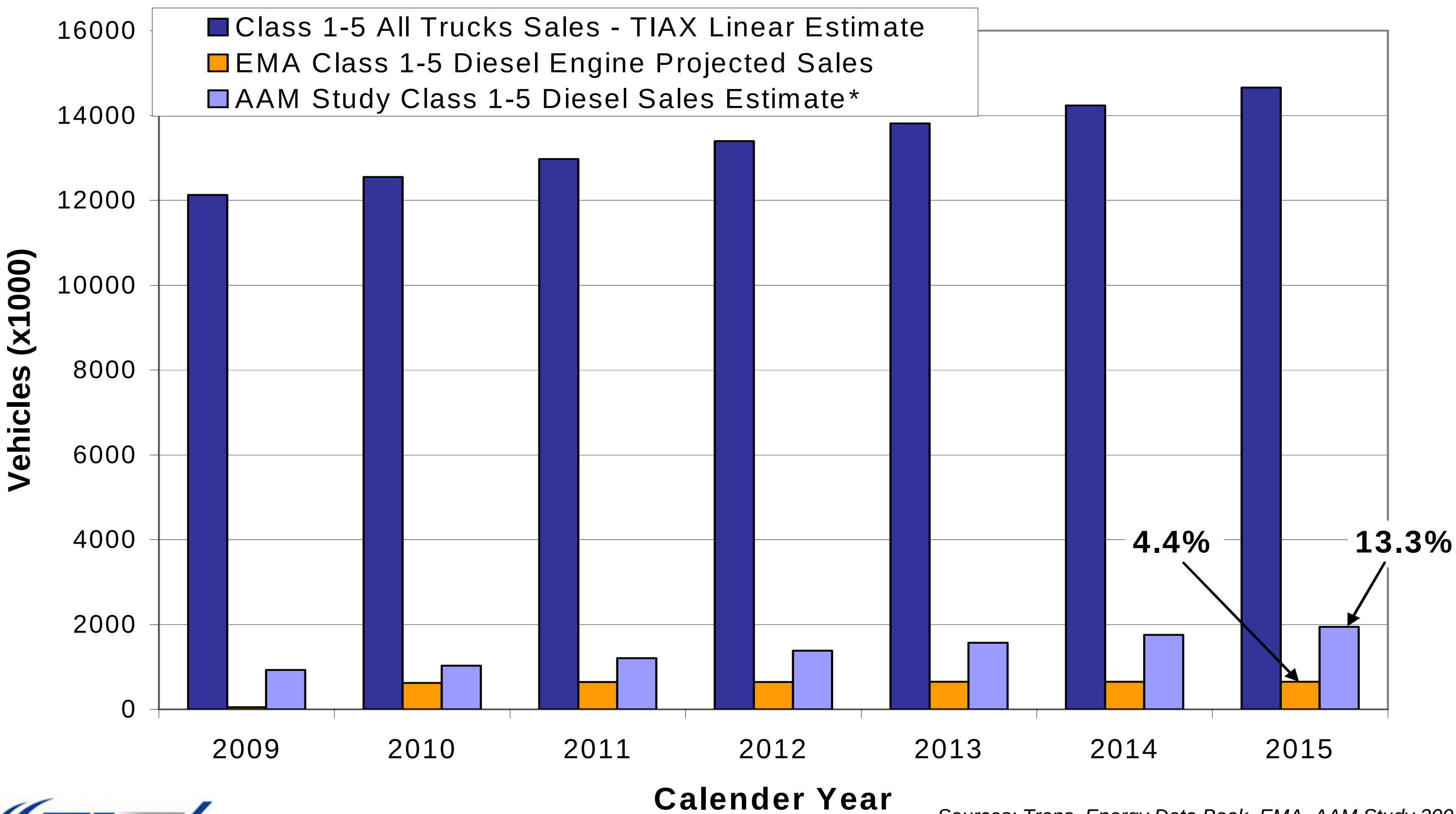
For the light and medium duty sales volume estimate, we compared a projection from the Transportation Energy Data Book (based on Ward's data) to the EMA's sales estimate and to the results from the AAM light-duty vehicle study



* AAM diesel sales estimate includes cars

Sources: Trans. Energy Data Book, EMA, AAM Study 2004

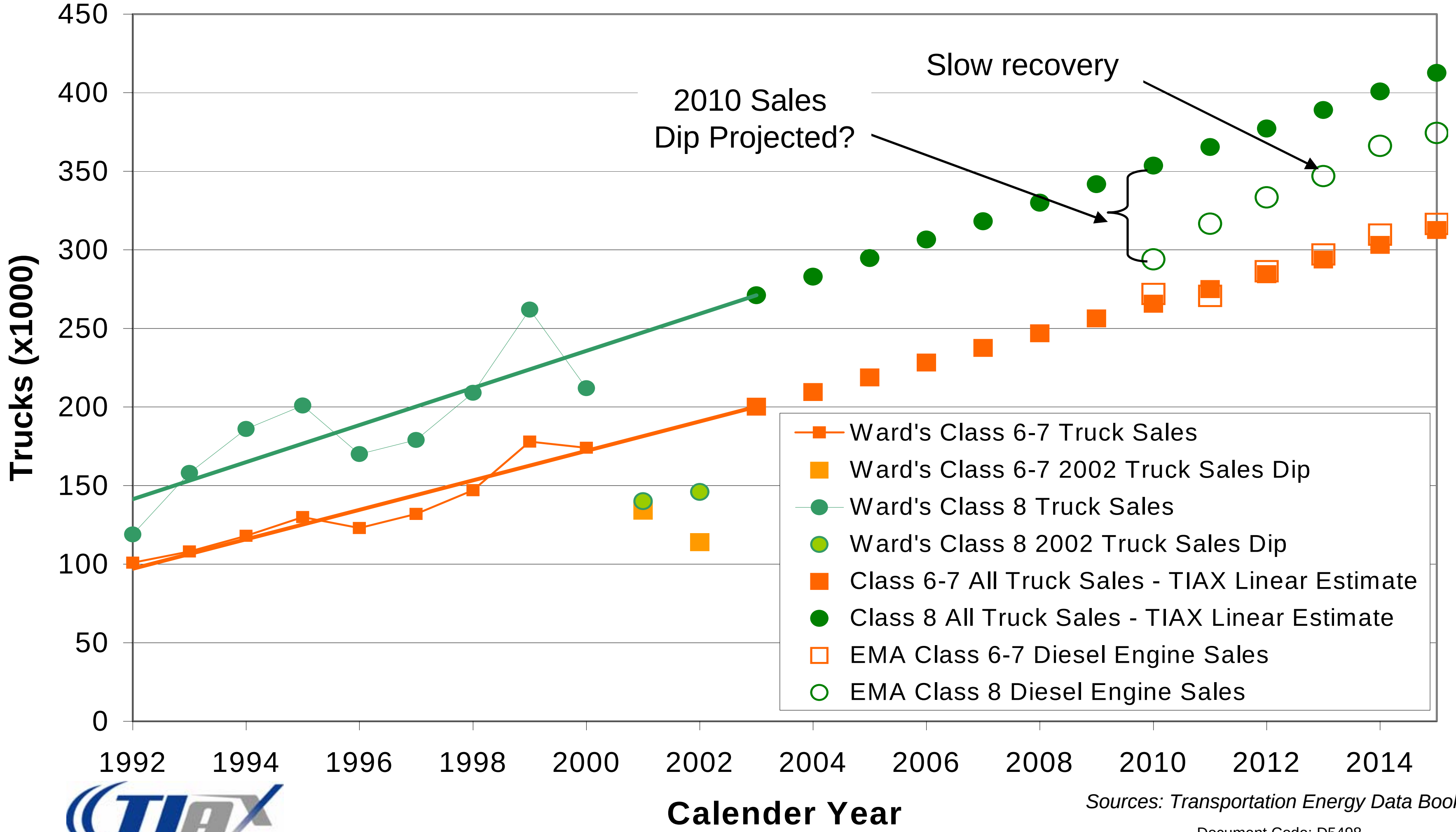
The EMA sales estimate is equivalent to 4.4% of the Light-duty truck sales projection, while the AAM study sales estimate is equivalent to 13.3% in 2015



*- AAM diesel sales estimate includes cars

Sources: Trans. Energy Data Book, EMA, AAM Study 2004

For the heavy duty sales volume estimate, a projection from Trans. Energy Data Book (Ward's data) was compared to the EMA's sales estimate. The 2002 sales dip is ignored in the linear projection of HD sales.



Sources: Transportation Energy Data Book, EMA

The VIUS 2002 database was used to determine the annual vehicle miles traveled (VMT) and the fuel economy (FE) for the different classes of diesel vehicles was used for urea consumption estimates

Class	1	2	3	4	5	6	7	8	Average Across Classes
Gross Vehicle Weight (lbs.)	< 6,001	6,001 - 10,000	10,001 - 14,000	14,001 - 16,000	16,001 - 19,500	19,501 - 26,000	26,001 - 33,000	> 33,000	
Annual VMT	11,800	14,000	13,300	14,900	13,700	12,900	13,400	41,500	13,100
Fuel Economy (mpg)	15.45	17.93	13.27	11.18	13.49	8.67	7.16	6.51	11.83

Urea consumption = sales estimate x VMT x FE x urea consumption %

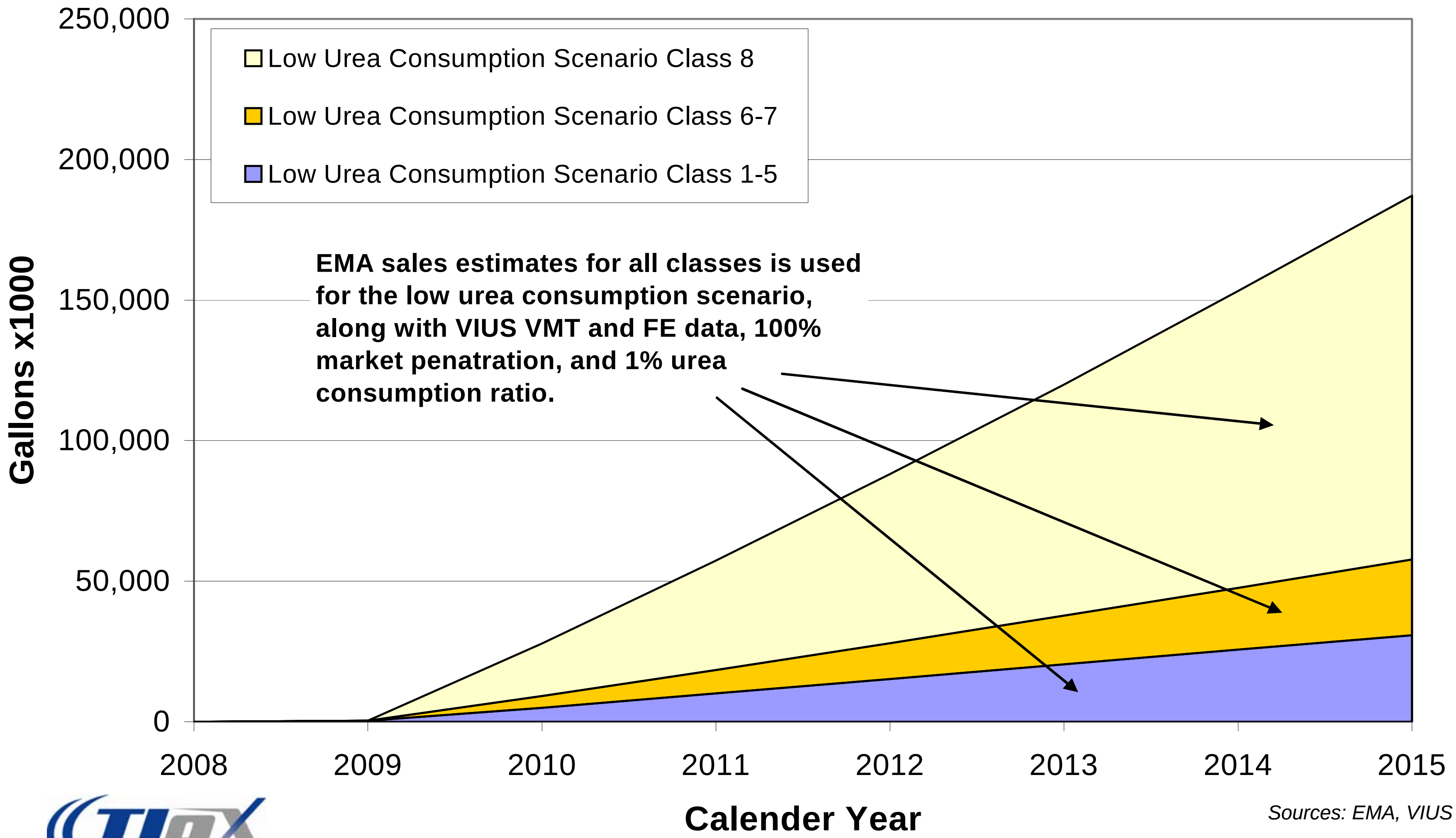
- Consumption estimates were calculated for each class
- VIUS 2002 data was segmented in order to provide a reasonable outlook
  - All diesel vehicles on the road are used to determine annual VMT
  - Trucks that were less than 1 year old were used to determine fuel economy

Source: VIUS 2002

The EMA projected sales data were used to estimate urea consumption in all areas except the high case for LDD Classes 1-5

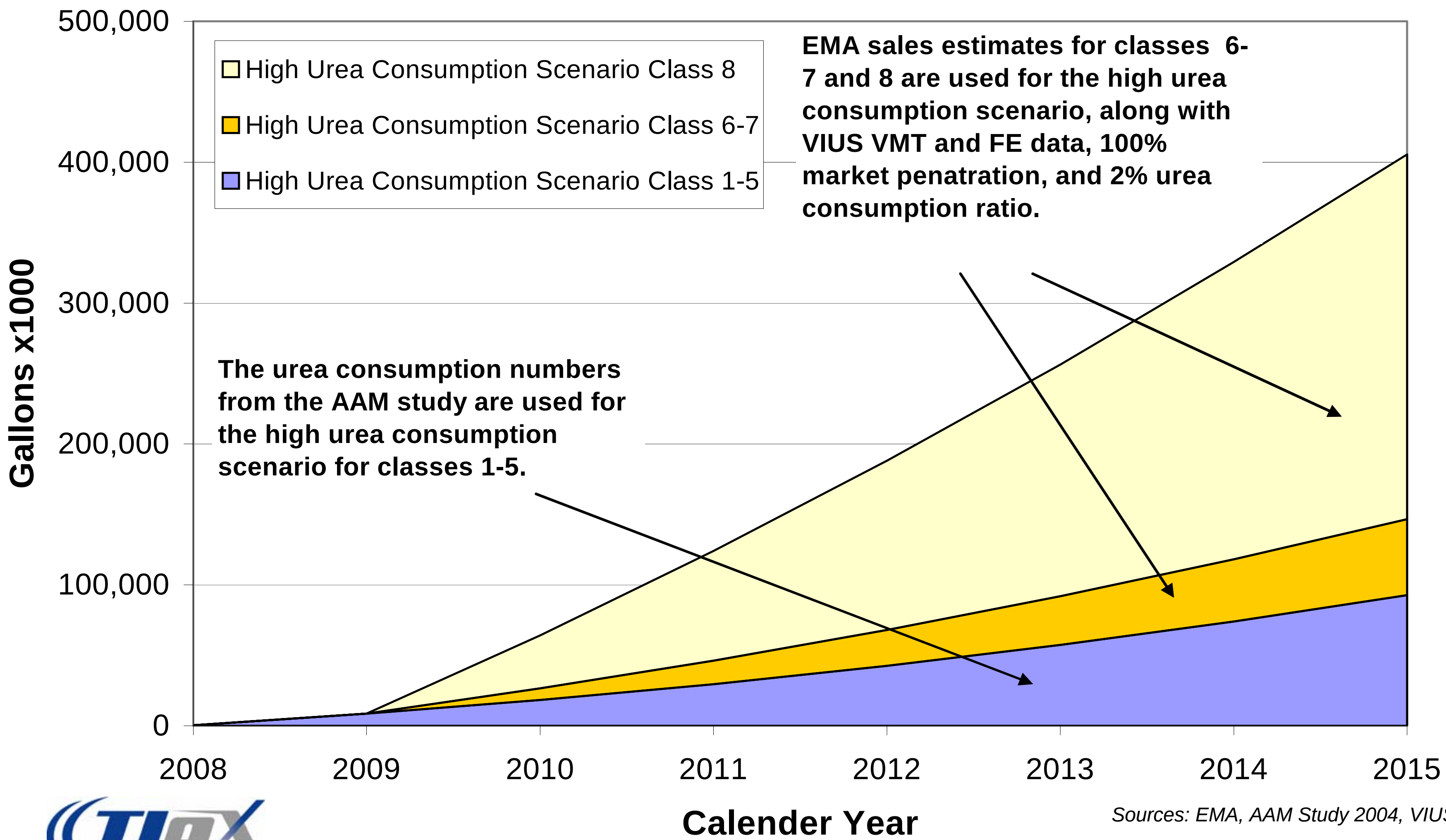
- While EMA projections were below the linear projection for Ward's sales data for Class 8, there is an expected dip in sales for 2007 and 2010 when new emission regulations are enacted
- Urea consumption ratios of 1% and 2% per diesel gallon are used for the low and high consumption scenarios
  - Low scenario uses EMA sales projections at 1% consumption ratio for all classes
  - High scenario uses EMA sales data for Classes 6-8 at 2% consumption ratio
- Classes 1-5 consumption estimate for the high scenario uses AAM study results which take into account an increase in market share for LDD passenger cars, including foreign makes, and therefore does not overlap with EMA engine estimates

By 2015, 70% of the urea is consumed in Class 8 trucks for the low scenario case. Because of the longer lifetime of these trucks, the % of total urea consumption will be less than the % of total diesel consumed.



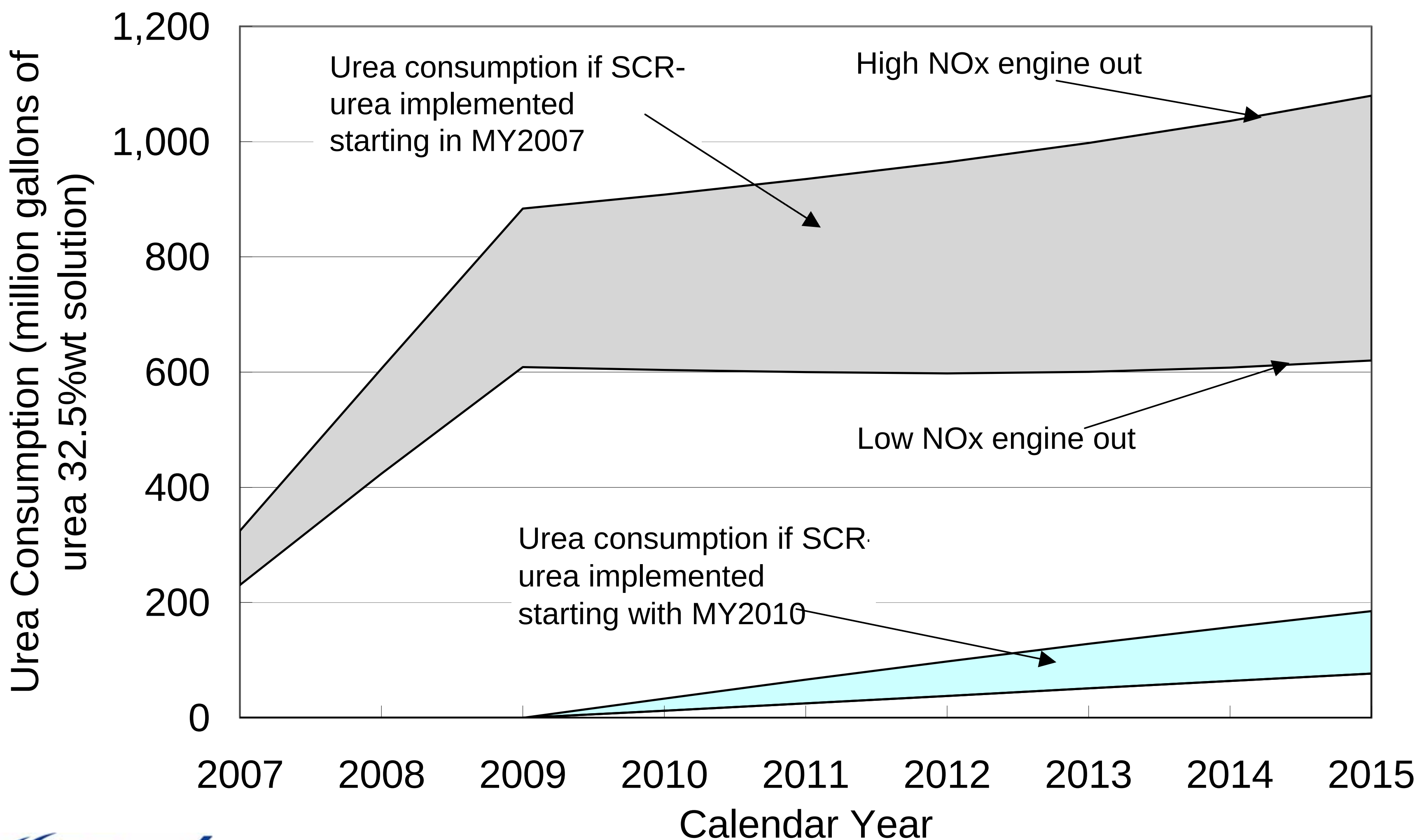
Sources: EMA, VIUS 2002

Using the Classes 1-5 sales estimates from the AAM study for the high scenario results in Class 8 consumption in 2015 of 64% of total urea. Classes 1-5 urea consumption grows to 23% during this scenario.



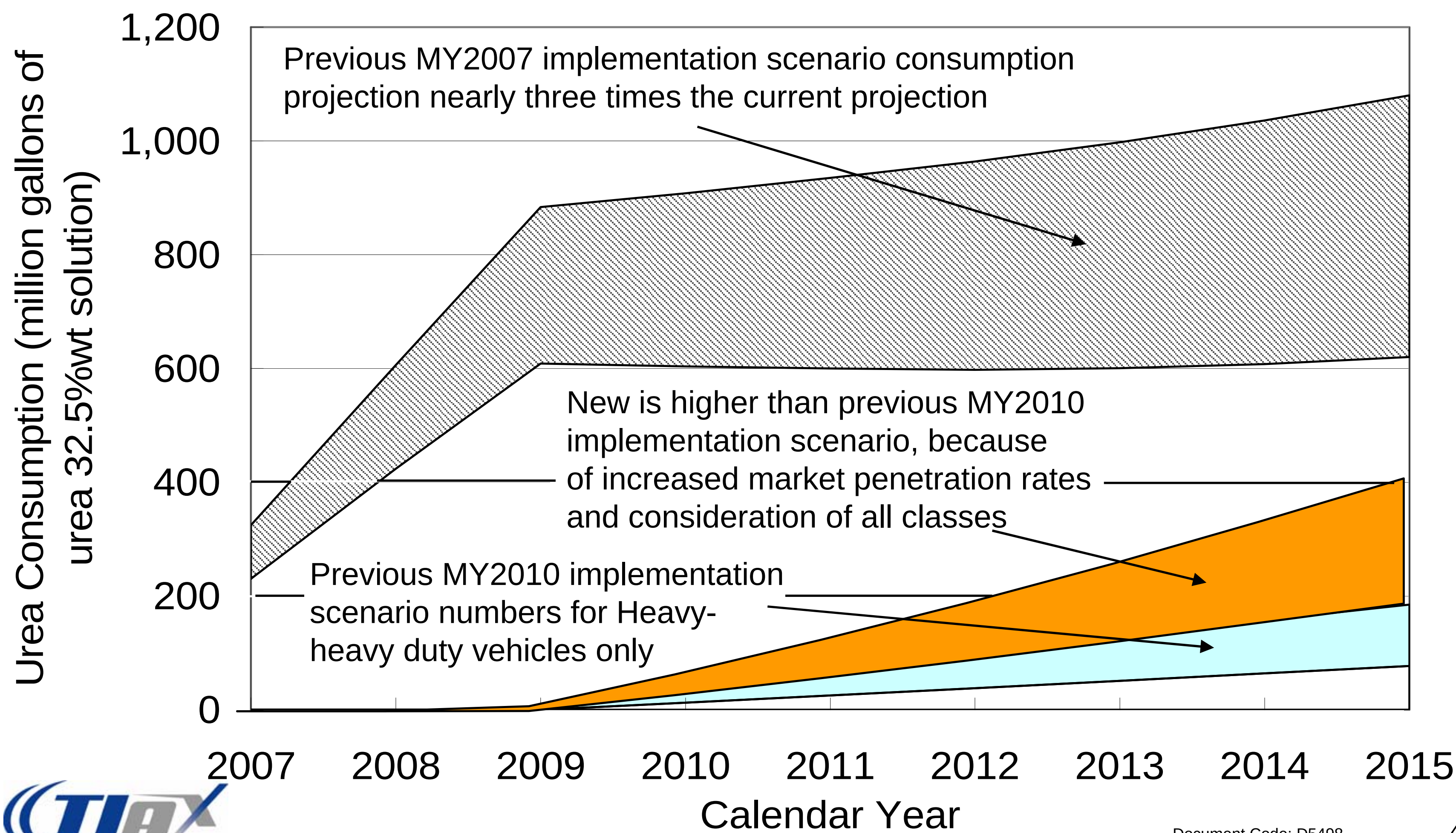
Sources: EMA, AAM Study 2004, VIUS 2002

Estimated urea consumption for MY2007 implementation and MY2010 implementation from the 2003 EMA study are shown below



Sources: EMA Study 2003

New estimated urea consumption is significantly lower than the MY2007 implementation scenario consumption numbers that were used to project urea station throughput in the previous study…



…However, the estimated urea consumption in the United States is projected to be greater than the MY2010 implementation estimates from the previous study

- Urea consumption ratios of 4.0% to 5.6% were analyzed for the MY2007 introduction case because of the higher engine-out NOx expected from 2007 engines
- 2007 consumption estimates were predominately used through the previous study to identify the needs of the infrastructure
- 2010 engines are projected to have much lower engine-out NOx levels, but this could vary from manufacturer to manufacturer
- There are three main reasons that the new projection for MY2010 implementation is higher than the previous study
  - All classes of vehicles were included in this study, previous study concentrated on Heavy-heavy duty trucks
  - Projected increase in LDD passenger car sales
  - Urea consumption ratio is assumed to be between 1% and 2%, rather than 0.8% and 1.2%

1	Approach for the SCR-Urea Update
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3	**Task 2 – Update Truck Segmentation**
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TASK 2
Update Truck Segmentation

Estimate Truck Populations
(Source: VIUS)

Estimate On-road Diesel Consumption
(Source: VIUS, TIAX reports)

Review fuel station profiles and truck fueling habits
(Source: VIUS, NATSO, others for central fleet information, etc.)

Determine urea consumption per station

Inputs

Input from Task 1:
- Projected urea consumption by phase-in years 2009–2015

Confirm from previous studies:
- Truck payload, diesel fuel tank, and SCR-Urea tank capacities

VIUS 2002 database

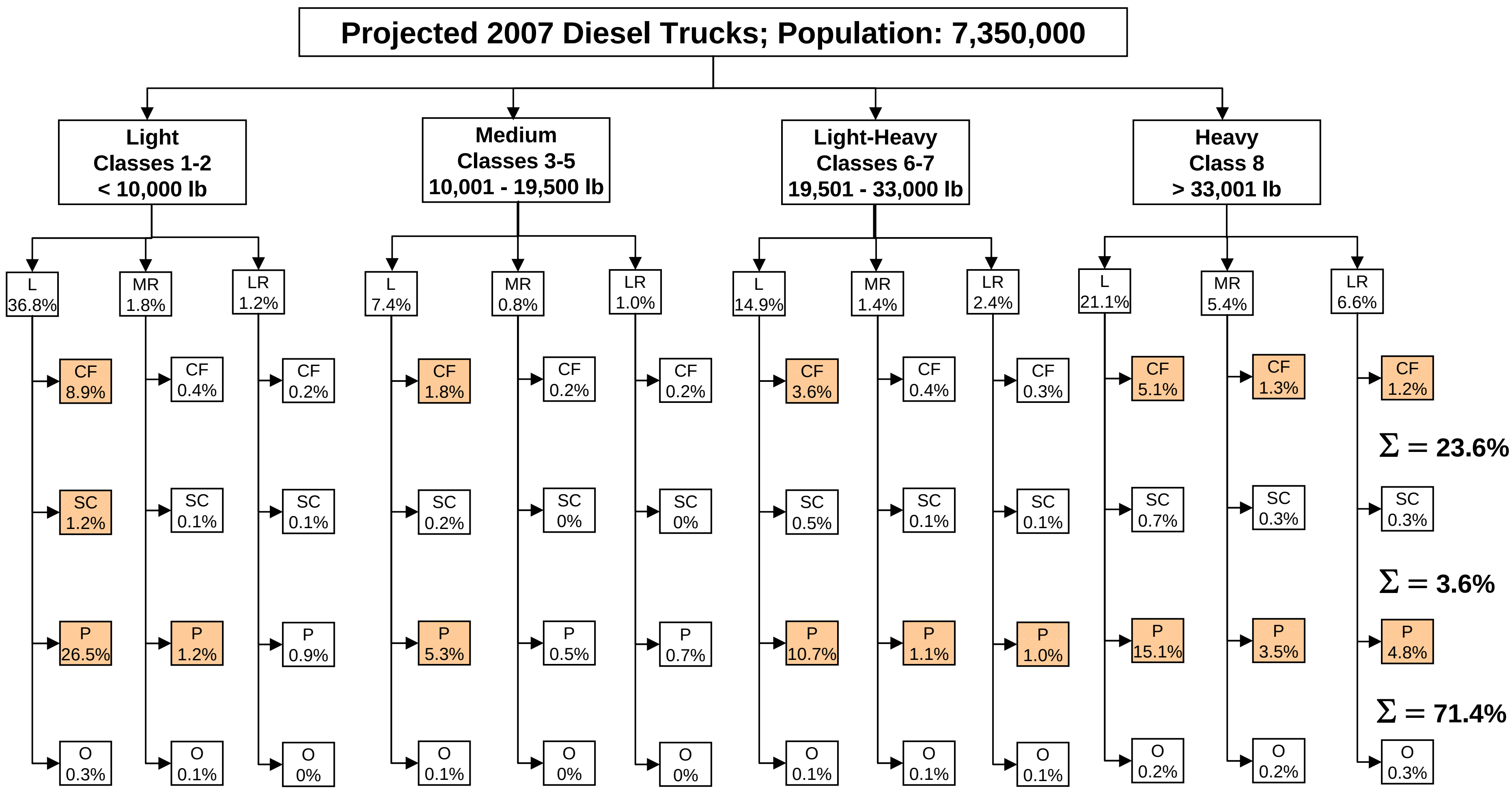
Fueling Station Profile Reports used in previous TIAX EMA study

Outputs

- Diesel throughput at fueling stations
- Segment SCR diesel truck population by market, general traffic patterns and diesel consumption
- Segment SCR diesel truck population by market, general traffic patterns and diesel consumption
- Identify potential segments for developing business cases

The VIUS 2002 database was used to define fueling habits of on-road diesel trucks

- Estimated 2007 truck populations and use profiles are found using the VIUS 2002 database, which is a probability sample of private and commercial trucks registered in the United States as of July 2002
- Analysis includes all vehicles, including pick-ups, panel vans, SUVs, and station wagons, classified as trucks by state registration practices
- Annual growth rate for all diesel trucks is assumed to be 3.7%
- Average annual miles for local, medium range, and long range trucks within the classes were estimated and compared to the overall VIUS 2002 mileage by class



L = Local; < 200 miles
MR = Medium Range; 200 - 500 miles
LR = Long Range; > 500 miles
CF = Central company-owned fueling station; Fleet Stations
SC = Single contract fueling facility located off site; Cardlocks
P = Public fueling station; Truck stops and conventional retail stations
O = Other fueling habit

= 1% - 10%   = > 10%

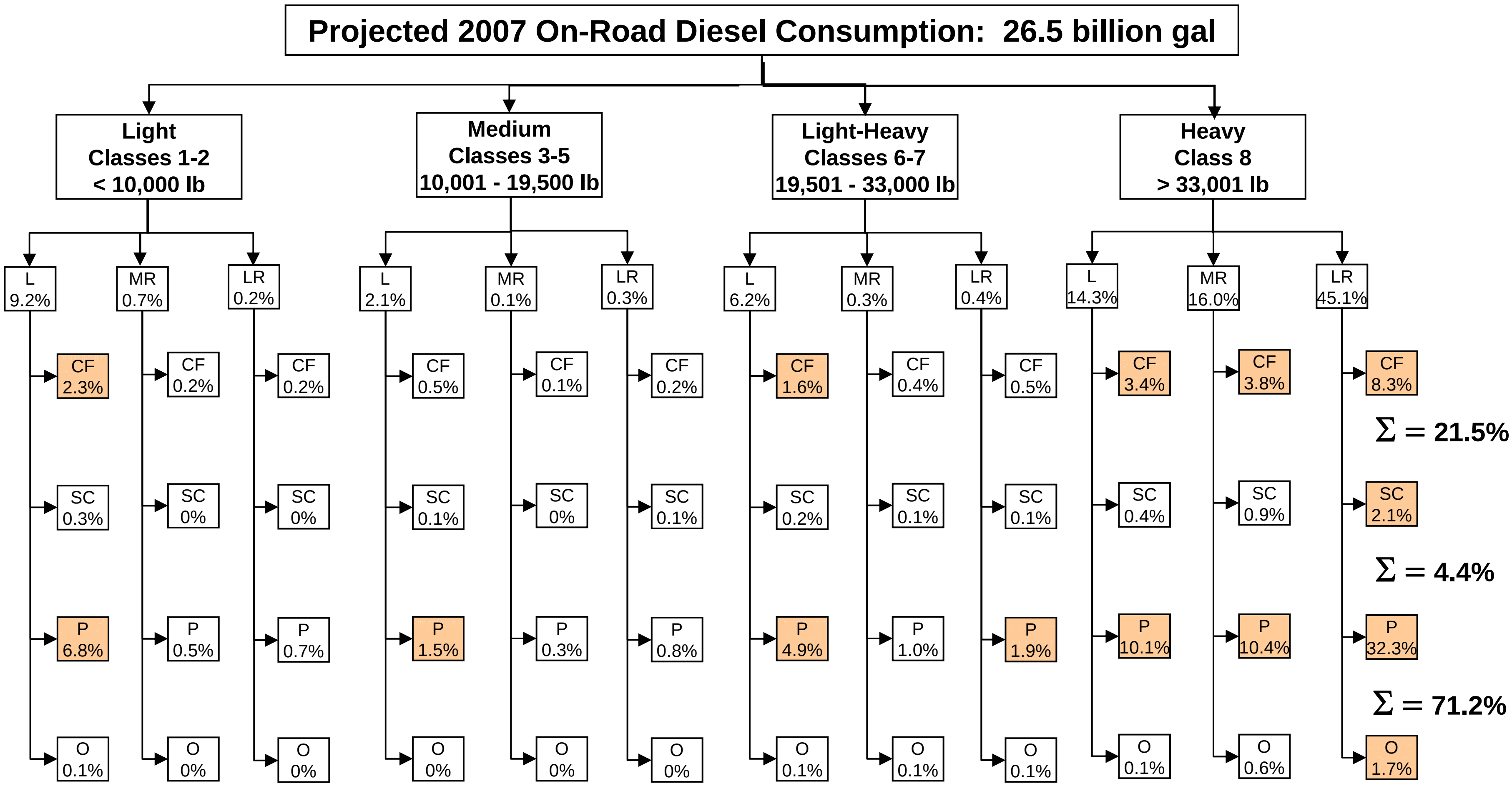
Source: VIUS 2002

VIUS 2002 database numbers for all diesel trucks on the road are used to calculate the diesel on-road consumption from the truck population

	Diesel consumption x 1000 gal												Total
	Light; Class 1-2			Medium; Class 3-5			Light-Heavy; Class 6-7			Heavy; Class 8			
	< 10,000 lb			10,001 - 19,500 lb			19,501 - 33,000 lb			> 33,000 lb			
	Local	Medium Range	Long Range	Local	Medium Range	Long Range	Local	Medium Range	Long Range	Local	Medium Range	Long Range	
	< 200 miles	200 - 500 miles	> 500 miles	< 200 miles	201 - 500 miles	> 500 miles	< 200 miles	202 - 500 miles	> 500 miles	< 200 miles	203 - 500 miles	> 500 miles	
Fuel Economy, mpg *	13.48	13.48	13.48	9.75	9.75	9.75	6.11	6.11	6.11	5.18	5.18	5.18	
Average Miles/Yr	12,500	20,000	40,000	10,000	20,000	40,000	10,000	20,000	40,000	12,500	55,000	125,000	
Central company-owned fueling facility	607,182	47,278	50,242	135,596	27,355	54,424	432,189	95,011	127,457	902,817	1,002,618	2,204,031	**5,686,201**
Single contract fueling facility located off-site	78,917	11,539	12,739	17,624	6,677	13,799	56,173	23,190	32,316	117,342	244,712	558,821	**1,173,848**
Public fueling stations	1,804,217	130,105	194,841	402,919	75,280	211,060	1,284,231	261,464	494,285	2,682,684	2,759,138	8,547,328	**18,847,553**
Other	19,759	7,954	10,368	4,413	4,602	11,231	14,064	15,984	26,301	29,379	168,674	454,808	**767,535**
Total	2,510,075	196,876	268,190	560,552	113,913	290,514	1,786,657	395,648	680,360	3,732,222	4,175,141	11,764,988	**26,475,137**

*Fuel Economy for the In-use diesel fleet is used here to estimate the total fuel consumption

Source: VIUS 2002



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O = Other fueling habit

= 1% - 10%   = > 10%

Source: VIUS 2002

Analysis of the VIUS 2002 database shows some changes in diesel vehicle populations and fueling habits

- This analysis predicts 74% of the diesel consumed on the road in 2007 will be from Class 8 trucks; previous EMA Study estimate included both Classes 7 & 8 at 85%
- Because this study intends to include all on-road diesel vehicles rather than just commercial diesel vehicles, as was done in the previous study completed for EMA, the percentage of fuel consumed by Classes 1-2 is now predicted to be 11.2%, while the previous study indicated only 2.9%
- Fueling station profiles and truck activity continues to focus on the heavy heavy-duty truck segment, using much of the same data as the previous study, because of the majority of fuel used in this segment

Truck stops include a range of fueling throughputs and profiles. Central fueling stations and cardlocks are subsets of the truck stop profiles.

Heavy-Heavy Duty (Class 8) Fueling Station Profiles

Public (P) Truck Stops

- 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

Single Contract (SC) Cardlocks

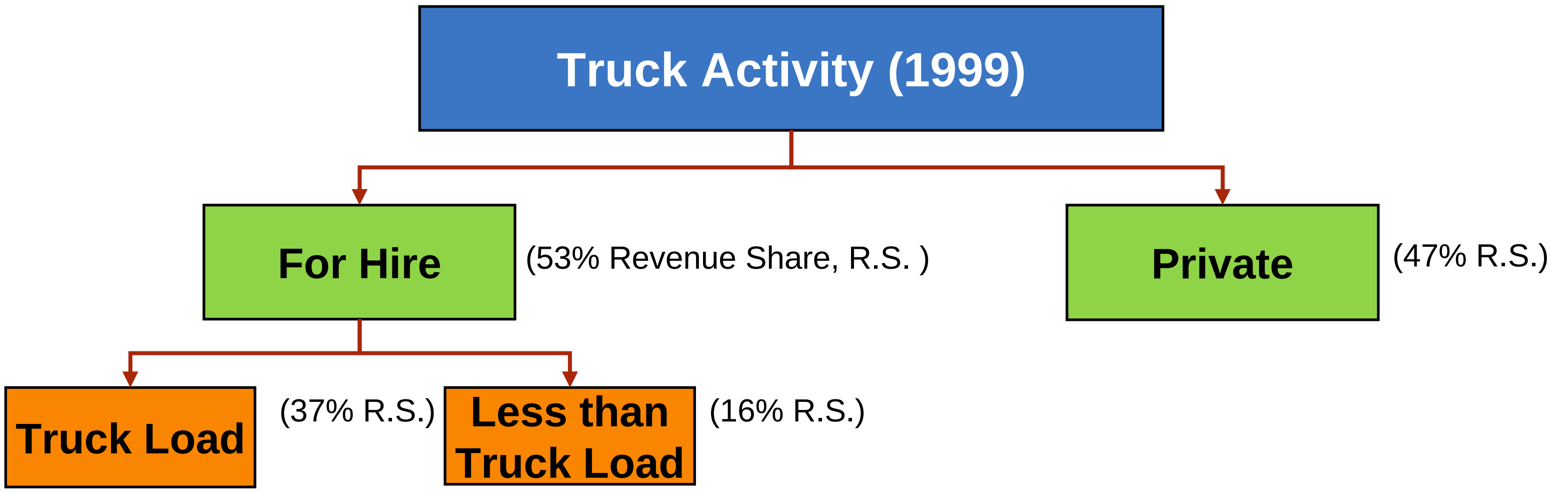
- 2,500 cardlocks serving HD truck diesel
- Distributed throughout the country. Skewed towards urban centers.
- 4% of all on-road diesel consumption
- Average fuel throughput estimated based on the VIUS database (DB) = 80,000 gal/mo

Central Fueling (CF)

- 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

Truck activity identified in 1999 show the relative fueling habits of private vs. for hire fleets



- Avg distance: 375-425 miles
- Gaining market share from private fleets

<u>Fueling Habits - Percent of Fuel Consumption</u>

62% Truck Stops

35% Company owned fueling stations

2% Cardlocks

1% Other (Mobile Fueling)

- Avg distance: 50-100 miles
- Market share (revenues) expected to shrink to 42% by 2007
- Most private fleets are used in regional or local hauls

<u>Fueling Habits - Percent of Fuel Consumption</u>

23% Truck Stops

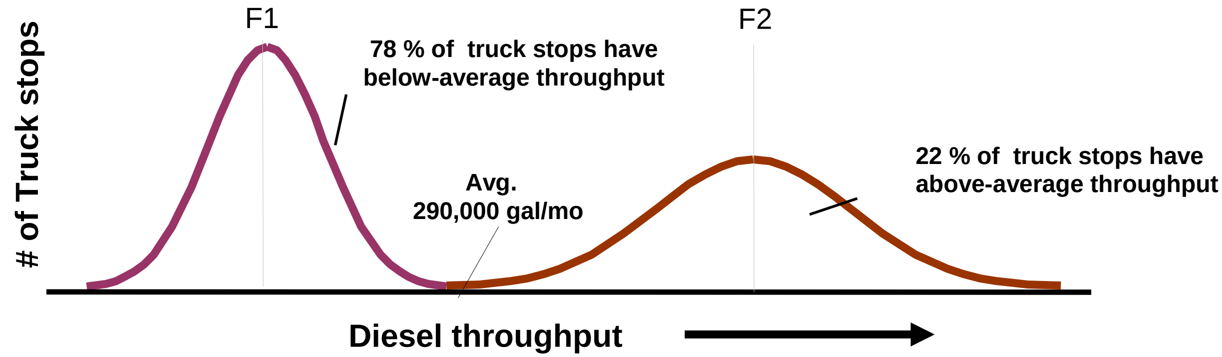
66% Company owned fueling stations

6% Cardlocks

5% Other (Mobile Fueling)

Sources: EMA Study 2003: :NATSO, OneSource Market Report

This study uses the diesel station distribution analysis that was completed for the previous EMA study in 2003



Monthly Diesel Fuel Throughput (gallons/station)		
Fuel Throughput Range		Number of Stations
High	Low	
2,000,000	1,300,000	310
1,300,000	1,000,000	1,128
1,000,000	300,000	515
300,000	200,000	262
200,000	140,000	2,436
140,000	80,000	1,115
80,000	10,000	2,491
10,000	100	24,251
Total Number of Stations		**32,509**

- A bimodal distribution as shown here, was developed to profile the truck stops. **0.78F1 + 0.22F2 = 290,000 gal/month** where F1 and F2 are average throughputs for each segment.

Sources: EMA Study 2003: EPA, NATSO, ATA, VIUS97

The urea consumption numbers from Task 1 were then distributed among diesel fueling stations using the diesel throughput percentages

Monthly Diesel Fuel Throughput (gallons/station)			
High	**Low**	**Number of Stations**	**% of Diesel Sales**
2,000,000	1,300,000	310	17%
1,300,000	1,000,000	1,128	44%
1,000,000	300,000	515	11%
300,000	200,000	262	2%
200,000	140,000	2,436	14%
140,000	80,000	1,115	4%
80,000	10,000	2,491	4%
10,000	100	24,251	4%

As shown in the table on the left, 74% of the urea will be consumed in the larger diesel fueling stations, 18% in the medium throughput fueling stations (includes truck stops, cardlock, and central fleet stations)

Heavy-duty Station Size Designation	Monthly Urea Throughput (gallons/station)				
	Number of Stations	2010		2015	
		High	Low	High	Low
XXL	310	2,114	1,057	14,427	7,213
XL	1,128	1,473	737	10,055	5,028
L	515	833	416	5,683	2,842
ML	262	320	160	2,186	1,093
M	2,436	218	109	1,486	743
MS	1,115	141	70	962	481
S	2,491	58	29	393	197
XS	24,251	6	3	44	22

Urea throughput estimates identify urea distribution mode and the infrastructure pathway for different station sizes

- Pathway and distribution mode were found to be dependant on the urea throughput in previous TIAX studies
- Distribution mode, or delivery method to vehicle, are different for the light-duty and heavy-duty segments
  - LDD vehicles are assumed to be on a maintenance interval and will have an under hood filling location
  - HDD vehicles are assumed to be on a fueling interval and will have on board storage tank filled with a fuel nozzle at fueling locations
- Urea distribution pathways are discussed in detail in Task 3 of this report, Task 4 will assign the pathway to the categorized stations

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TASK 3

Revise TIAX SCR Urea Cost Model

Inputs

Input from TIAX Urea Reports

- Full-scale implementation costs
- Urea TS&D costs for full-scale implementation
- Cost of urea for full-scale implementation

Input from Stakeholders:

- Cost of bottled SCR-Urea at retail stations
- Cost of other SCR-Urea dispensing technologies

Chemical Engineering Plant and Equipment Cost Indices

Granular Urea Basket Price

US Industrial Natural Gas Prices

AdBlue experiences in Europe

Task 3

Revise cost assumptions for transportation, distribution, storage
(Source: CE indices, EIA)

Verify urea production costs as a function of natural gas prices

Review Experiences in Europe

Develop functional relationships between urea dispensing technologies, urea price (per gallon or per mile basis) and urea consumption/throughput
Small volumes vs. large volumes

Obtain SCR-urea specification to refine previous urea TS&D costs analyses (specification source: EMA)

Define sensitivity parameters, e.g.: price of raw material urea variability in costs of dispensing technologies

Regional variations in above costs

Outputs

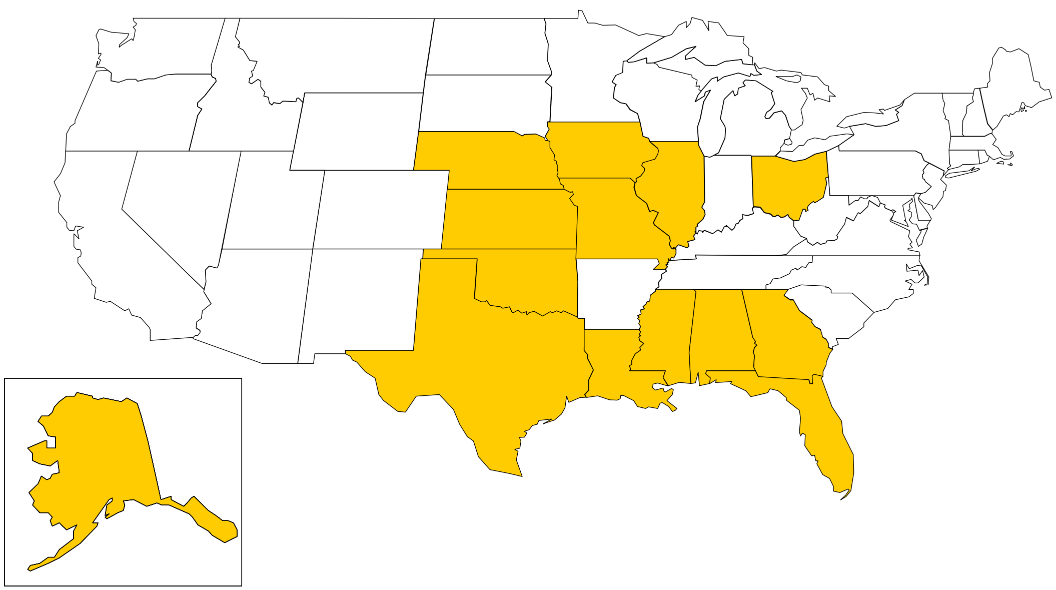
Urea Cost Model

- Urea cost ($/gal) at end of pipe retail for:
  - Infrastructure (UST/AST)
  - Refillable Stillages
  - Totes & Barrels
  - Bottles
- Potential business cases

The current major urea-producing states are in close proximity to abundant natural gas sources, like the Gulf of Mexico and Alaska

Major Urea* Producing States in the United States

* Includes both urea and urea ammonium nitrate



Key Urea Manufacturing Companies in the U.S.	Capacity	
	2002[1] Million TPY	2005[2] Million TPY
Agrium	1.2	0.9
CF Industries	2.4	3.3
PCS Nitrogen	1.9	1.0
Terra Industries	1.4	1.3
Other	3.1	1.7
Total	**10.1**	**8.2**

1. www.the-innovation-group.com
2. British Sulphur Consultants, CRU Group for 2005

U.S. Capacity has decreased over the past 3 years from 10 to 8 Million TPY

Sources: The Innovation Group, British Sulphur Consultants

U.S. urea consumption is supported by domestic and world urea producers

- Urea production and import levels are heavily influenced by the price of natural gas, the main feedstock for urea production
- Rise in domestic natural gas prices leads to increased urea imports
- Roughly one-half of current domestic consumption is foreign urea imported by domestic distributors
- SCR urea will likely come from domestic suppliers of concentrated solution rather than imported granular urea
- Total on-road SCR-urea demand is projected to be 0.6 tons/yr by 2015
- Sufficient worldwide urea production capacity exists to meet U.S. on-road SCR-urea demand

Urea Production and Distribution

All Urea Grades		Million short tons/year
WORLD[1]	Demand	137
	Production	138
	Capacity	162
DOMESTIC (U.S.)[1]	Demand	12.4
	Production	6.0
	Capacity	8.2
Projected 2015 U.S. On Road Diesel Vehicle	Urea Demand	0.6[2]

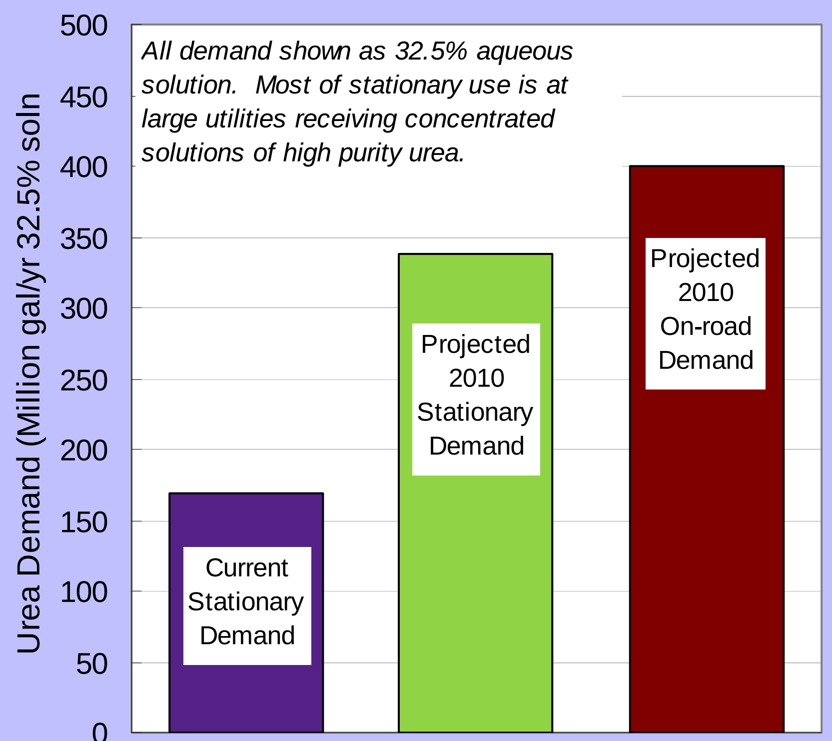
1 British Sulphur Consultants, CRU Group for 2005

2. Equivalent to 400 Million gallons 32.5% soln

Sources: British Sulphur Consultants

Urea for stationary source NOx control is an established and growing market

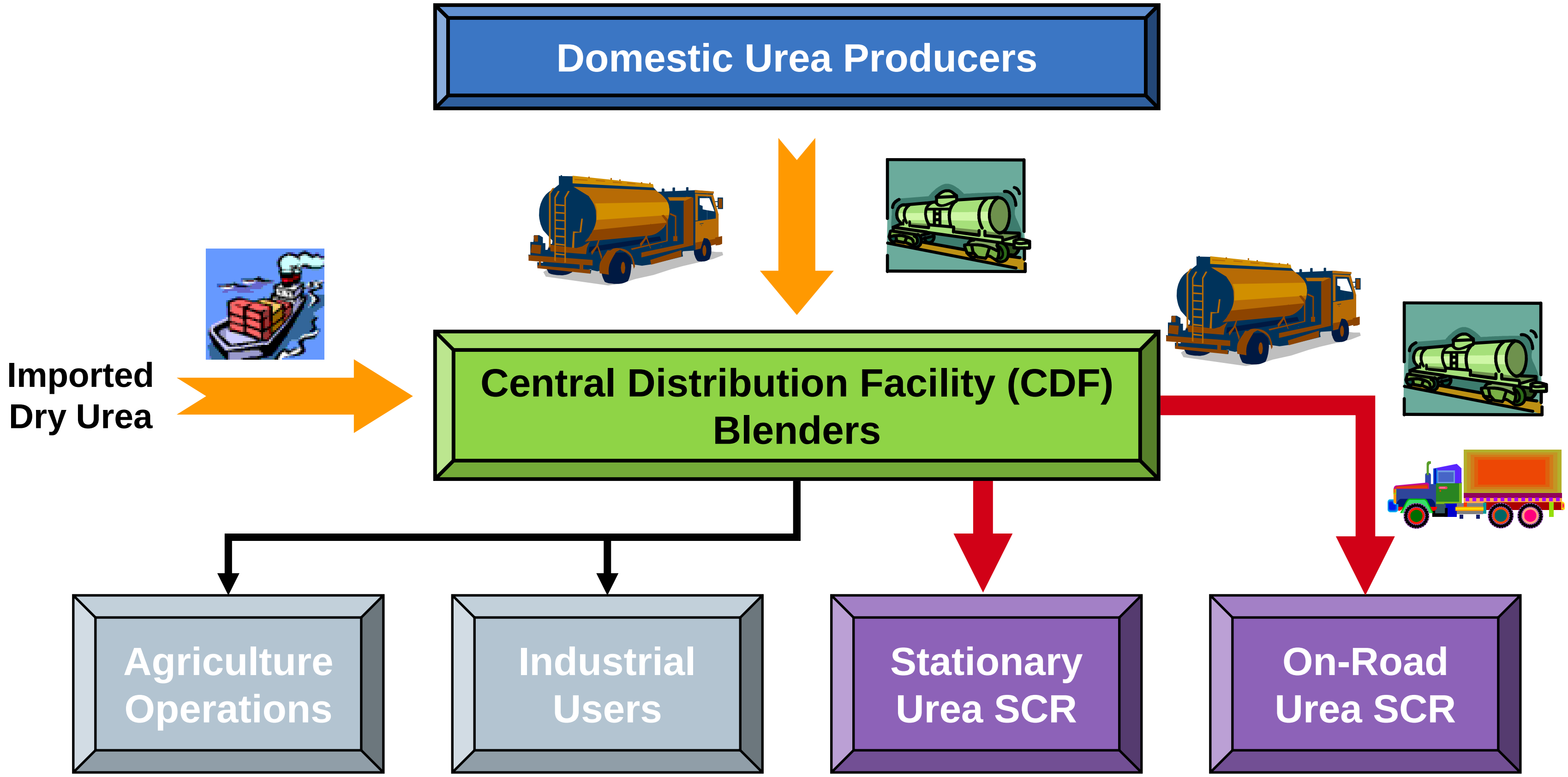
- SCR systems have been installed on ~200 utility boilers and hundreds of combustion turbines
  - Needed to comply with NSR, SIP Call, other state & local limitations
  - SIP Call requires only seasonal use
- CAIR Rule limits effective 2009 with another ratchet in 2015
  - Effectively expands SIP Call to 12 more states (~150 more units)
  - For most states, requires annual rather than seasonal use
- Utilities trending towards urea melt based systems rather than anhydrous and aqueous ammonia due to environmental, safety, and homeland security concerns
- BACT for non-emergency diesel generators is SCR. Some of these sources currently procure DIN70070 in totes.



Stationary demand a rough estimate by Terra Industries

Sources: EPA Website, Terra Industries

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

Key pathways for SCR-urea distribution studied in this analysis are identified below

Pathway 1a — Dry urea or urea melt is blended to 32.5% solution at a CDF and trucked in tanker loads to retail stations equipped with storage tanks and dispensing facilities

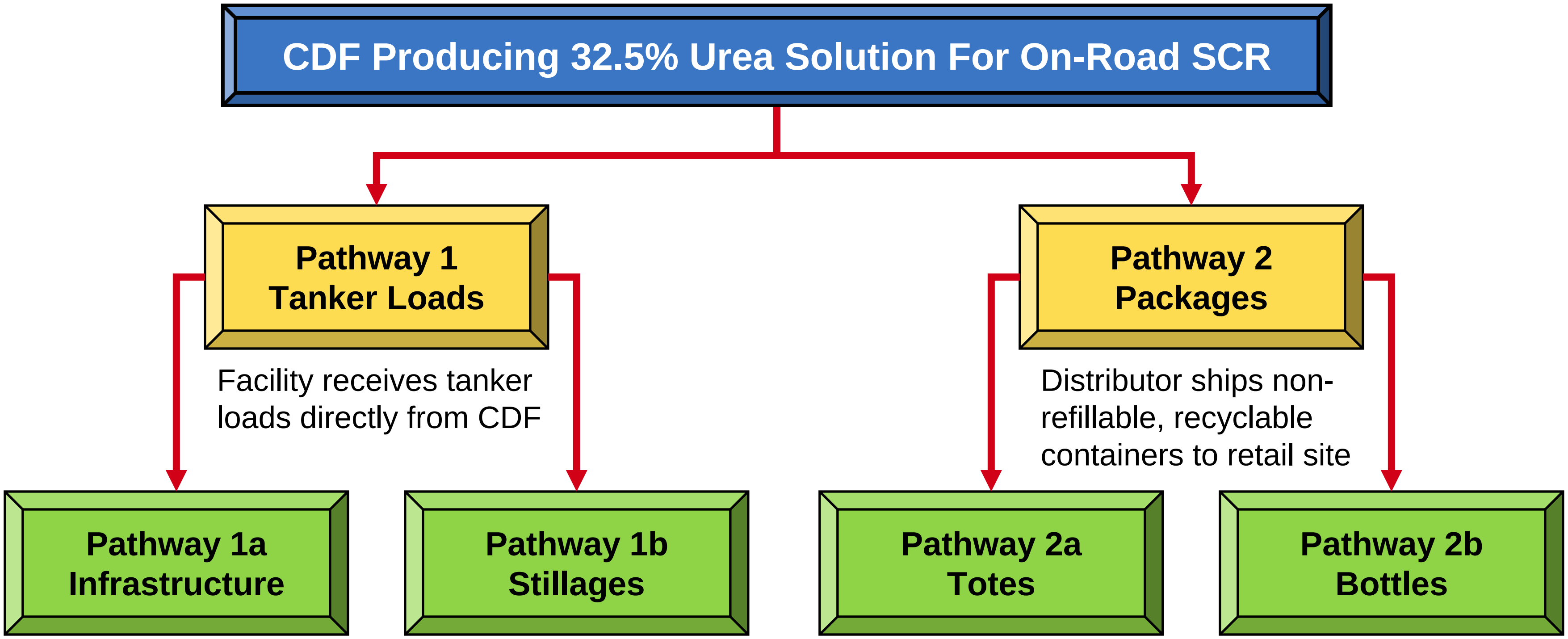
Pathway 1b — Dry or urea melt is blended to 32.5% solution at a CDF and trucked in tanker loads to retail stations using purchased intermediate size dispensing systems (stillages) with storage capacities of 5500 gallons and less

Pathway 2a — Dry or urea melt is blended to 32.5% solution at a CDF. The CDF or a packager and ships to retailers in totes (55-280 gallons).

Pathway 2b — Dry or urea melt is blended to 32.5% solution at a CDF. The solution is bottled (1-5 gallons) and shipped to retailers.

On-site blending at large truck stops was previously considered as a pathway, but concerns of tampering from EPA and the lack of interest by retailers (additional infrastructure/procedures) eliminate this pathway

Two main pathways for urea delivery are tanker loads and packages



Pathway 1a – Infrastructure

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

Pathway 1b – Stillages

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

Pathway 2a – Totes

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

Pathway 2b – Bottles

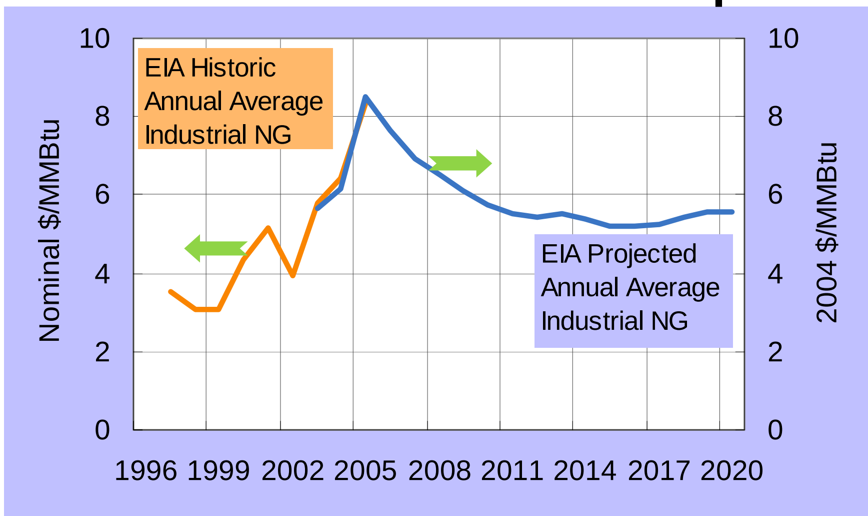
- Sales < 500 gal/month
- Retail site uses bottles and/or sells bottles to customers

A previously developed cost model was used to determine retail costs for Pathway 1.

Key model inputs that impact the calculated retail cost of urea include:

1) Cost of raw materials (primarily the cost of natural gas)
2) The urea throughput at the CDF and retailer
3) The initial capital outlay, and capital recovery requirements of the CDFs and the retailers
4) Cost of transportation from the urea plant to the CDF and the CDF to the retailer
   - Distances traveled
   - Travel mode (rail or truck)

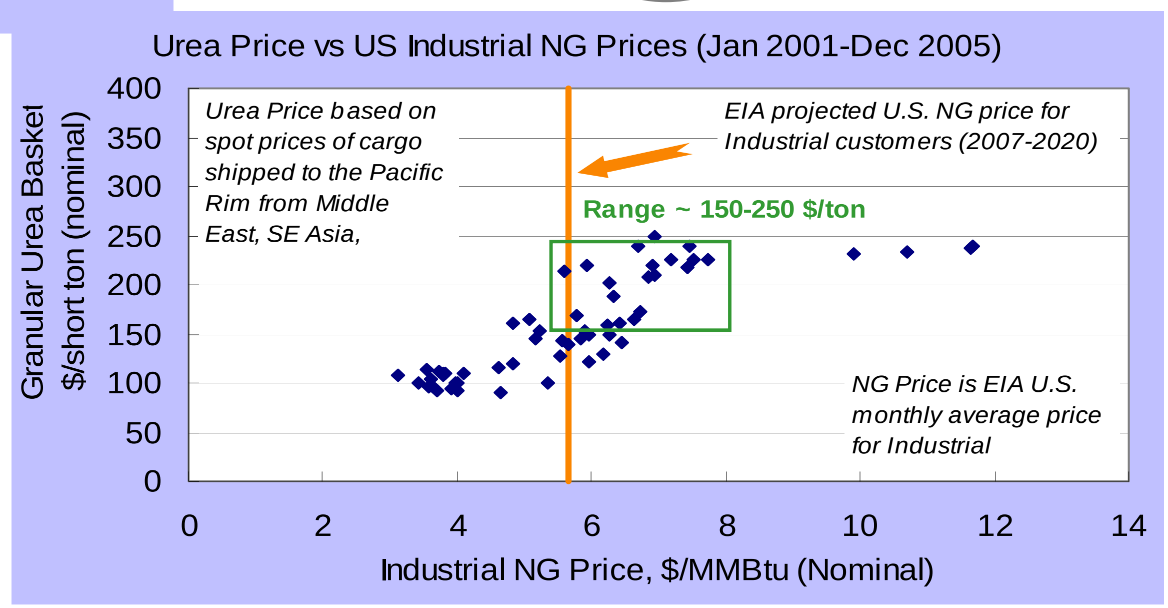
The model assumes a urea price based on predicted future NG prices



Selected Nominal price of 200 $/ton

Evaluated cost impact over range 150-250 $/ton

- Urea price dependent on natural gas prices
- EIA predicts stable NG prices for US industrial customers ~ $5.7 per MMBtu for 2007-2020 period
- NG prices > 7 $/MMBtu has minimal impact on urea price due to increased imports



Sources: EIA AEO2006, Urea Basket Price Report

Urea transport distances and modes are assumed for shipping from producer to CDF and CDF to retail

- Transport Mode Assumptions
  - From Port/Producer to CDF
    - Average transport distance 800 miles
    - Miles split 75/25 between rail and truck
  - From CDF to Retailer
    - Average transport distance 350 miles
    - Miles split 50/50 between rail and truck
- Shipping Cost Assumptions
    - Trucking cost = $3.33 per mile for a 24 ton load (5200 gal/delivery) (ref 1,2)
    - Rail cost = $0.025 $/ton-mile (ref 3)
- "Less than Tanker Load" (LTL) Shipments to Retailer
    - 20% markup on urea price
    - Assumed LTL orders are trucked
    - Transport cost is $3.33 per mile[1]
    - Assume travels from CDF each fill (no load sharing with nearby stations)

1. Conversation with Luis Delgado of CDI Urea Marketing and Distribution, 3/20/06
2. Conversation with Jerry Kroon of Agrium, 3/27/06
3. "Overview of US Freight Railroads", Association of American Railroads, Jan 2006

Sources: CDI, Agrium, Association of American Railroads

CDF Costs are dependent on capital investment requirements, capital recovery assumptions, and throughput

- Expected to include existing agricultural and petroleum terminals as well as new facilities constructed to blend SCR urea
- About 200 CDFs are expected to be involved by 2015 for an average throughput of 2 million gallons of 32.5% solution per year
- CDF costs to blend dry urea or urea melt to a 32.5% aqueous urea solution include:
  - Solids storage and handling equipment (granular urea processing only)
  - Blending equipment and storage tanks
  - Heating and dispensing equipment
  - Systems integration and installation
  - Annual operating costs
- The cost of urea presented in $/gal includes operating and amortized capital costs using a capital recovery period of 3 years and a cost of capital of 12%
- Cost differences between CDF processing of urea melt or granular urea are:
  - Urea melt slightly less expensive (70-85% of granular urea cost)[1]
  - Transportation cost to CDF higher
  - Lower CDF capital investment at (solids handling equipment not required)

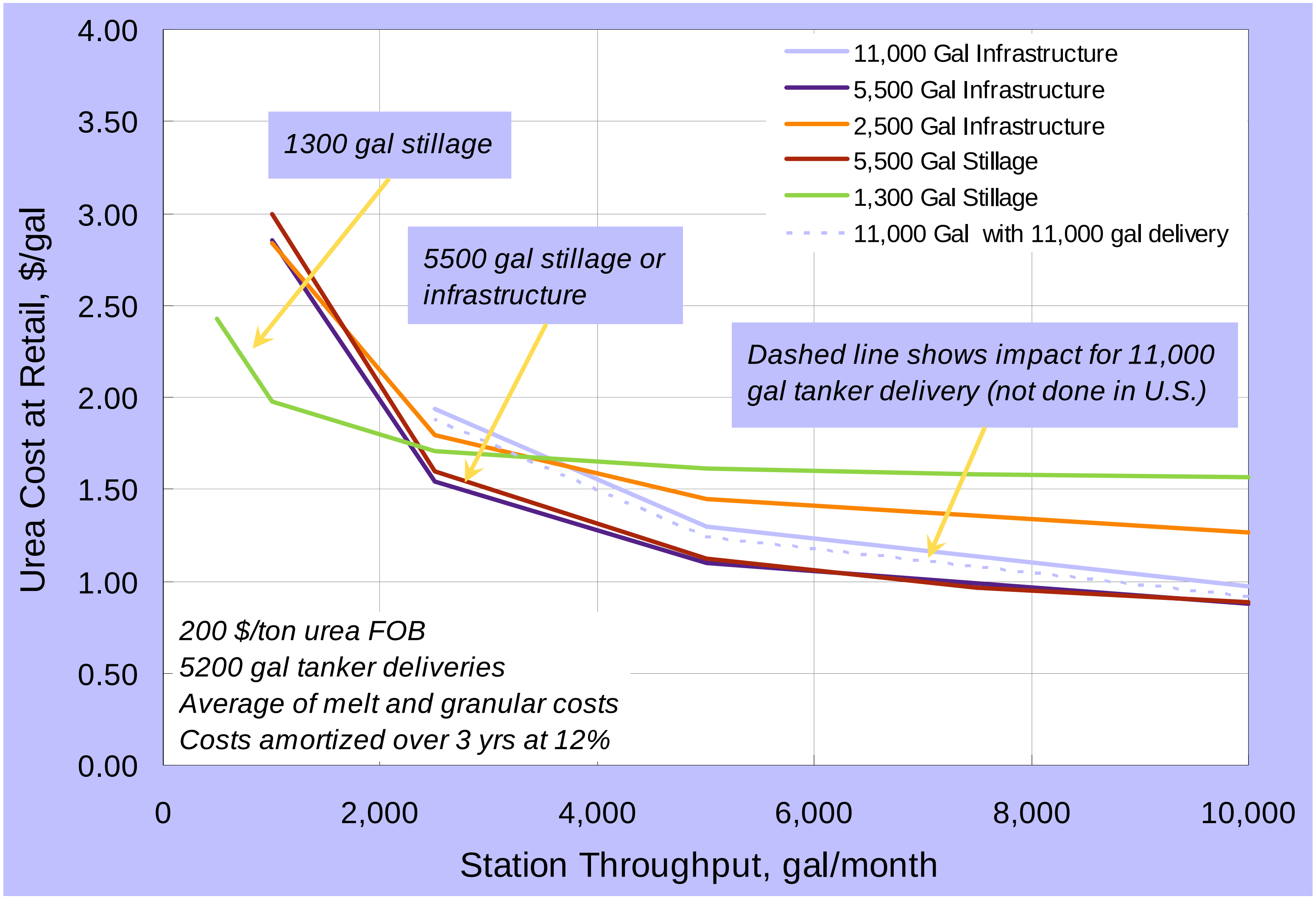
1. Conversations with Luis Delgado (CDI) and Barry Lonsdale (Terra Industries)

Sources: CDI, Terra Industries

Retailer costs are dependent on capital investment requirements, capital recovery assumptions, and throughput

- Retail Station Capital Costs
  - Pathway 1a Infrastructure Costs
    - Storage in UST/AST
    - Heating and dispensing equipment
    - Installation and annual operating costs
  - Pathway 1b Stillage Costs
    - Based on current (2006) AdBlue stillage prices
    - Taxes and permitting costs equivalent to the infrastructure cases were added
    - Operating costs equivalent to the Pathway 1a (throughput dependent) were included
- All capital costs are amortized over a 3-yr period using a 12% cost of capital.

Urea retail cost at end-of-pipe is a function of retailer throughput



Example Scenario:

5,000 gal/month retail station with a 5500 gal tank purchasing 32.5% aqueous urea solution from a CDF utilizing urea melt.

Urea Melt

- The model assumes 200 $/ton urea FOB discounted 20% for melt.
- **Cost = $0.24/gal** product urea **(A)**

Transportation To Central Distribution Facility (CDF)

- Transportation of urea melt to CDF from plant
- Assume 800 miles from plant to CDF 75% by rail, 25% by truck.
- **Cost = $0.12/gal** product urea **(B)**

Processing @ CDF to 32.5 wt%

- Blending, storage and distribution of 32.5% urea at CDF with 2 million gal/yr throughput
- Capital investment = $470K with $16k/yr operating costs, 12% interest over 2.5 yrs.
- **Cost = $0.13/gal** product urea **(C)**
- **Expected CDF profit mark-up = $ 0.09 to $0.24 per gal product urea (D)**

Transport To Retail

- Transportation of 32.5% urea solution 350 miles from CDF to retailer
- Assume $3.33 per mile for a 24 ton truck (5200 gal 32.5% solution)
- **Cost = $0.13/gal** product urea basis **(E)**

Retail Station Storage & Dispensing

- Storage & dispensing at a 10,000 gal/month station
- Capital investment = $60K at 12% over 3 yrs with $3k/yr operating costs
- **Cost = $0.46/gal** product urea **(F)**
- **Expected retail profit mark-up = $ 0.07 to $0.12 per gal (G)**

The cost model does not include mark-ups; mark-ups were added here for illustration

Average Expected Price = (A) + (B) + (C) + (D) + (E) + (F) + (G) = 1.24 to 1.44 $/gal

Example Scenario:

2,500 gal/month retail station with a 1300 gal stillage buying 32.5% aqueous solution from a CDF utilizing urea melt.

Urea Melt

- The model assumes 200 $/ton urea FOB discounted 20% for melt.
- **Cost = $0.24/gal** product urea **(A)**

Transportation To Central Distribution Facility (CDF)

- Transportation of urea melt to CDF from plant
- Assume 800 miles from plant to CDF 75% by rail, 25% by truck.
- **Cost = $0.12/gal** product urea **(B)**

Processing @ CDF to 32.5 wt%

- Blending, storage and distribution of 32.5% urea at CDF with 2 million gal/yr throughput
- Capital investment = $470K with $16k/yr operating costs, 12% interest over 2.5 yrs.
- **Cost = $0.13/gal** product urea **(C)**
- **Expected CDF profit mark-up = $ 0.09 to $0.24 per gal product urea (D)**

Transport To Retail

- Transportation of 32.5% urea solution 350 miles from CDF to retailer
- Less than load transport cost is $3.33/mile plus 20% surcharge
- **Cost = $1.00/gal** product urea **(E)**

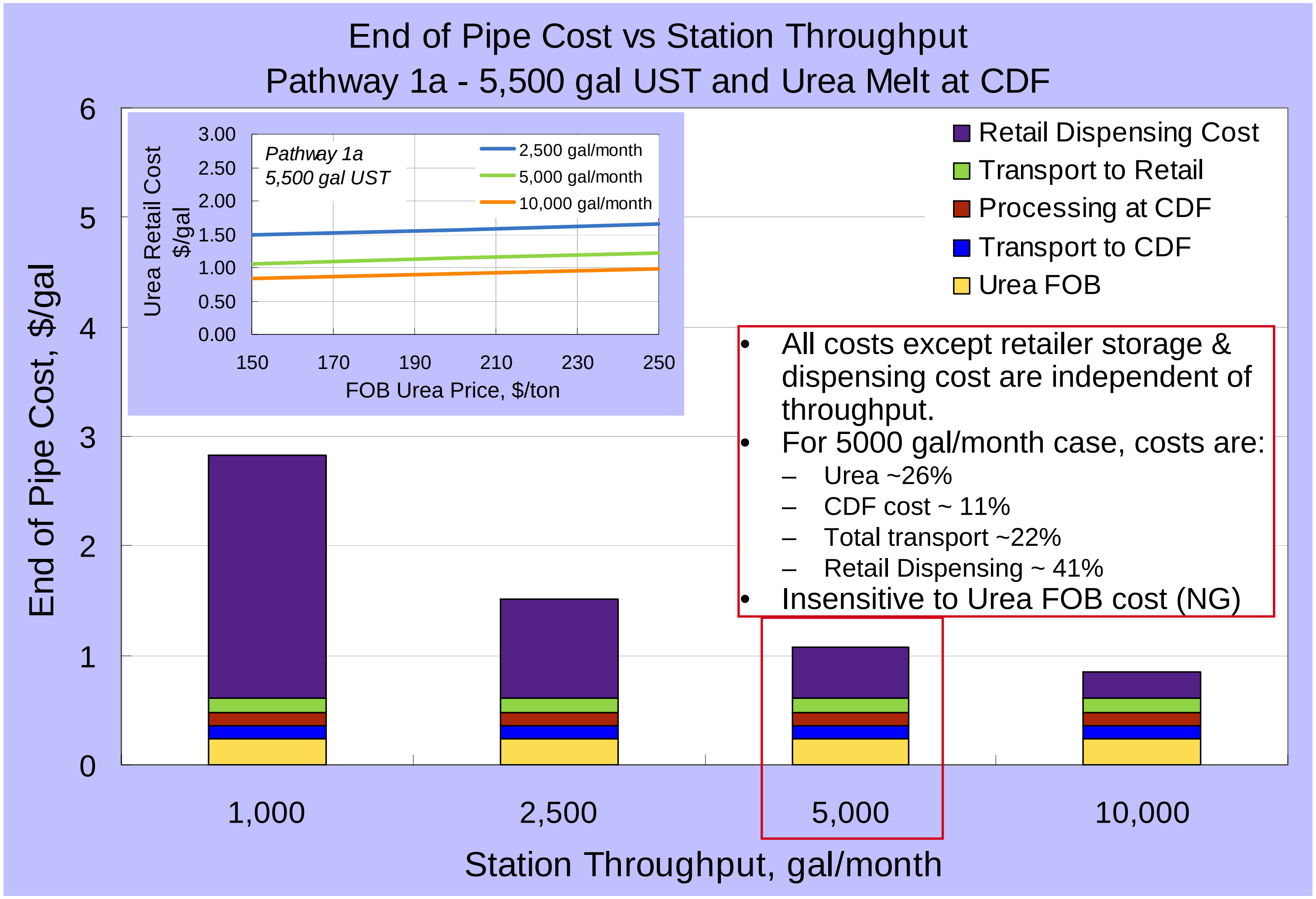
Retail Station Storage & Dispensing

- Storage & dispensing at a 2,500 gal/month station with 1300 gal capacity
- Capital investment = $10K at 12% over 3 yrs with $1.7k/yr operating costs
- **Average cost = $0.20/gal** product urea **(F)**
- **Expected retail profit mark-up = $ 0.07 to $0.12 per gal (G)**

The cost model does not include mark-ups; mark-ups were added here for illustration

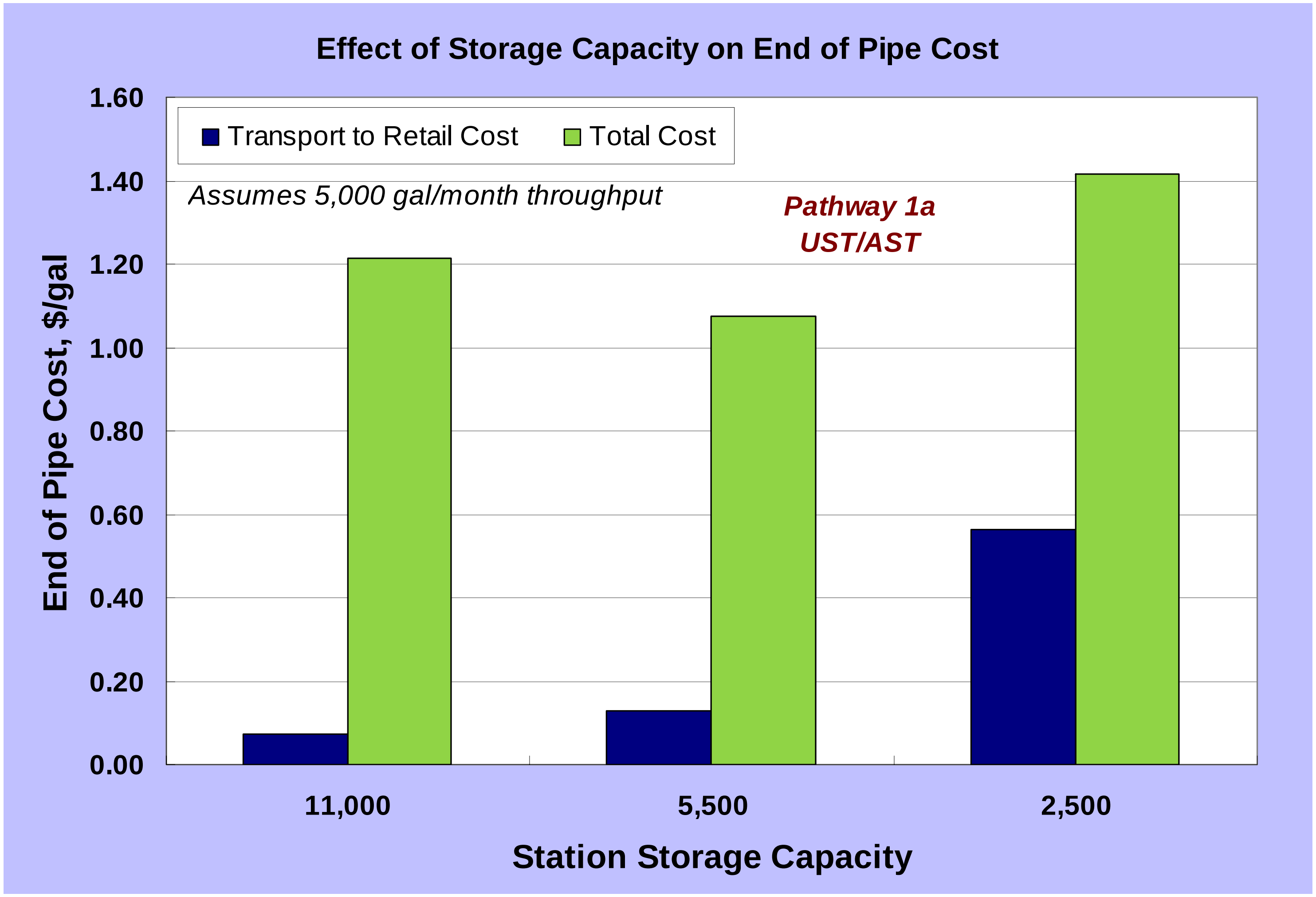
Average Expected Price = (A) + (B) + (C) + (D) + (E) + (F) + (G) = 1.85 to 2.05 $/gal

For stations selling less than 10,000 gal/month*, retailer costs dominate the end of pipe urea cost



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

Station storage capacity sized to accommodate a full tanker load significantly decrease end of pipe cost



The cost model indicates that station storage capacity and throughput dictate end of pipe urea cost

- The retail cost of urea is highly dependent on station throughput
- All urea retail costs on a $/gal basis are independent of station throughput and storage capacity except for:
  - Retailer storage and dispensing costs
    - Retailer cost represents ~ $2 per gal or 2/3 of total cost at a 1,000 gal/month station
    - Retailer cost represents ~ $0.1 per gal or 1/8 of total cost at 20,000 gal/month station
  - Transport cost from CDF to retailer with storage capacity less than 5500 gal
    - LTL delivery costs on $/gal basis can be significant
    - For 1300 gal stillage case with 2500 gal/month throughput, delivery cost is $1.00/gal, nearly 60% of retailer cost.
- Urea solution retail cost is insensitive to variability in natural gas price
  - As urea FOB price varies from $150 to $250 per ton, the retail price only increases $0.15 per gal for the 5,000 gal/month throughput case
- Costs to install tanks with capacities greater than 5500 gallons (full tanker load) are not justified for any stations at projected urea throughput levels

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.

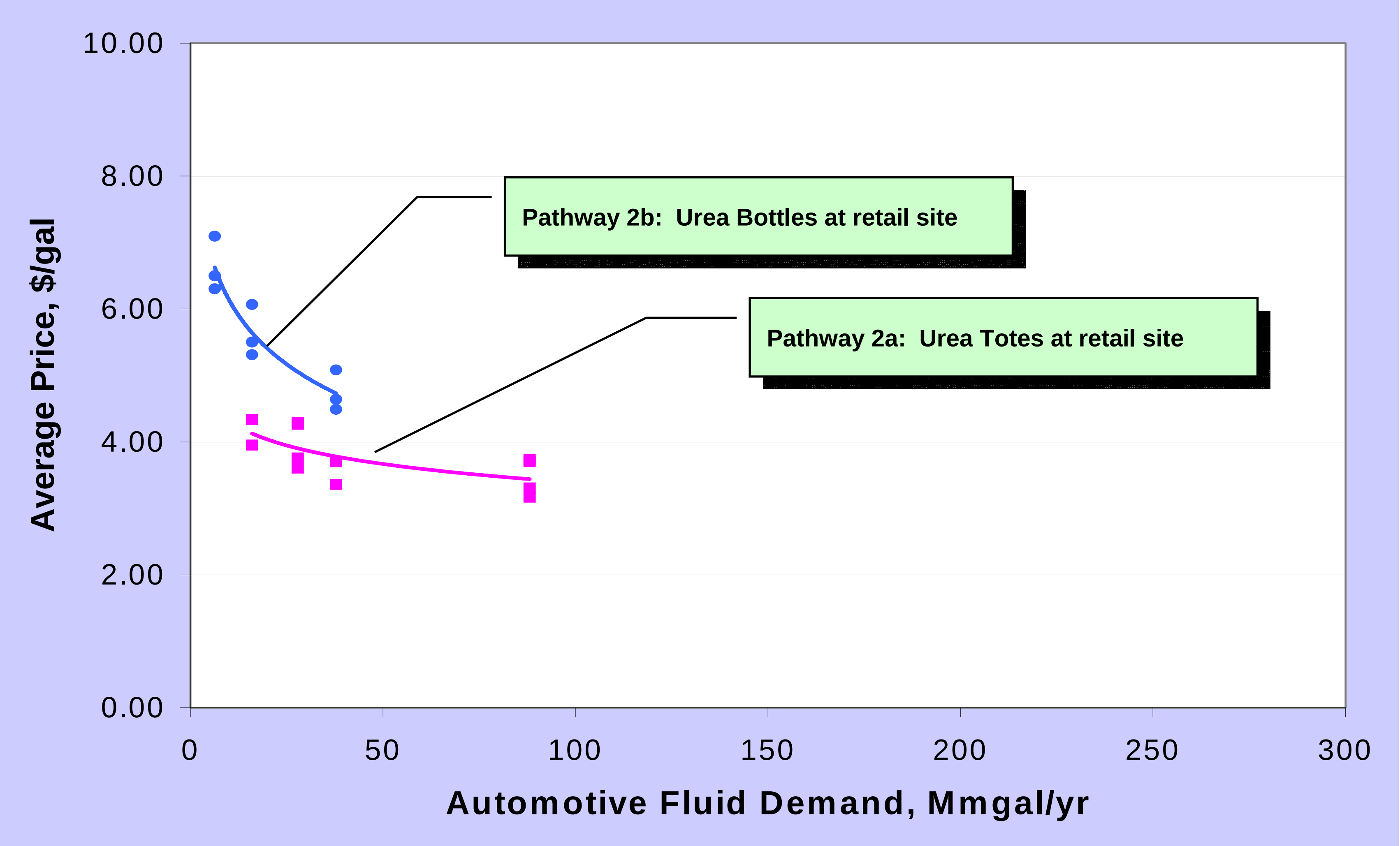
Sources: AAM Study 2004

The US can gain insight from the European AdBlue experience

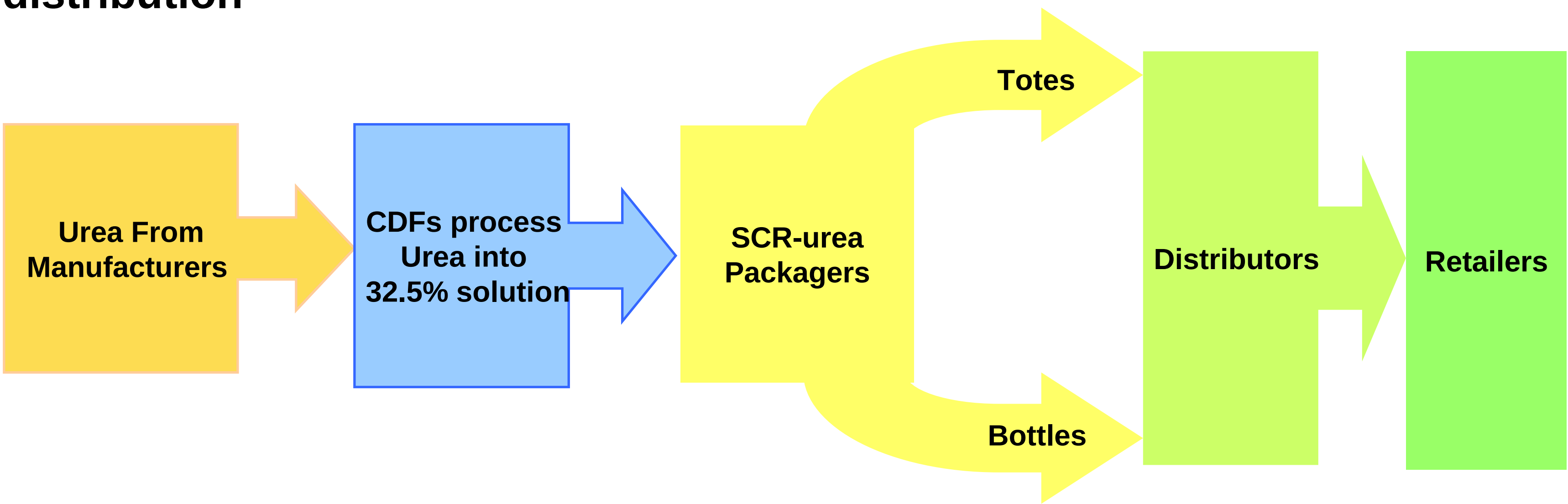
- AdBlue marketed by several firms for Euro IV (2005) and Euro V (2009) compliance
  - Yara manufactures and distributes through Brenntag as Air1
    - ➢Deliver within 48 hours of order and offer telemetric monitoring for stock management
  - GreenChem (UK)
  - Dureal™ (Division of Univar)
  - BlueCat (UK)
- All vendor websites mention 5% fuel savings (reduced EGR)
- Compliance
  - Sensors measure NOx and store data in the on board diagnostic system[2].
  - Trucks registered after Oct 2007 will have tank level sensors[3]. Empty tanks trigger limp home mode at 50% power over 100 km (62 miles). Recommend a spare 10 liter jerry can in the cab.
- Usage rates[1,3]:
  - 4-5% of diesel use by volume for Euro IV (2.9 g/bhp-hr)
    - ➢1.5 liters per 100 km (~0.6 gal per 100 mile) or
    - ➢30-40 liters per week
  - Truck's urea tank capacity ~125 liter (~33 gal), therefore ~55-gallon drums are not used
  - 5-7% of diesel use by volume expected for Euro V (1.5 g/bhp-hr)

Sources: 1. Yara website 2. Greenchem website 3.Bluecat website

The light-duty cost model used in the AAM study was modified with new urea costs through the CDF



The urea cost to the retailer in Pathway 2 is tied to the packaging and distribution



SCR-urea Package Description	Container Volume	Range of Costs to Retailer ($/gal)*
Totes	280-gallons 55-gallons	2.00 – 2.50
Bottles	2.5-gallons 1-gallon 1-quart	2.80 – 4.00

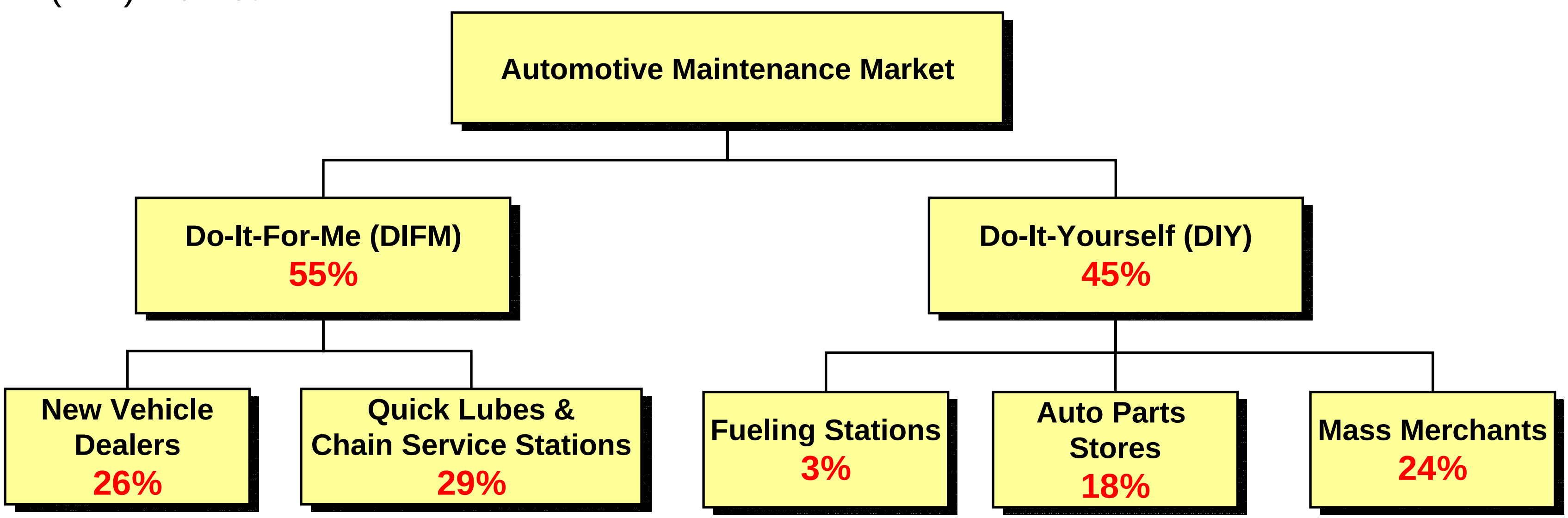
Costs to retailers include variances in:
• Margins of upstream distributors • Urea throughput • Storage costs at the retailer

* From AAM Light-Duty Cost Model

Sources: AAM Study 2004

Pathway 2 market will develop in a substantially different way because of the mature automotive maintenance market

- The automotive maintenance market is dominated by new vehicle dealers and service stations due to the larger do-it-for-me (DIFM) market
- The market split represents maintenance on the current vehicle mix of new and aging light-duty vehicles
- It is likely that as vehicles become more complex, the DIFM share will increase further
- The chain service stations (e.g., Jiffy Lube) capture the largest fraction of the DIFM market, while the mass merchandisers capture the largest fraction for the do-it-yourself (DIY) market

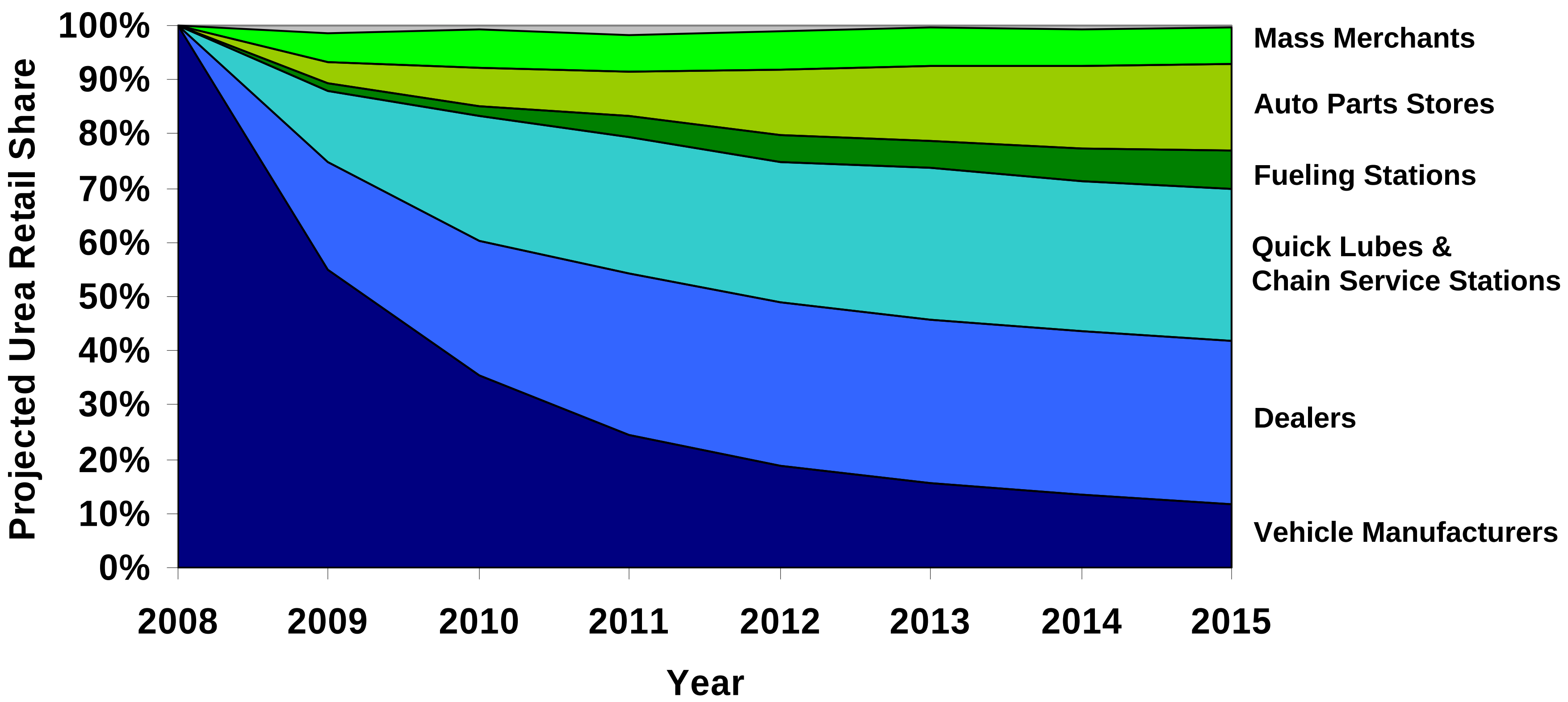


Note: Market share analysis derived from various industry reports including AfterMarket Business, 2004; Packaged Facts Market for Automotive Products; etc.

Sources: AAM Study 2004

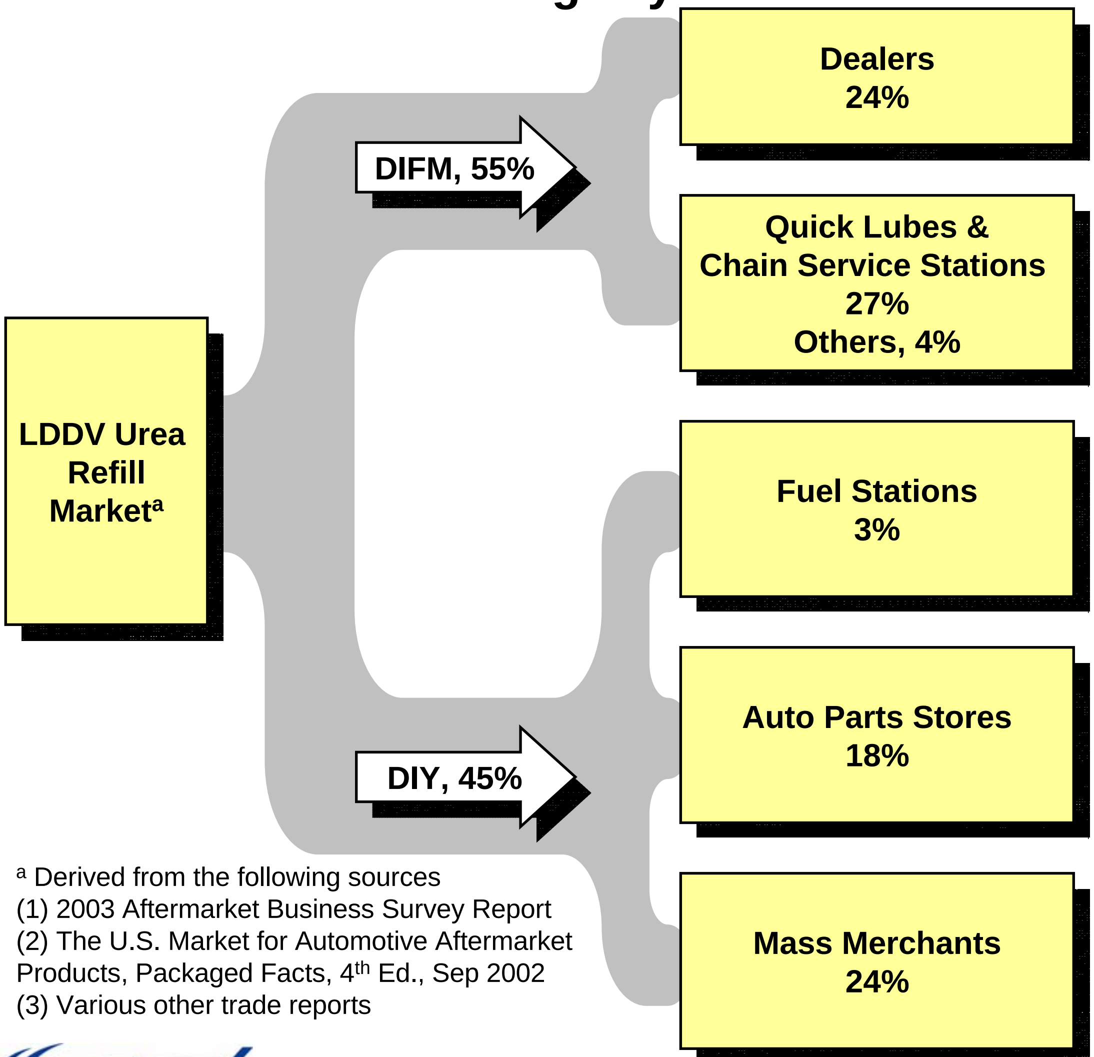
Urea distribution channels will depend on product development discussions between auto manufacturers and EPA

- Over time, the retail market share for urea in light-duty vehicles will mature to resemble the general automotive maintenance market
- The DIFM segment will select larger containers of urea (totes to stillages)
- The DIY segment will select small containers of urea (bottles)



Sources: AAM Study 2004

The existing automotive maintenance market share in the U.S. can be divided into the following key retail channels:

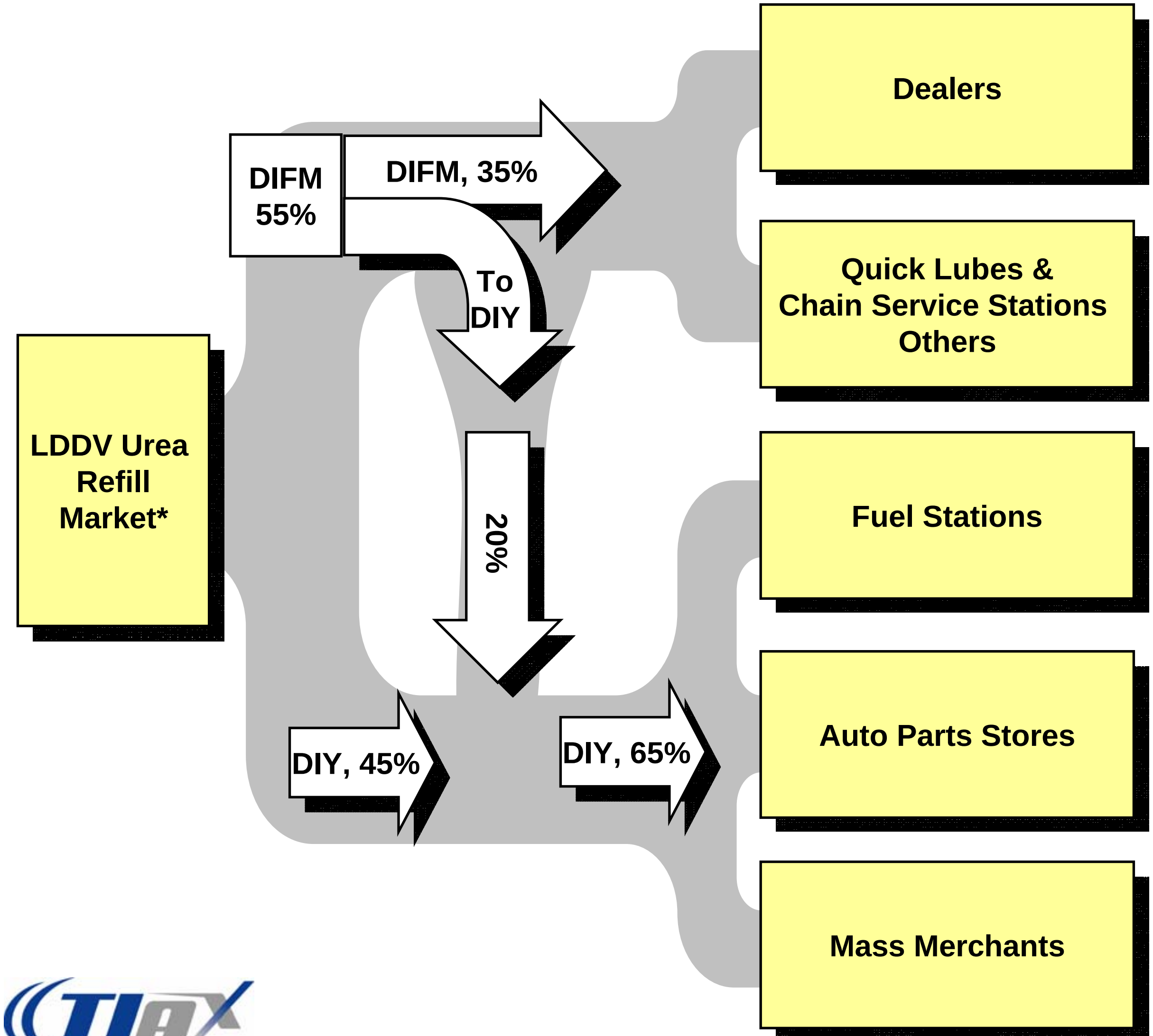


- On average, the existing automotive maintenance market share is also applicable to motor oil change
- It can be expected that any new automotive aftermarket functional fluid will exhibit similar retail characteristics on maturity
- SCR-urea is likely to have a price point that is similar to that of 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

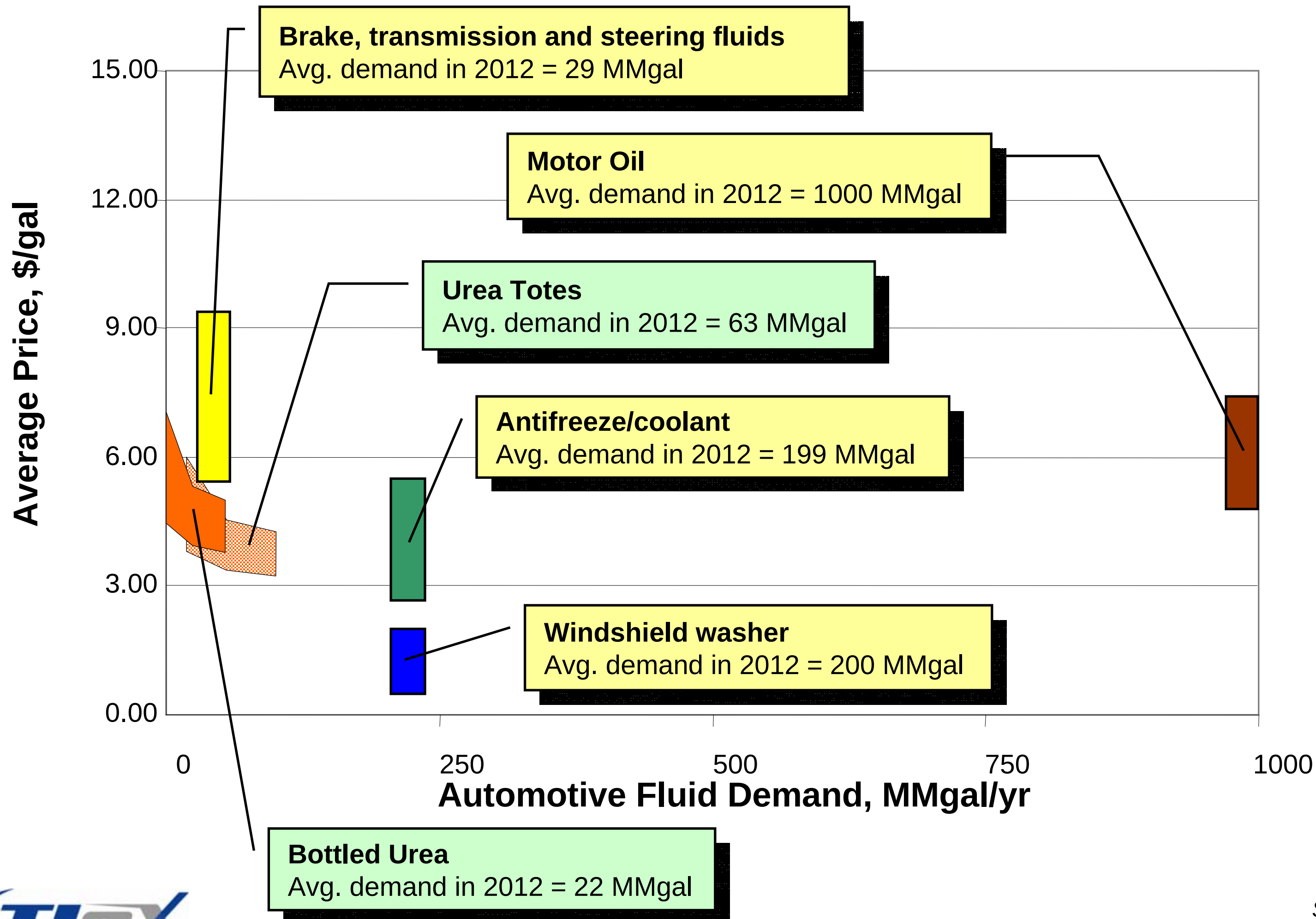
Variances from scheduled urea refill frequency and shorter refill frequency in the LD segment will result in urea DIFM'ers behaving as urea DIY'ers



- The shift in urea DIFM'ers to urea DIY'ers is estimated to be about 20% (see figure on left)
- Based on cost structure of the retailers in the DIY segment and urea throughput volumes, gas stations can be the price setters in the DIY segment, and the price of urea will not vary much between the three types of DIY retailers
- Consequently, gas stations are likely to capture a greater share of the urea market in the DIY segment as they present the most "convenient" option to the LD owner

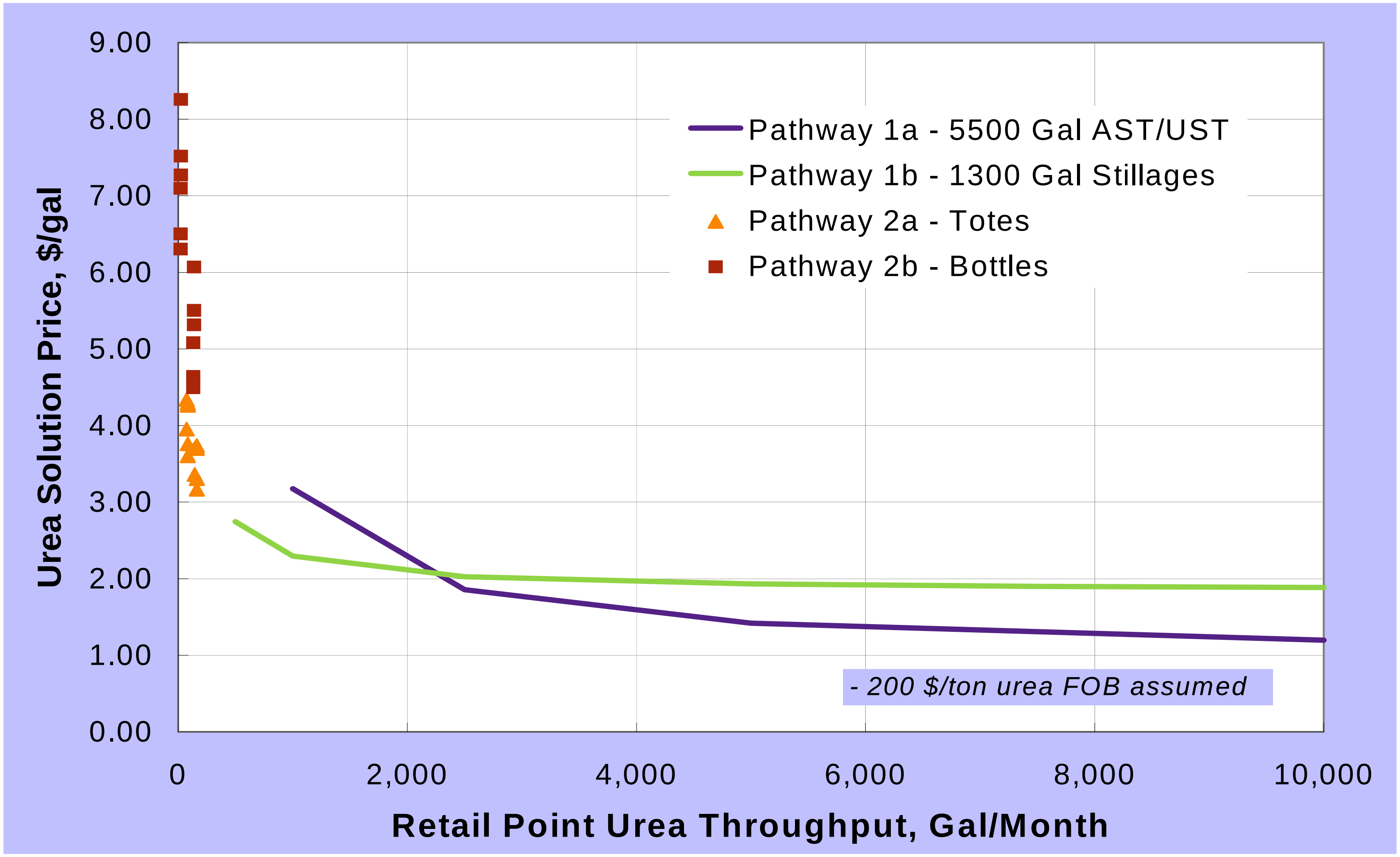
Sources: AAM Study 2004

A comparison of urea market price and size with the automotive fluids market indicates that urea would be generally similar in price and demand to most automotive fluids

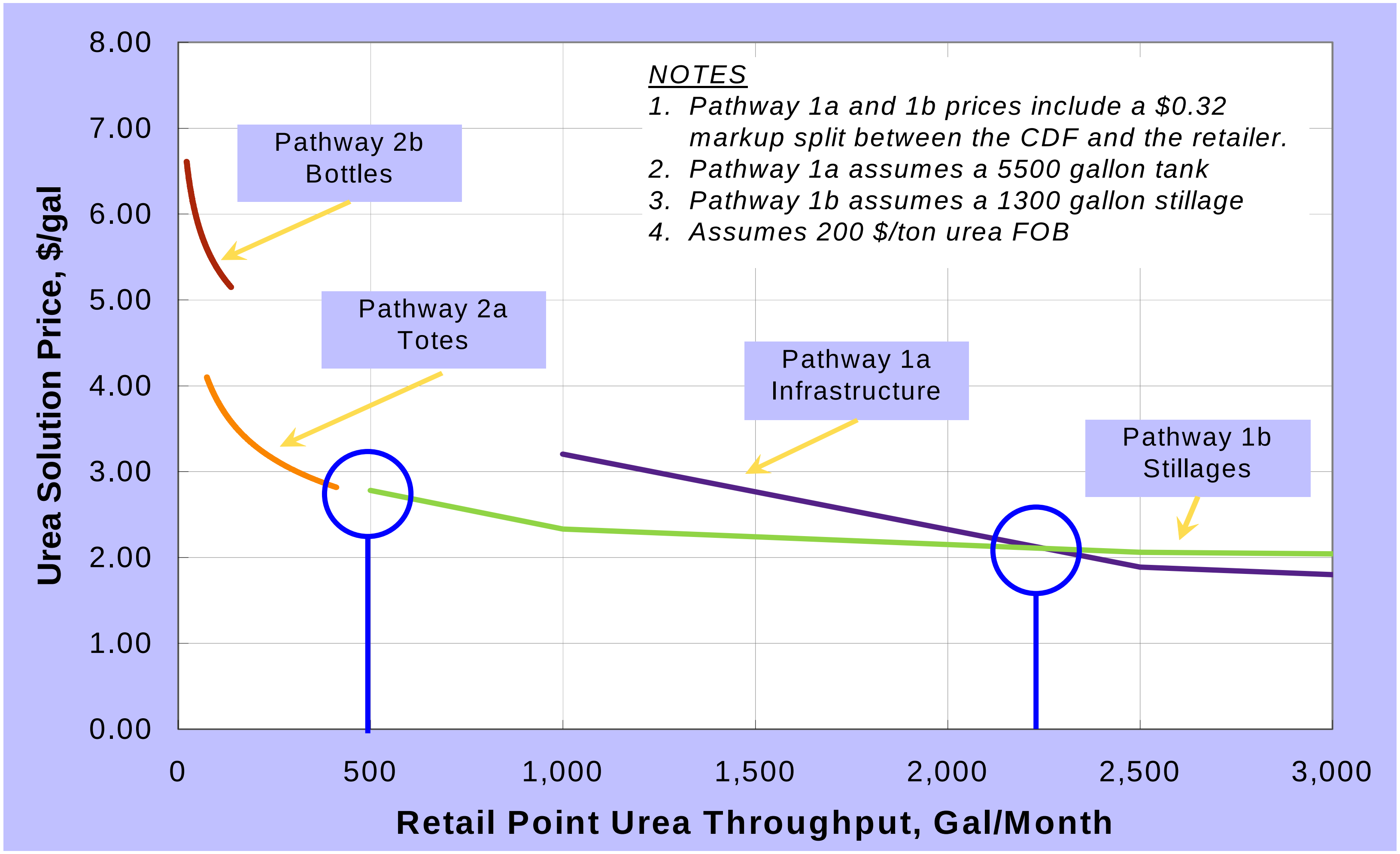


Sources: AAM Study 2004

Average price of retail SCR-urea to truck operators, as a function of retail station throughput, was determined



Pathway cross-over points and gaps are identified to assign distribution strategies to retail locations



The model clearly indicates appropriate pathway for a given retailer throughput

- Urea prices predicted by cost models for bottles, totes and stillages are consistent with current European AdBlue prices.
- Urea prices are inversely proportional to retailer throughput
- For Pathway 1
  – Stillages for throughputs 500-2250 gal/month
  – UST/AST for throughputs > 2250 gal/month
  – Retailer storage and dispensing costs represent 1/8 to 2/3 of end of pipe urea cost as monthly station throughput drops from 20,000 to 1,000 gal/month.
  – In most cases, retailer storage capacity should be 5500 gal
    - Large enough to avoid LTL delivery costs
    - Not oversized - projected station throughputs do not justify expense of larger tanks.
  – For Pathway 2
    - Urea market price and volumes are comparable to the automotive fluids market
    - Bottles would be chosen by retailers selling < 100 gal/month
    - Totes and barrels would be used by 100-500 gal/month retailers.

1	Approach for the SCR-Urea Update
2	Task 1 – Update Urea Consumption Estimates
3	Task 2 – Update Truck Segmentation
4	Task 3 – Revise TIAX SCR-Urea Cost Model
5	**Task 4 – Analyze Potential Business Cases**
6	Task 5 – Perform Critical Path Analysis

TASK 4
Analyze Potential Business Cases

Inputs

Urea consumption estimates: Task 1

Truck segmentation, Urea distribution: Task 2

Feasible-cost scenarios Source: Task 3

Task 4 activities

Analyze scenarios for each case:
- Large diesel fueling stations
- Tote urea dispensing
- Small container dispensing

Assess overall viability of market for complete urea coverage

Overall cost to truck owners/economic impact of operating a vehicle

Outputs

- Rank-order potential business cases
- Economic analysis of costs

The heavy-duty diesel stations that were binned by size in Task 2 are assigned monthly throughput quantities for 2010 through 2015

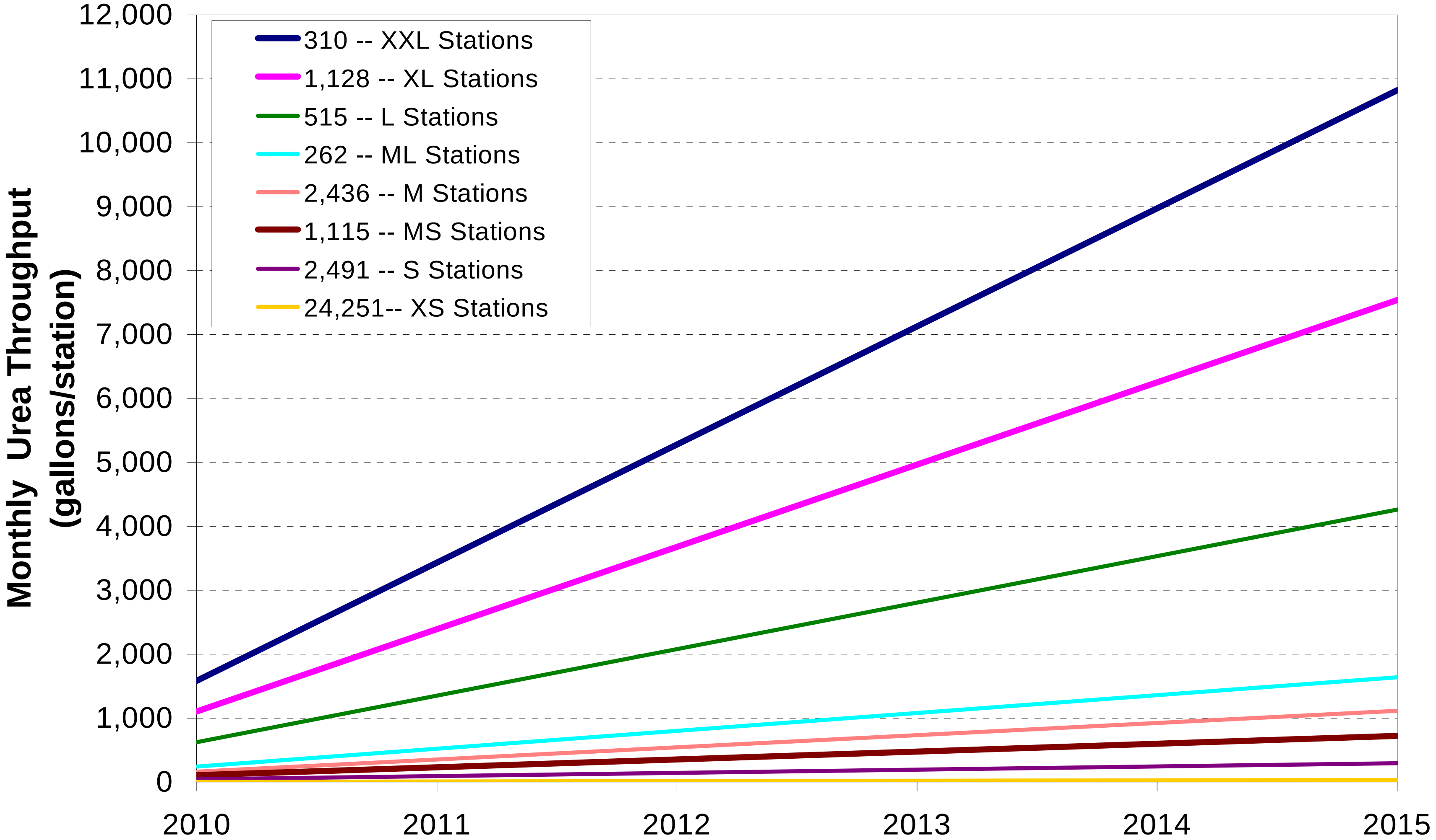
- Monthly urea throughput determined by segmenting the high and low urea consumption estimates established in Task 1
  - High consumption scenario is based on a 2% consumption rate and the EMA projected engine sales for HDD, LDD estimates based on AAM study
  - Low consumption scenario is based on a 1% consumption rate and the EMA projected engine sales for all classes

Heavy-duty Station Size Designation	Monthly Urea Throughput (gallons/station)				
	Number of Stations	2010		2015	
		High	Low	High	Low
XXL	310	2,114	1,057	14,427	7,213
XL	1,128	1,473	737	10,055	5,028
L	515	833	416	5,683	2,842
ML	262	320	160	2,186	1,093
M	2,436	218	109	1,486	743
MS	1,115	141	70	962	481
S	2,491	58	29	393	197
XS	24,251	6	3	44	22

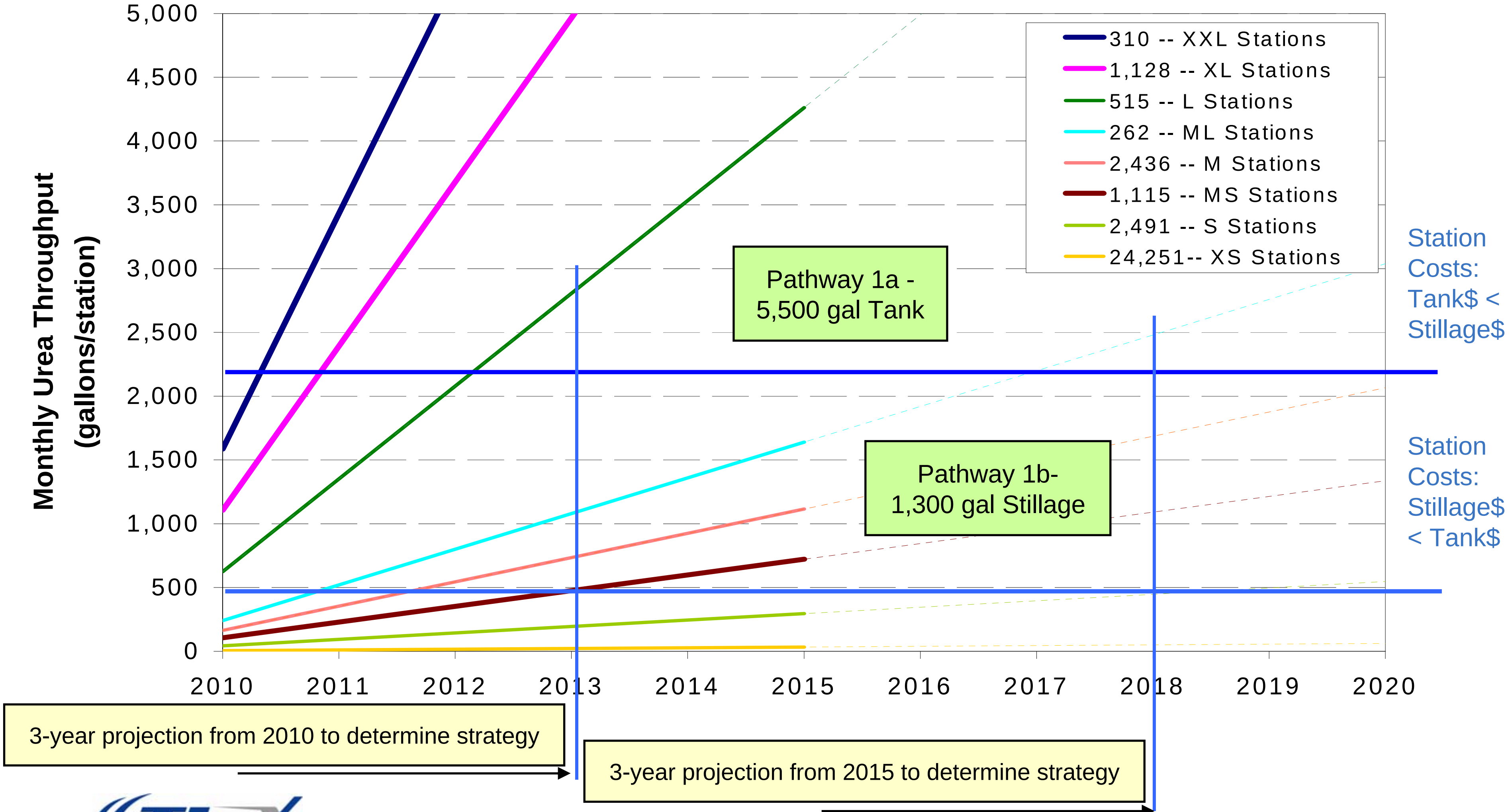
The distribution strategies for the heavy-duty diesel stations are identified for eight station sizes ranging from extra, extra large (XXL) to extra small (XS)

- The high and low consumption scenarios are used to determine an average consumption throughput for each station size
- Assume linear growth in station throughput for each station size between 2010 and 2015
- The monthly average throughput is then compared against the throughput break-points identified in the cost model to determine the most cost effective distribution strategy
- Because the infrastructure required for Pathway 1 takes capital investment, a 3 year outlook on estimated throughput is used to group station distribution strategies for the years 2010 and 2015
- The 3 year outlook should provide stations with a single distribution strategy that is viable until the capital investment is paid off

The average monthly urea throughput for each station size increases over time



Assuming continued linear throughput growth through the year 2020, distribution strategies are identified for the heavy-duty stations



The heavy-duty fueling station groups are assumed to employ the lowest cost distribution strategy of that group

- Extra-extra large (XXL), extra large (XL), and large (L) sized HDD fueling stations will employ storage tanks for distribution of urea
  - This strategy will work for both the 2010 and 2015 timeframes
  - Both above ground and below ground tanks will be used, dictated by the environmental conditions of the location and the pumping method
  - 5,500 gal. tanks appear to be the most economic choice in all cases
- Medium large (ML), medium (M), and medium small (MS), sized HDD fueling stations will employ stillages for distribution of urea
  - Stillages will work in 2010 for these stations, ML stations may transition to tanks around 2015
  - 1,300 gal stillages appear to be the most economic choice in all cases
- Small (S) HDD fueling stations will employ totes for distribution of urea
  - Assume that at least some of these stations are central fueling stations even though throughput is low

The distribution strategies for light-duty retail locations follows other automotive fluids, as discussed in Task 3

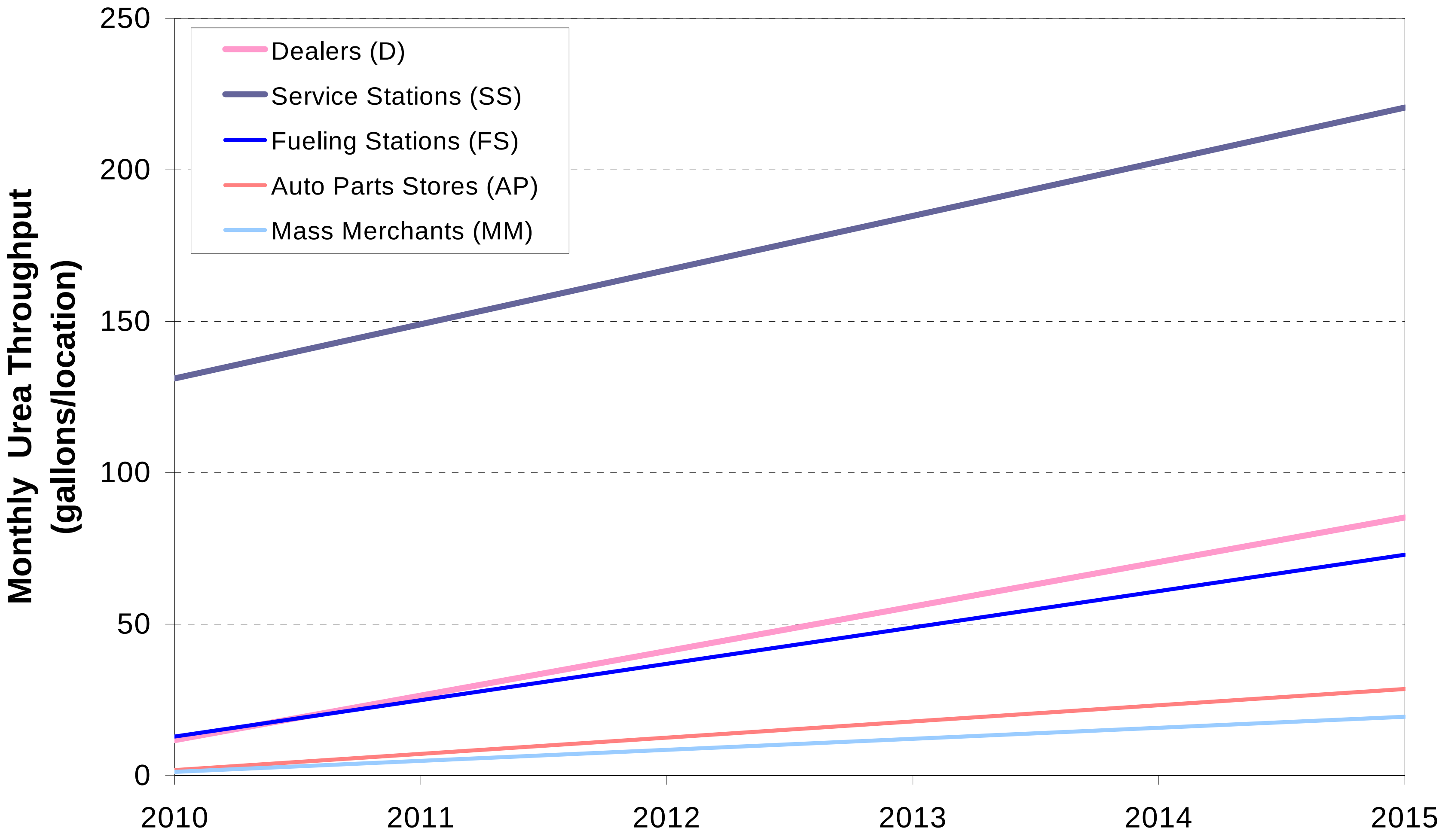
Light-duty Retail Location	Number of Locations		% of Urea Sales in LD Vehicles		Monthly Urea Throughput (gallons/location)			
					2010		2015	
	2010	2015	2010	2015	High	Low	High	Low
Dealers (D)	17,252	18,714	21.0%	31.0%	18	5	128	43
Service Stations (SS)	1,400	7,000	19.0%	30.0%	206	56	331	110
Fueling Stations (FS)	6,000	12,000	8.0%	17.0%	20	6	109	36
Auto Parts Stores (AP)	2,696	10,784	0.5%	6.0%	3	1	43	14
Mass Merchants (MM)	3,978	15,910	0.5%	6.0%	2	1	29	10

- **Number of Fueling Stations determined by Air Improvement Resource Inc. Study that identified needed stations to provide coverage within 20 miles to a high percent of the U.S. population, the remaining retail locations were determined during the AAM study**

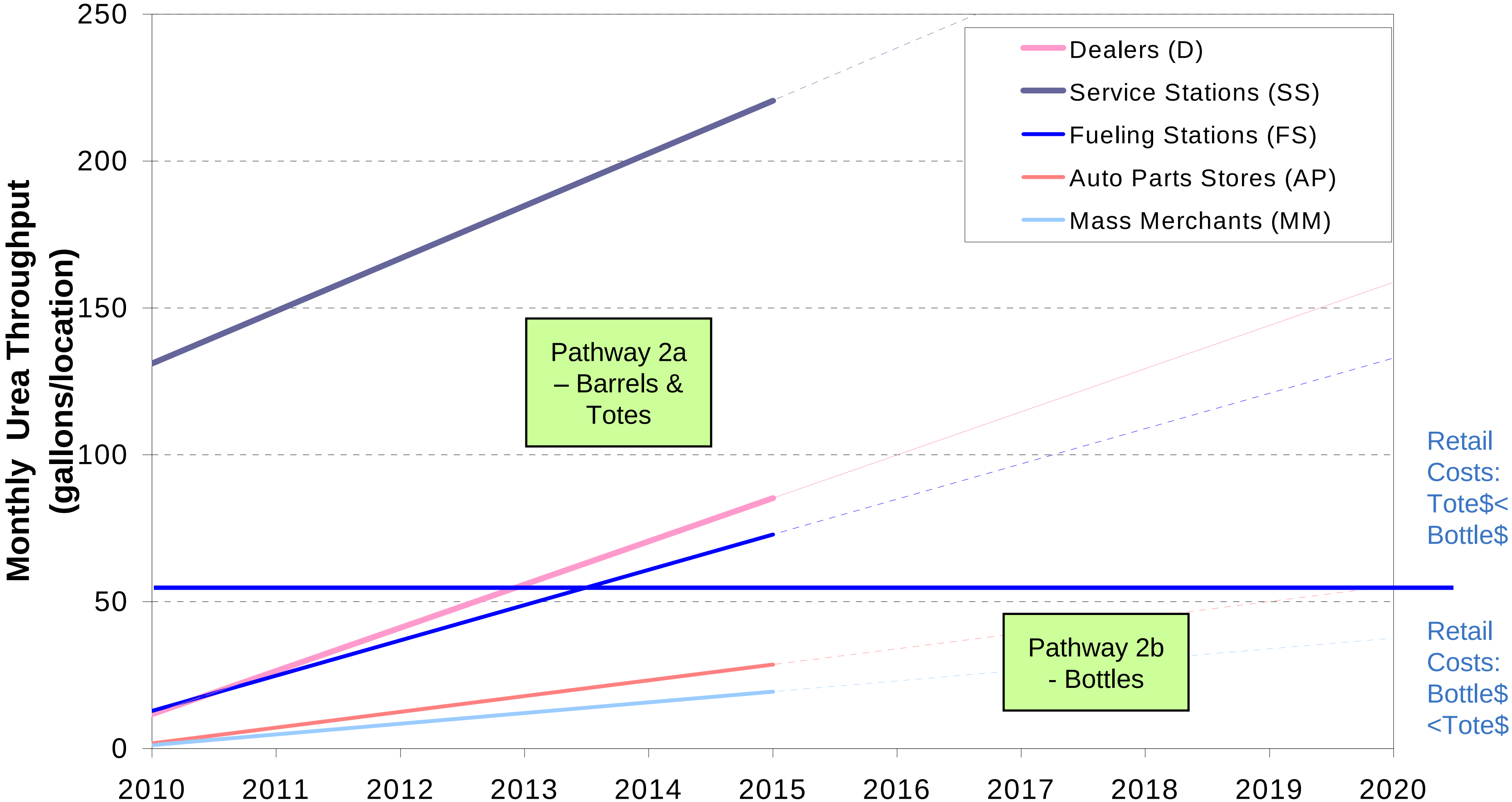
- **Remaining percentage of urea sales in LDD is through the vehicle original equipment manufacturers (OEMs): 51% in 2010, 10% in 2015**

Sources: AAM Study 2004, Air Improvement Res. Inc. Study 2005

The average monthly urea throughput for the retail locations is dependant on the assumed number of distribution locations



Assuming continued linear throughput growth through the year 2020, distribution strategies are identified for the light-duty retail sites

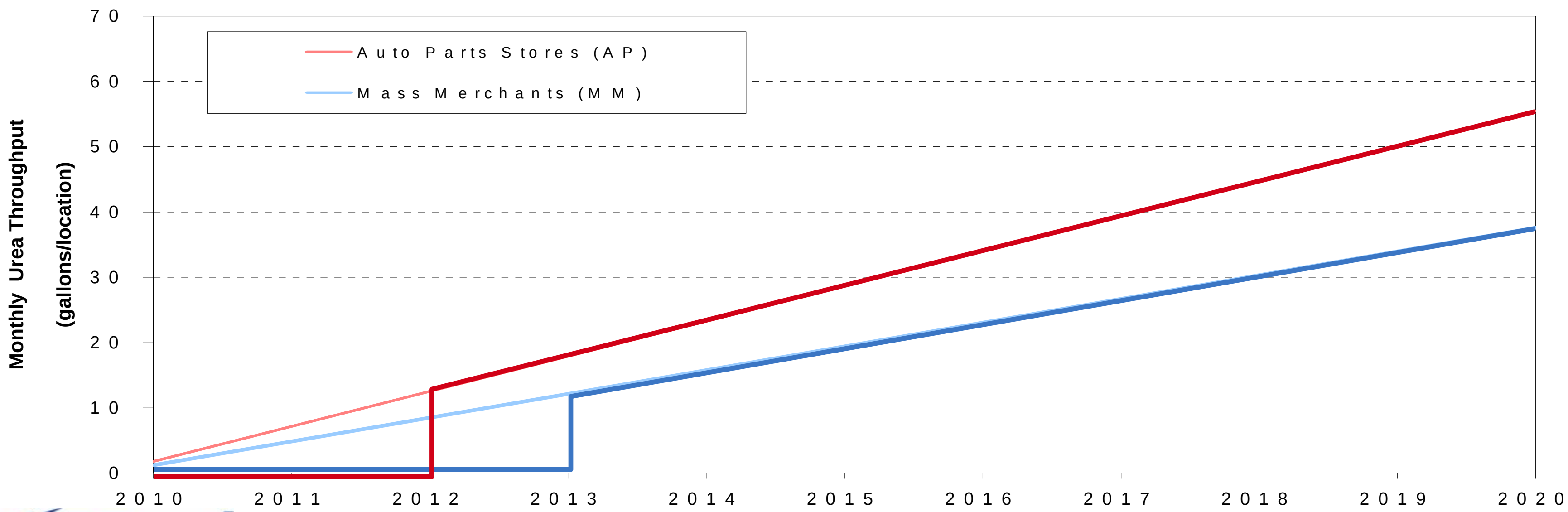


The light-duty retail locations are assumed to employ the lowest cost distribution strategy for that group

- Dealers would be the first to have urea in order to prepare and service the vehicles they sell
  - Bottles will be used at first with dealers transitioning to barrels or totes in the 2013 timeframe
- Chain service stations (e.g., Jiffy Lube) would react to market and compete for the oil change services to the new diesel vehicle
  - Barrels and totes are most economical for these locations given the higher throughput
- Light-duty fueling stations will need to sell urea in order to provide the infrastructure coverage to the U.S. population that may be required by EPA
  - There is not a good case for the market to support the large number of these locations and retailers will likely need to be subsidized in some way
  - Bottles would be used at first, transitioning to barrels or totes in the 2013 timeframe

The light-duty retail locations that supply only bottles will have slightly different throughput profile

- Auto part stores (e.g., Napa) and mass merchants (e.g., Wal-Mart) will stock bottles to fill customer demand as they do with other auto. fluids
  - Bottles will be used at all throughput levels because of the DIY market segment that is being supplied (i.e., people filling up on their own)
  - There will likely be minimum inventory turns that are required for this channel before these retailers stock the bottles, so the chart will likely have a step function in the 2012 – 2013 timeframe



Using average throughput numbers for similar retail sites we identified the number of retail outlets by distribution type in 2010

Heavy-duty Station Size Designation	Number of Stations	% of Urea Sales in HD Vehicles
XXL	310	17%
XL	1,128	44%
L	515	11%
ML	262	2%
M	2,436	14%
MS	1,115	4%
S	2,491	4%
XS	24,251	4%

Light-duty Retail Location	Number of Retail Sites	% of Urea Sales in LD Vehicles
Dealers (D)	17,252	21%
Service Stations (SS)	1,400	19%
Fueling Stations (FS)	6,000	8%
Auto Parts Stores (AP)	2,696	1%
Mass Merchants (MM)	3,978	1%

Urea Throughput (gal/month)	2010			
	Bottles	Barrels & Totes	Stillages	Tanks
10,000 - 5,000				
5,000 - 2,500				310 XXL
2,500 - 1,000				1,128 XL
1,000 - 500				515 L
500 - 250			262 ML	
250 - 100		1,400 SS	2,436 M	
< 100	17,252 D 6,000 FS 2,696 AP 3,978 MM	1,115 MS 2,491 S		
Total Retail Sites	29,926	5,006	2,698	1,953

- **24,251 XS Heavy-duty fueling stations are not categorized because urea distribution at 6,000 public fueling stations give coverage within 20 miles to >80% of US population***

**Source: Air Improvement Res. Inc. Study 2005*

In most cases, infrastructure decisions made for 2010 urea volumes allow for the increased throughput projected in 2015

Heavy-duty Station Size Designation	Number of Stations	% of Urea Sales in HD Vehicles
XXL	310	17%
XL	1,128	44%
L	515	11%
ML	262	2%
M	2,436	14%
MS	1,115	4%
S	2,491	4%
XS	24,251	4%

Light-duty Retail Designation	Number of Retail Sites	% of Urea Sales in LD Vehicles
Dealers (D)	18,714	31%
Service Stations (SS)	7,000	30%
Fueling Stations (FS)	12,000	17%
Auto Parts Stores (AP)	10,784	6%
Mass Merchants (MM)	15,910	6%

Urea Throughput (gal/month)	2015			
	Bottles	Barrels & Totes	Stillages	Tanks
10,000 - 5,000				310 XXL 1,128 XL
5,000 - 2,500				515 L
2,500 - 1,000			2,436 M	262 ML
1,000 - 500			1,115 MS	
500 - 250		2,491 S		
250 - 100		7,000 SS		
< 100	10,784 AP 15,910 MM	18,714 D 12,000 FS		
Total Retail Sites	26,694	40,205	3,551	2,215

- **24,251 XS Heavy-duty fueling stations are not categorized because urea distribution at 12,000 public fueling stations give coverage within 20 miles to >90% of U.S. population***

**Source: Air Improvement Res. Inc. Study 2005*

This analysis can also give an estimate to the overall distribution of urea for the two different scenarios:

- The urea volume designated for the XS HD fueling stations would be purchased in bottles from other retail locations

Year	Urea Scenario	Distribution of Urea (million gallons/year)				
		LD OEM	Bottles	Barrels & Totes	Stillages	Tanks
2010	Low	2.5	2.4	2.7	3.7	16.5
	High	9.3	7.4	7.1	7.4	32.9
2015	Low	3.1	10.1	29.9	28.2	115.9
	High	9.3	24.0	84.1	56.3	231.8

- The urea volume designated for the XS HD fueling stations would shift to larger HD fueling stations that carry urea in larger quantities and at lower cost

Year	Urea Scenario	Distribution of Urea (million gallons/year)				
		LD OEM	Bottles	Barrels & Totes	Stillages	Tanks
2010	Low	2.5	1.5	3.1	4.0	16.8
	High	9.3	5.5	7.7	8.0	33.6
2015	Low	3.1	3.7	32.1	30.3	118.0
	High	9.3	11.1	88.4	60.6	236.1

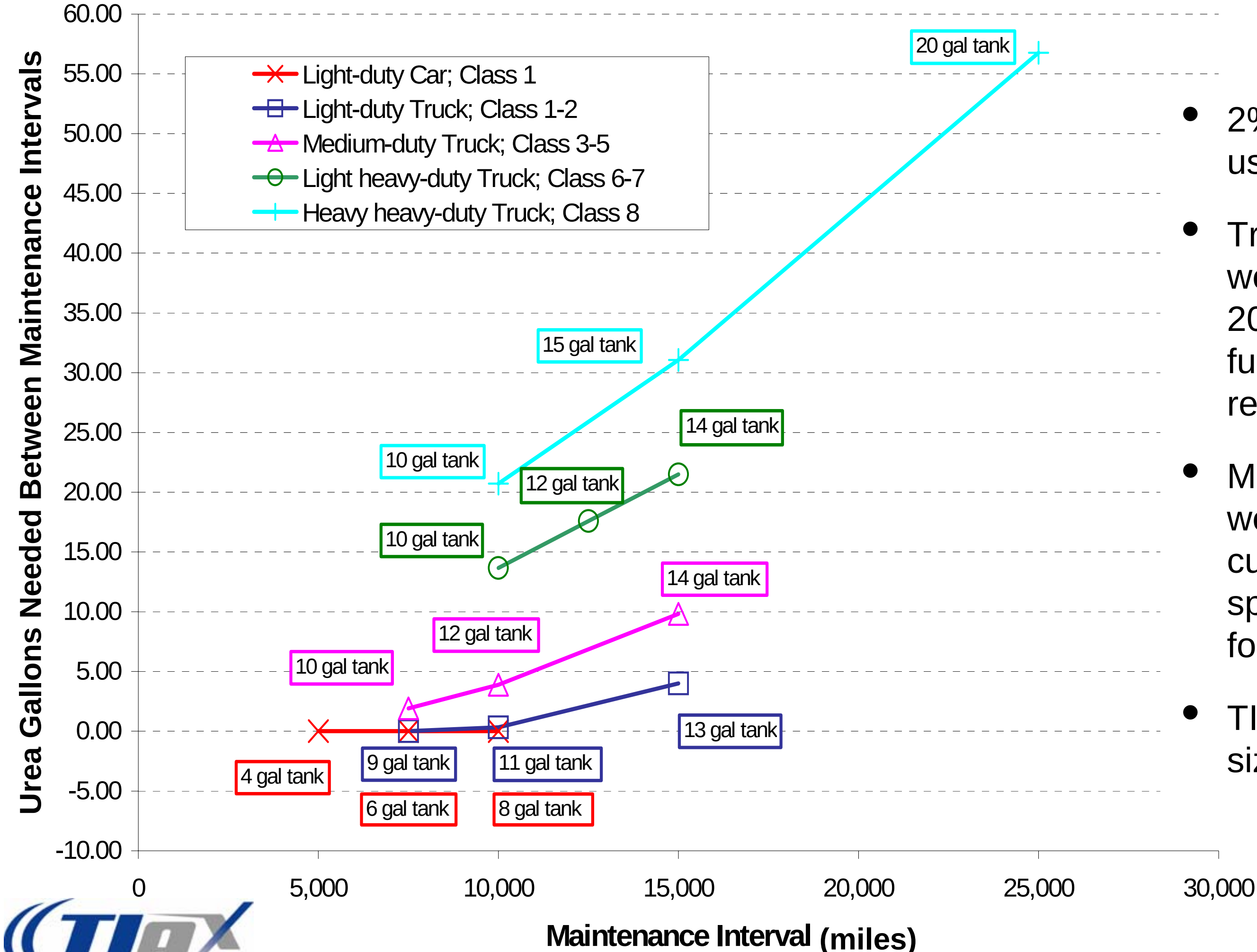
Two distinctly different distribution strategies were investigated for the heavy-duty and light-duty markets

- Heavy-duty urea distribution is assumed to follow diesel fuel
  - This results in the Pathway 1 for the majority of HDD fueling stations and a significant percentage of the overall on-road urea throughput
  - Urea tank size on the vehicles will have an effect on this assumption
- Light-duty urea distribution is assumed to correspond with regular maintenance, like oil change intervals
  - This results in the Pathway 2 for the majority of light-duty retail locations
  - Again, urea fill intervals will be dependent on the vehicle urea tank size
- Some overlap will occur in distribution strategies
  - HDD fueling stations could provide downward price pressure on the light-duty retail distribution
  - Light-duty retail locations would provide the HDD vehicles emergency urea infrastructure

In order to characterize some of the overlap that may occur between the distribution strategies, an analysis was completed to identify gallons of urea needed between maintenance intervals

- Fuel Economy (FE) for truck classes found using VIUS 2002 database, Light-duty car FE determined during AAM study
- Maintenance interval estimates found though internet searches of current North American diesel vehicle specifications
- “Reasonable” sized tanks were used for each class of vehicle and then marginally increased for those vehicles that have been specified as have longer maintenance intervals. The manufacturers have not yet determined urea tanks size for production vehicles.
- The urea tank range was determined based on the urea tank size, the class fuel economy and a 2% urea consumption ratio
- The urea tank range was then compared to the maintenance interval
  - If urea tank range > maintenance interval, no additional urea gallons needed
  - If urea tank range < maintenance interval, urea gallons needed determined by difference in miles / FE * urea consumption ratio

The analysis of urea gallons needed between maintenance intervals for the different vehicle classes shows some of the overlap between fueling-interval needs and maintenance-interval needs



- 2% consumption ratio is used for all cases
- Truck fuel economies were found through VIUS 2002 database, LDD car fuel economy from AAM report by TIAX
- Maintenance intervals were estimated based on current vehicle specification examples found on the internet
- TIAX estimated urea tank size on vehicle

Sources: AAM Study 2004, VIUS 2002

Operating costs for urea are found to be lower than fuel penalty costs associated with most alternatives for 2010 compliance

- Fuel economy and average miles were found using VIUS 2002
- 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 $

	Annual Fueling Cost Analysis											
	Light; Class 1-2			Medium; Class 3-5			Light-Heavy; Class 6-7			Heavy; Class 8		
	< 10,000 lb			10,001 - 19,500 lb			19,501 - 33,000 lb			> 33,000 lb		
	Local	Medium Range	Long Range	Local	Medium Range	Long Range	Local	Medium Range	Long Range	Local	Medium Range	Long Range
	< 200 miles	200 - 500 miles	> 500 miles	< 200 miles	201 - 500 miles	> 500 miles	< 200 miles	202 - 500 miles	> 500 miles	< 200 miles	203 - 500 miles	> 500 miles
Fuel Economy, mpg	17.64			12.59			8.45			6.51		
Average Miles/Yr	13,100	25,000	50,000	10,000	24,000	50,000	8,000	20,000	50,000	15,000	50,000	125,000
Urea Consumption %	1% - 2% (TIAX estimate)											
Average Urea Cost $/gal	$4.97 (Pathway 2 Average Price)						$1.99 (Pathway 1 Average Price)					
Ave. Diesel Cost $/gal	$1.82 - $2.94 (EIA projected price in 2010 vs. Today's price)											
5% FE Penalty $/year	$68 - $109	$129 - $208	$258 - $417	$72 - $117	$173 - $280	$361- $584	$86- $139	$215 - $348	$538 - $870	$210 - $339	$699- $1,129	$1,747- $2,821
Urea Cost $/year	$37 -$74	$70 - $141	$141 - $282	$39 -$79	$95 - $189	$197 - $395	$19 -$38	$47 - $94	$118 - $238	$46 -$92	$153 - $306	$382 - $764

Sources:, VIUS 2002, EIA AEO2006

1	Approach for the SCR-Urea Update
2	Task 1 – Update Urea Consumption Estimates
3	Task 2 – Update Truck Segmentation
4	Task 3 – Revise TIAX SCR-Urea Cost Model
5	Task 4 – Analyze Potential Business Cases
6	**Task 5 – Perform Critical Path Analysis**

TASK 5
Perform Critical Path Analysis

Inputs

Potential Business Cases: Task 4

Performa a critical path analysis to determine the "choke-points" in the potential feasible business cases identified in Task 4.

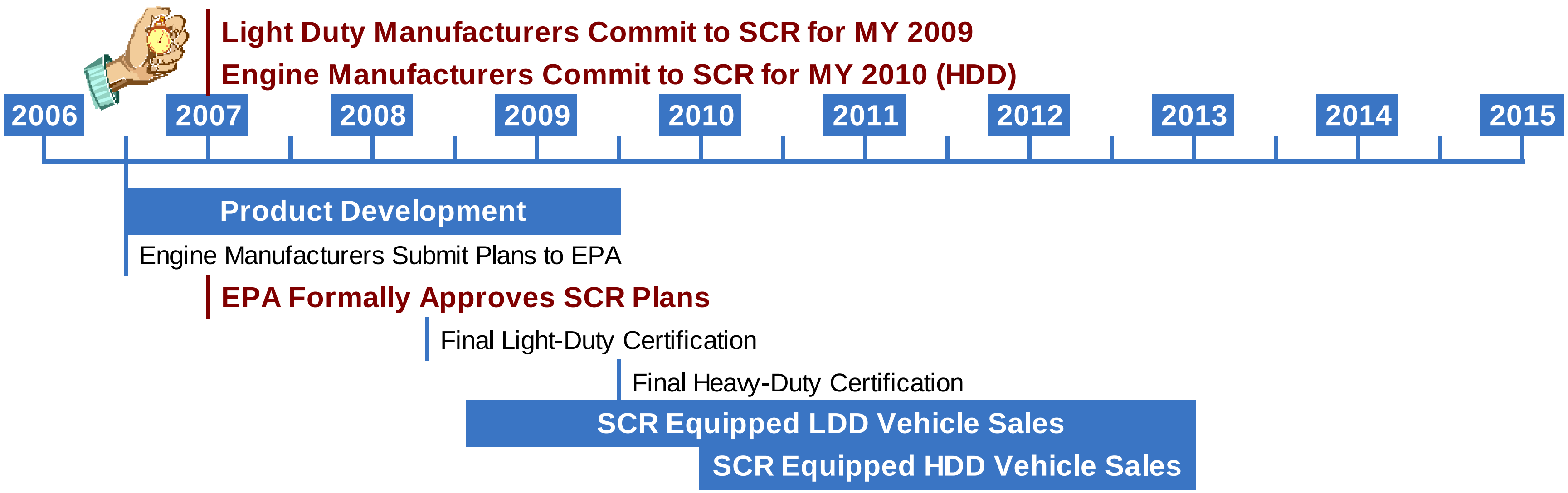
Interview key stakeholders (spot checks)

- Truck manufacturers
- Fueling station owners
- Potential urea distributors
- Urea manufacturers
- Engine manufacturers
- Potential urea bottlers
- Infrastructure construction companies

Outputs

- Critical Path charts and analysis for each feasible-cost infrastructure

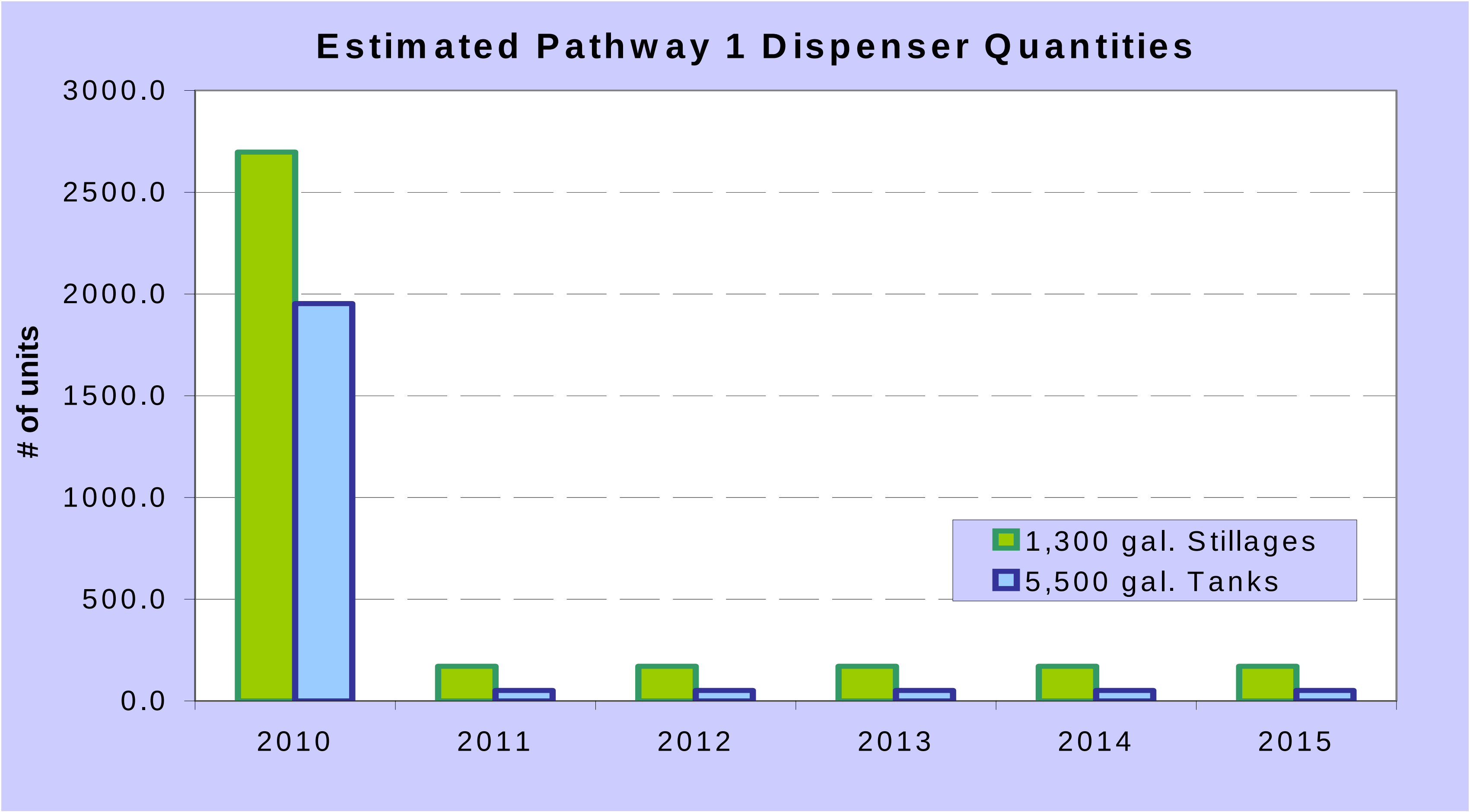
The regulatory timeline is a key component in the urea infrastructure critical path analysis



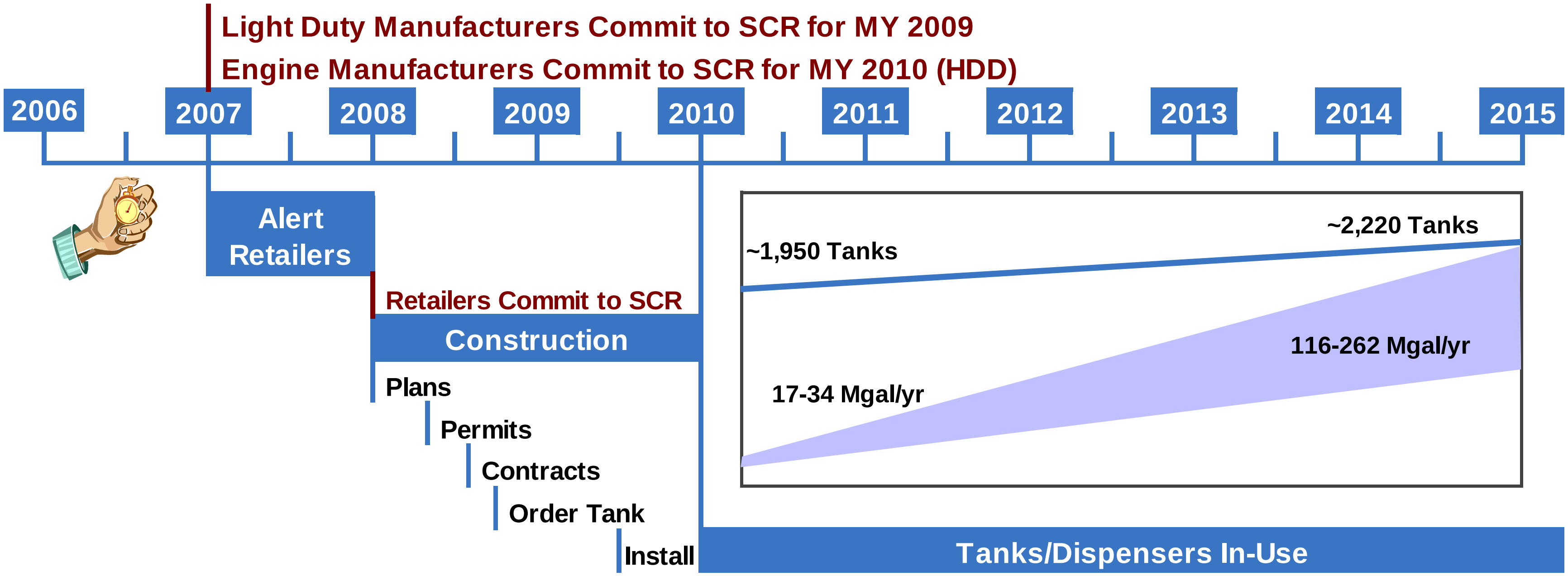
The original equipment manufacturers are working with U.S EPA to define urea-SCR certification requirements

- The first light-duty vehicles will be certified in 2 years
- Heavy-duty vehicles certified in 3 years
- Key issues include:
  - Urea retail infrastructure coverage
  - In-use compliance assurance
- Draft plans need to be submitted to EPA this year in order to provide sufficient vehicle development and manufacturing time
- The Engine Manufacturers Association and the Alliance of Automotive Manufacturers are helping facilitate the discussions

The analysis of average throughput gives estimates on the number of tanks and stillages that would be needed to support the estimated throughput



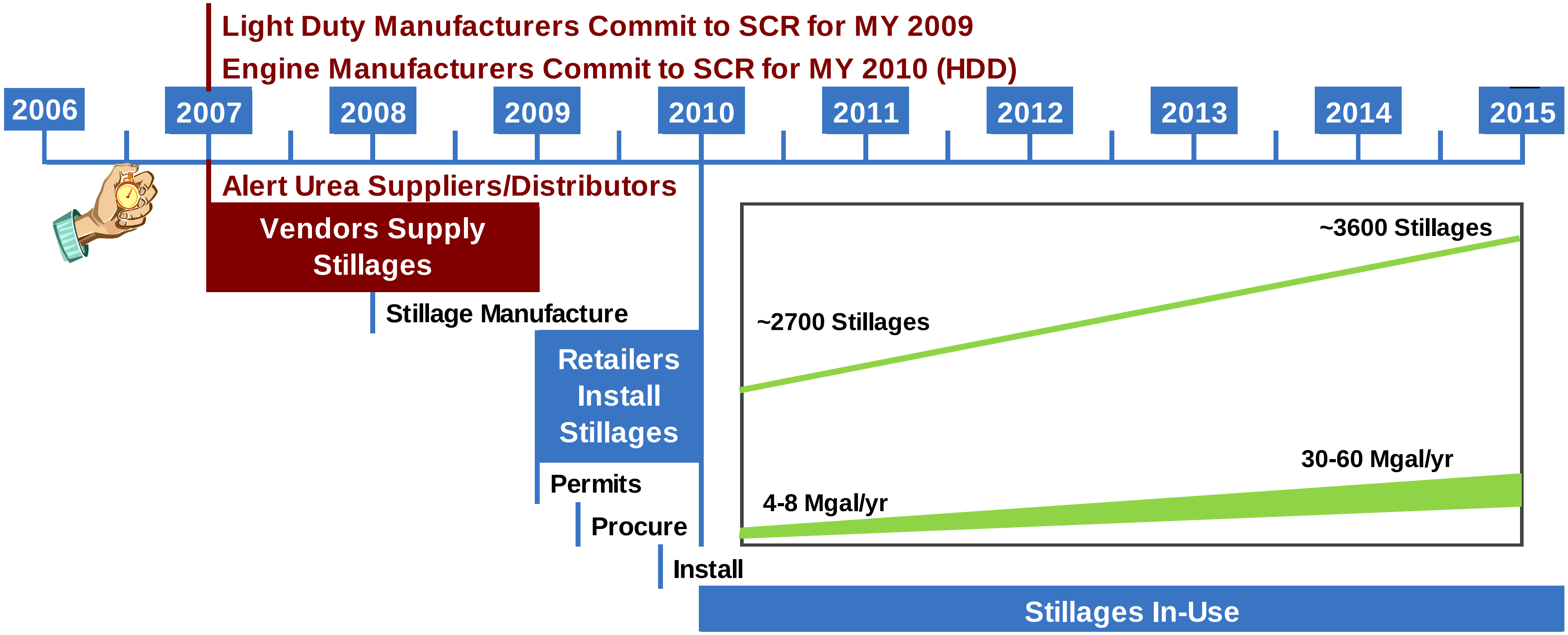
We estimate that nearly 2 years are required to install 1,950 tank/dispenser systems (Pathway 1A), therefore the construction process should begin Jan 2008



The critical path for distribution of urea through Pathway 1A (tanks) is the construction lead-time

- Notification to retail sites should begin in 2007
- Construction lead time includes design, permitting, procurement and contracting.
- Construction will occur through local contractors
- Fueling station contractors have experience in this level of construction
- Permits needed from local building/planning department
  - Not toxic, hazardous, or explosive
  - Containment to prevent soil contamination in the event of a spill
  - Permitting not a significant issue

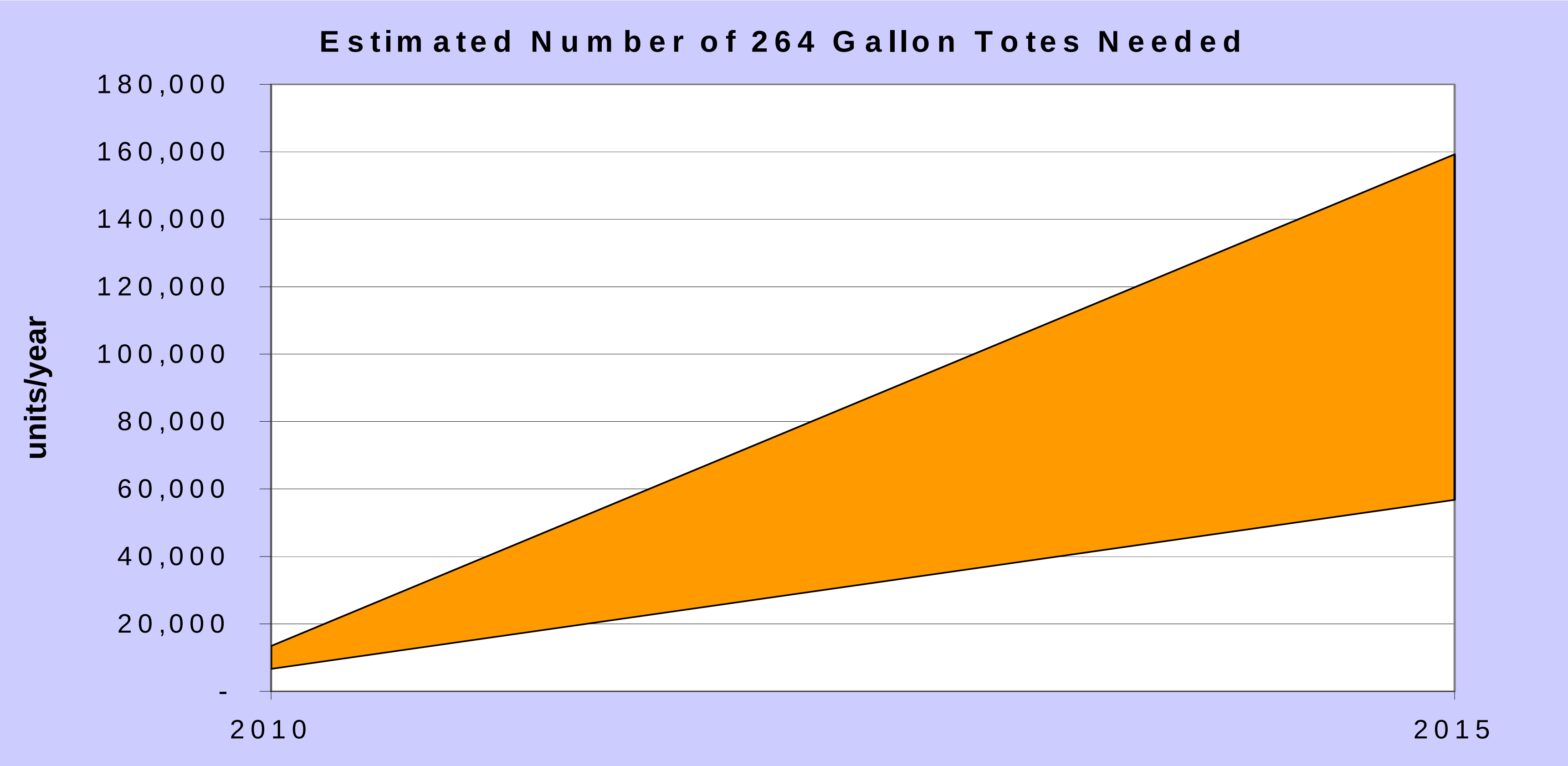
For stillages (Pathway 1B), we estimate 1 year for retailers to site and install 2,700 stillages by 2010



The critical path for Pathway 1B (stillages) is the design and manufacture of the stillages

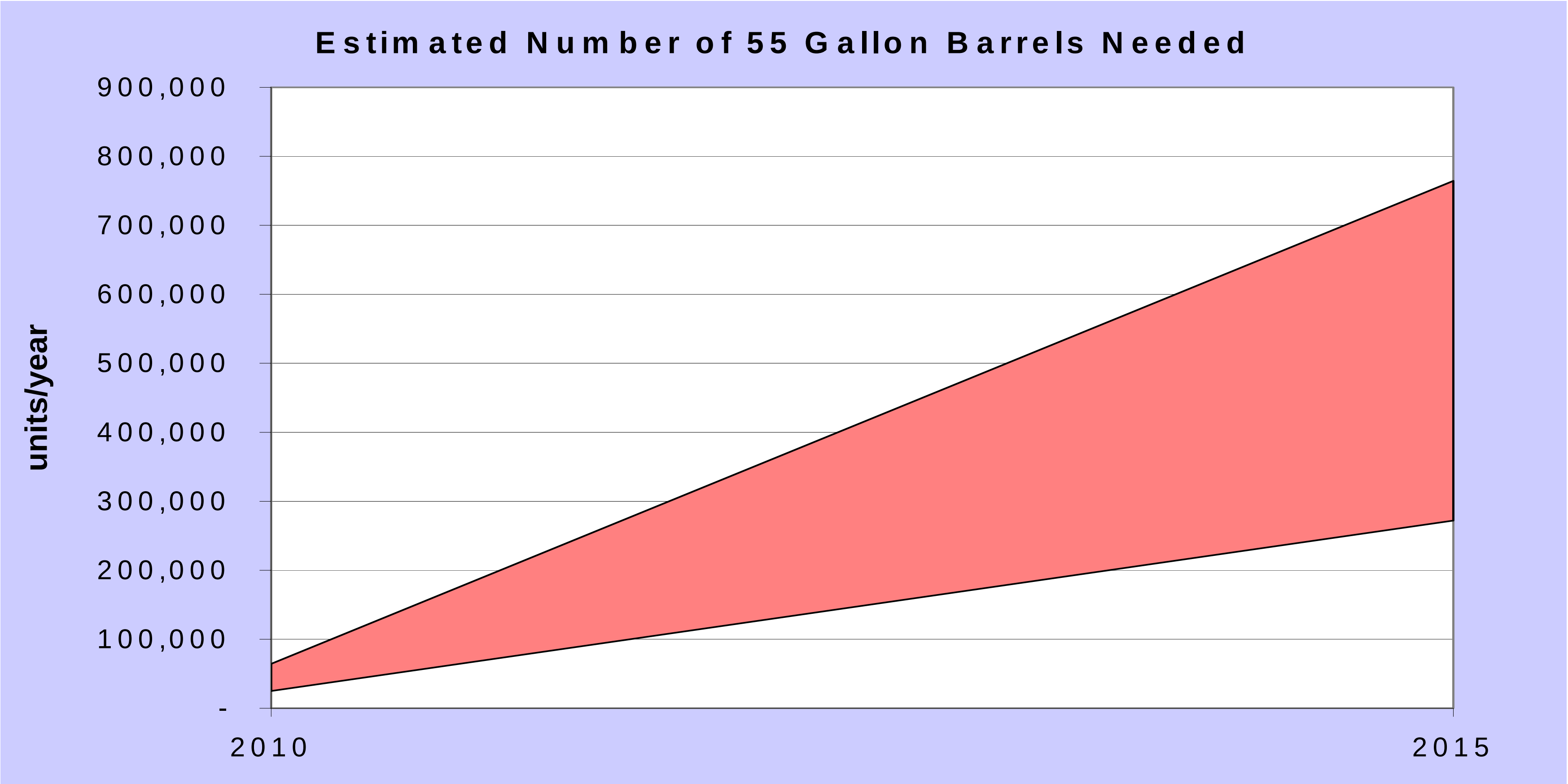
- Vendors will likely design/build stillages in the United States
- European vendors may offer their products in the United States
- Three European AdBlue vendors have supplied stillages to the European market
  - GreenChem distributes GreenStar stillages of various capacities
  - Dureal™ is a division of Univar N.V.
    - Dureal provides professional urea station stillages
    - Univar USA is a leading chemical distributor in the United States
  - Yara distributes urea through the Air1™ product name
    - Air1™ provides urea retail dispensing stillages
    - Yara North America is responsible for Hydros fertilizer in US

The number of totes is estimated by assuming a 50-50 split with barrels during pathway 2a and is a function of both urea throughput in the pathway and the number of retail locations. The range of units corresponds to the low and high urea consumption forecasts.

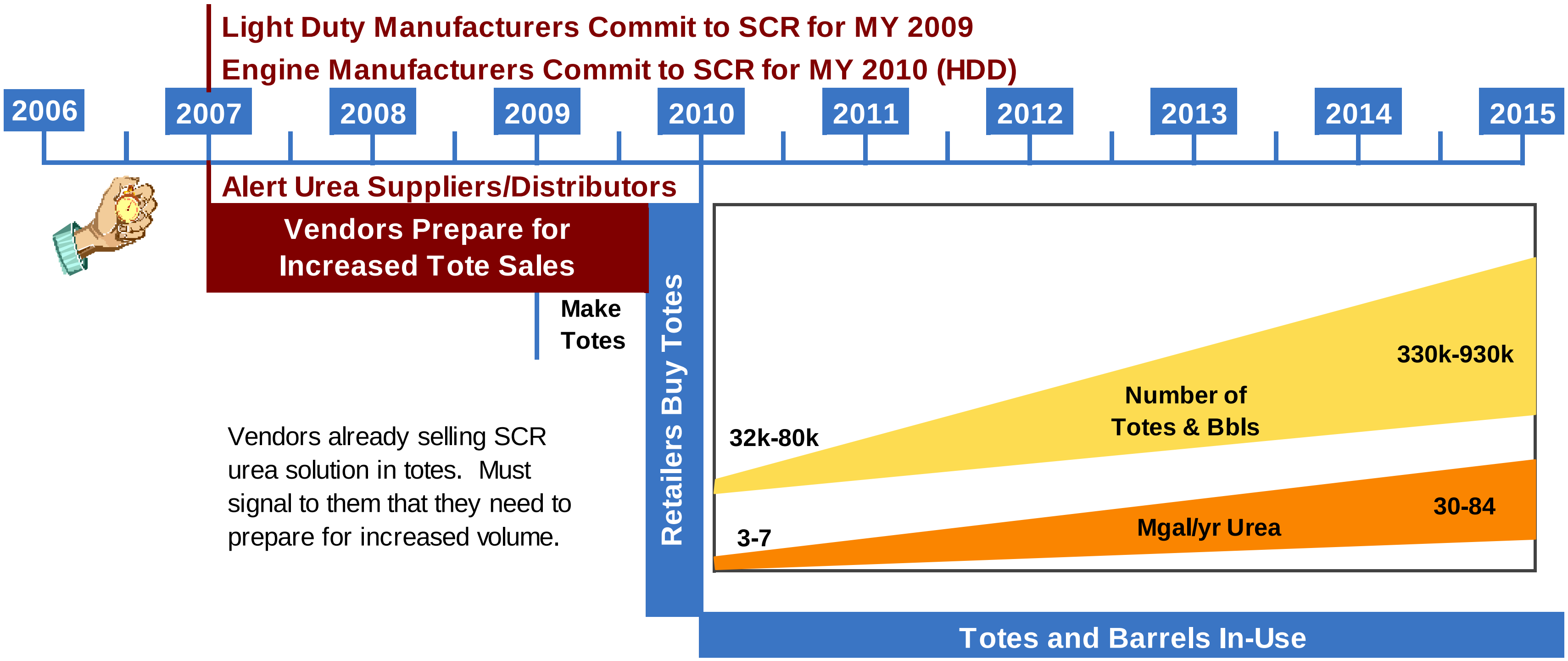


Note: 264 gallon (1000L) tote was used as estimate based on European experience, other sizes may be applicable to NA market

The number of barrels is estimated by assuming a 50-50 split with totes during pathway 2a and is a function of both urea throughput in the pathway and the number of retail locations. The range of units corresponds to the low and high urea consumption forecasts.



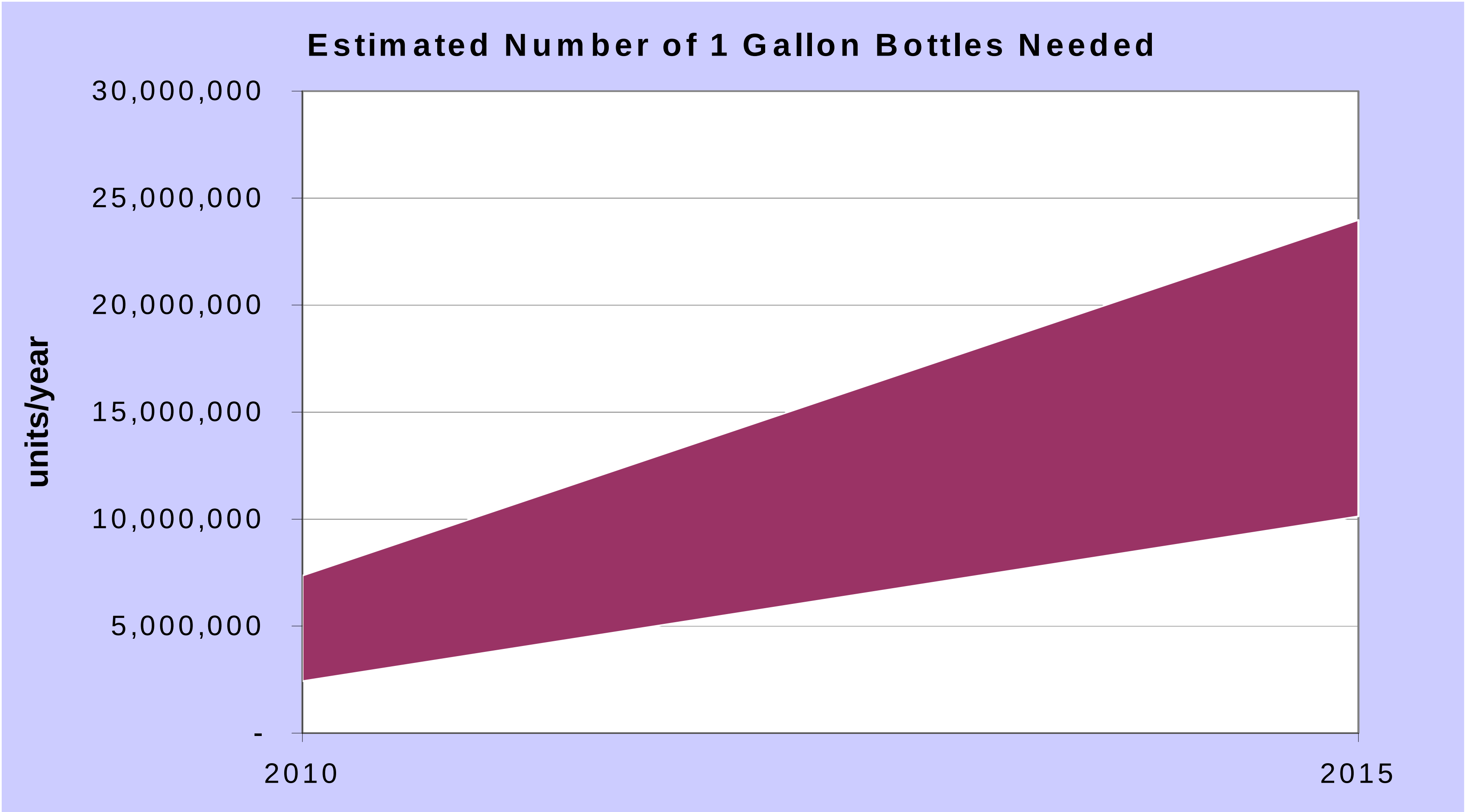
For Pathway 2A, vendors already sell urea solution in totes for stationary SCR use but will need to prepare for a significant jump in volume by 2010



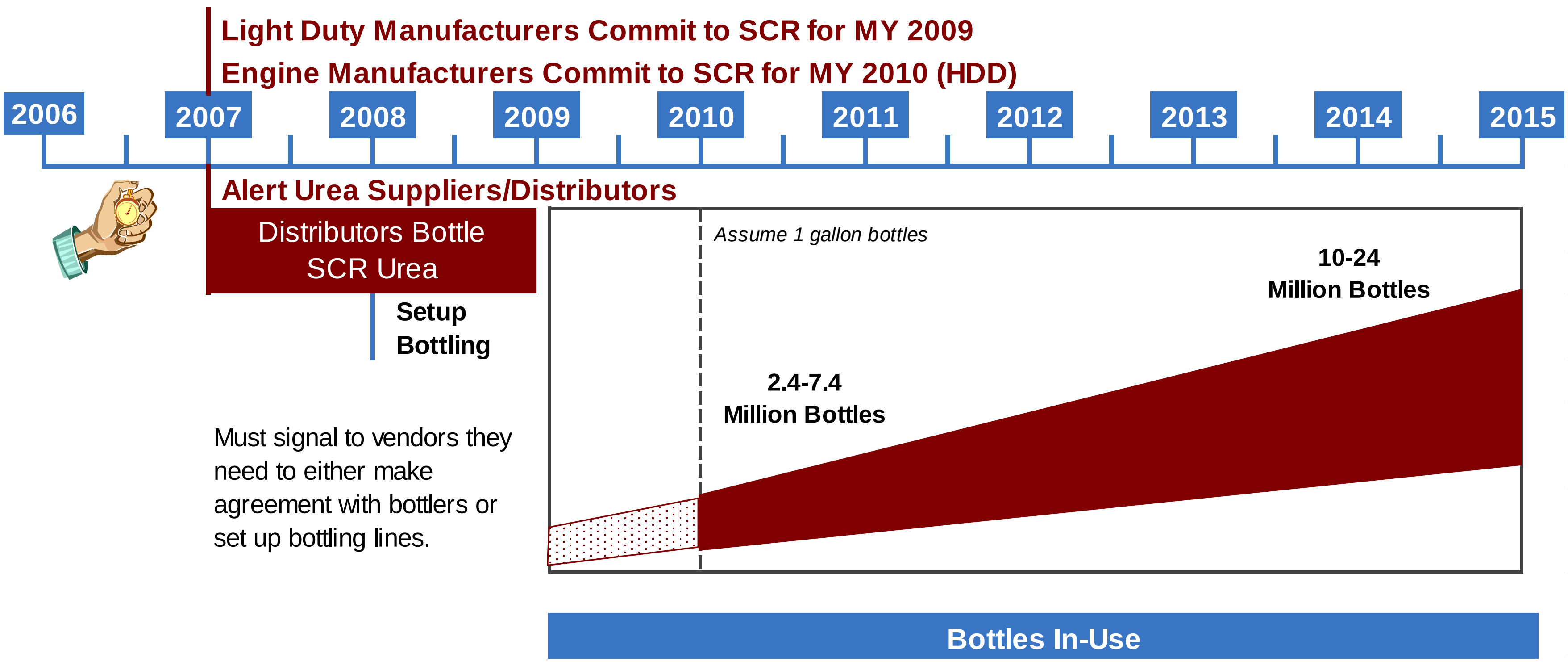
The critical path for Pathway 2A (totes and barrels) is the manufacture of the totes and barrels

- Current United States vendors will likely design/build totes and barrels.
  - Fleetguard provides StableGuard™ totes and barrels in 32.5% for stationary SCR applications
  - Terra Industries provides urea totes to the same DIN standard for stationary applications
- Tote manufacturer SpaceKraft currently supplies to Terra and others
- Three European AdBlue vendors have supplied totes to that market
  - GreenChem distributes GreenStar intermediate bulk containers (IBC)
  - Dureal™ provides IBCs and barrels
  - Yara distributes urea with the Air1™ IBCs

The estimated number bottles needed is a function of both urea throughput and the bottle size. The low and high urea consumption estimates provide the range within the year.



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



The critical path for Pathway 2B (bottles) is the distributors securing bottling production and distribution channels

- Current United States vendors that supply totes and barrels will likely provide bottled urea solutions because of their established infrastructure
  - Fleetguard and Terra Industries
  - Bottling lines exist today to handle projected 2015 volume*
- Initial bottles needed by LDD dealers could be provided, to start with, by a mature European industry, though this pathway is unlikely to be economically sustainable
- Three European AdBlue vendors have supplied bottles to the European market in various sizes
  - GreenChem distributes GreenStar Jerrycans in 5, 10, and 18L
  - Dureal™ provides 5L Jerrycan
  - Yara distributes urea with the Air1™ 10L can

* Conversation with Barry Lonsdale, Terra Industries, 4/17/06.

Sources: Terra Industries

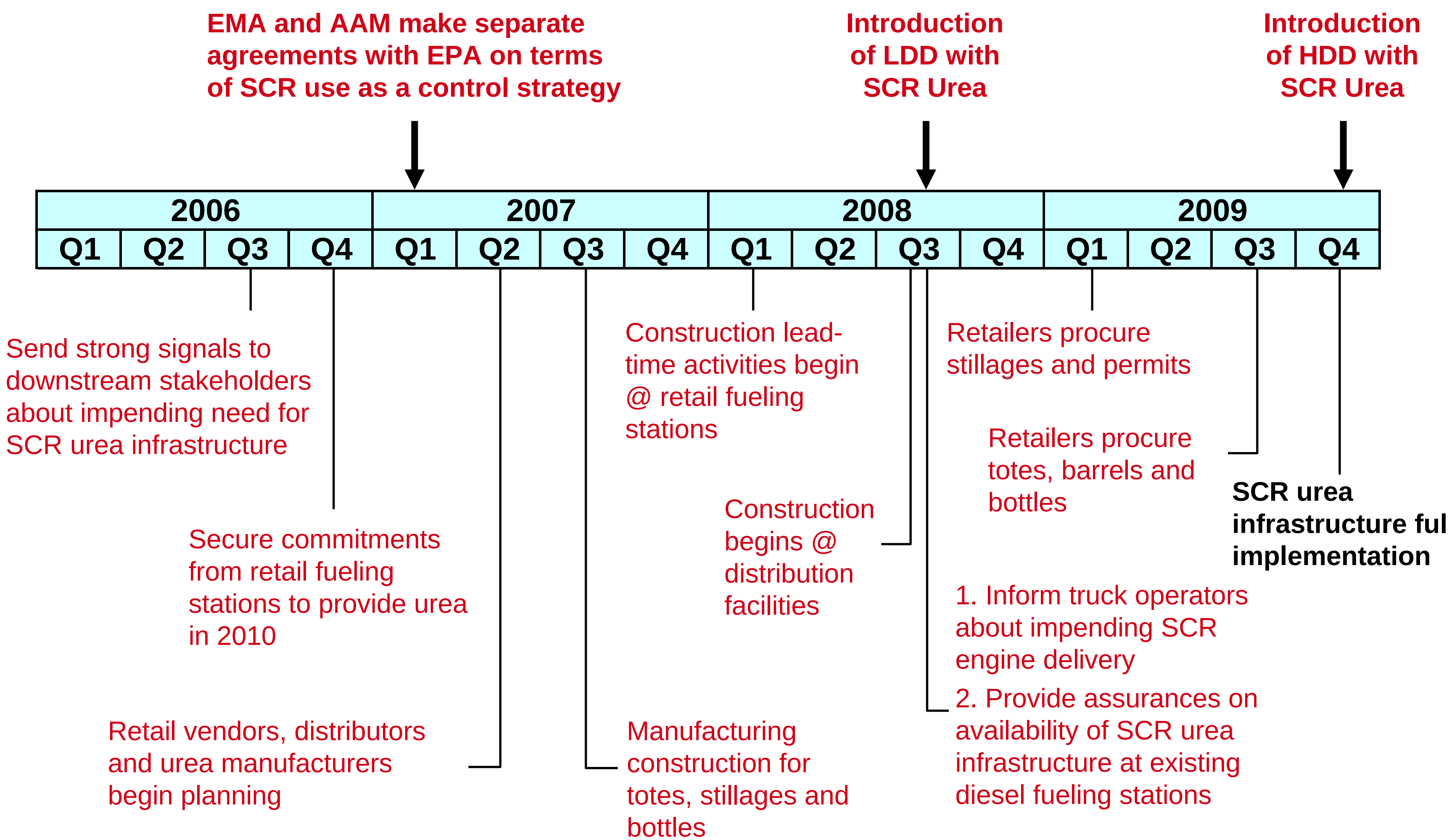
Summary of key issues for the major urea production and distribution stakeholders

Stakeholders	Systems Availability Issues	Construction Issues	Permit Issues	Signals & Business Planning Issues
Urea Manufacturers	Urea specification completed, no issues	No special issues	None	- Will require strong signals from distributor and retail level stakeholders - Timeline: minimum 1 year from planning to higher volume production
Urea Distributors (CDFs)	No special issues	- UST/AST installation - 0.5 years	Operating & construction permits 0.5 years	- Strong signals from truck operators and upwards such as engine manufacturers - Timeline: 1.5 - 2 years from planning to installation
Equipment & Systems Manufacturers	- Storage systems: no special issues - Dispensing system will be developed using European experience	- Manufacturing: 1 - 1.5 years lead time - Some dispensing units already being produced	None	- Strong signals from engine manufacturers, truck manufacturers, distributors and retailers - Development in the US will be accelerated by European experience Timeline: 1 - 1.5 years from planning through production

Summary of key issues for the major urea production and distribution stakeholders

Stakeholders	Systems Availability Issues	Construction Issues	Permit Issues	Signals & Business Planning Issues
Urea Retailers	- Tanks need to be defined and ordered - Expect turnkey dispensing systems/services - Totes & Barrels will need to be dispensed and picked up - Bottle distribution system needed	- Tank installation: 0.5 years - Power and space needed for stillages - Power and space needed for totes & barrels - Shelf space for bottles	- Tanks: operating & construction permits 0.25 years - Stillages: operating & construction permits 0.25 years None	- Strong signals required from truck operators and upstream from engine and truck manufacturers - Timeline: 1 - 1.5 years from planning to retail
Vehicle Operators	None	None	None	- Strong signals indicating impending sales of SCR-equipped vehicles - Assurances from manufacturers regarding the availability of SCR-urea and an easy-access refueling infrastructure - Truck operators will likely be catalyst in ensuring a urea distribution network by demanding urea from existing diesel refuelers

Milestones along the path to an on-road SCR-urea infrastructure



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- EMA SCR-urea committee members
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- Mr. Jerry Kroon, Agrium
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- Ms. Linda Van Arsdale, NATSO Foundation
- Mr. Luis Cervantes, CDI distributors
- Mr. Ken Nyiri, CRU Group
- Dr. Adam Schubert, BP
- Dr. Simon Godwin, Daimler Chrysler
- Dr. Joseph Kubsh, MECA
- Mr. Jeff Herzog, US EPA
- Mr. Don Kopinski, US EPA
- Mr. Charles McLaughlin, Cal. EPA

The following acronyms are used throughout the report

- AAM – Alliance of Automotive Manufacturers
- AST – Above-ground Storage Tank
- ATA – American Trucking Association
- BACT – Best Available Control Technology
- CAIR – Clean Air Interstate Rule
- CDF – Central Distribution Facility
- CE – Currency Equivalent
- CFN – Commercial Fueling Network
- CFR – Code of Federal Regulations
- DIN – Deutsches Institut for Normung
- DIFM – Do-it-for-me
- DIY – Do-it-yourself
- DOT – Department of Transportation
- DPF – Diesel Particulate Filter
- EIA – US Energy Information Administration
- EGR– Exhaust Gas Recirculation
- EMA – Engine Manufacturers Association
- EPA – US Environmental Protection Agency
- FE – Fuel Economy
- FOB – Free On Board, delivered price
- HDD – Heavy Duty Diesel
- IBC – Intermediate Bulk Container
- LDD – Light Duty Diesel
- LTL – Less-than Truck Load
- MMBtu – Million British Thermal Unit
- MMgal – Million gallons
- MSDS – Material Safety Data Sheets
- MY – Model Year
- NATSO – National Assoc. of Truck Stop Operators
- NG – Natural Gas
- NOx – Oxides of Nitrogen
- NMHC – Non-Methane Hydrocarbons
- NSR – New Source Review
- OSHA – Occupational Safety and Health Administration
- PM – Particulate Matter
- SCR – Selective Catalytic Reduction
- SNCR – Selective Non-Catalytic Reduction
- SIP – State Implementation Plan
- TL – Truck Load
- TPY – Tons Per Year
- TS&D – Transportation Storage and Distribution
- UST – Underground Storage Tank
- VIUS – Vehicle Inventory and Use Survey
- VMT – Vehicle Miles Traveled