Nonroad SCR-Urea Study Final Report

Engine Manufacturers Association

July 29, 2007

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Reference:D.5535

A	Approach for the SCR-Urea Nonroad Study
1	Task 1 – Nonroad Population and Fueling Habits
2	Task 2 – Project NR Urea Consumption 2014-2018
3	Task 3 – Identify Urea Distribution Pathways
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Having completed studies on the viability of a self-sustaining urea infrastructure for on-road diesel vehicles, the Engine Manufacturers Association (EMA*) and TIAX, LLC (TIAX) work to identify a complimentary infrastructure for nonroad diesel equipment

- Evolution from on-road urea infrastructure likely dependent on the fueling and maintenance habits of nonroad HD diesel equipment
  - Needed to identify the effects of bringing the fuel to the vehicle, rather than the vehicle to the fuel
  - Fuel consumption rates needed to be identified for equipment type, size and market segment
- Annual sales estimate of SCR-urea equipped engines required to determine urea consumption levels
  - Sales projections of equipment less available than for on-road vehicles
  - Engine and equipment sales much more fragmented, making estimates of existing sales difficult to generally analyze
- Impact analysis to previously identified on-road urea infrastructure needed
  - Overall demand increase due to nonroad equipment was unknown
  - Overlap between infrastructures and distribution points identification needed

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

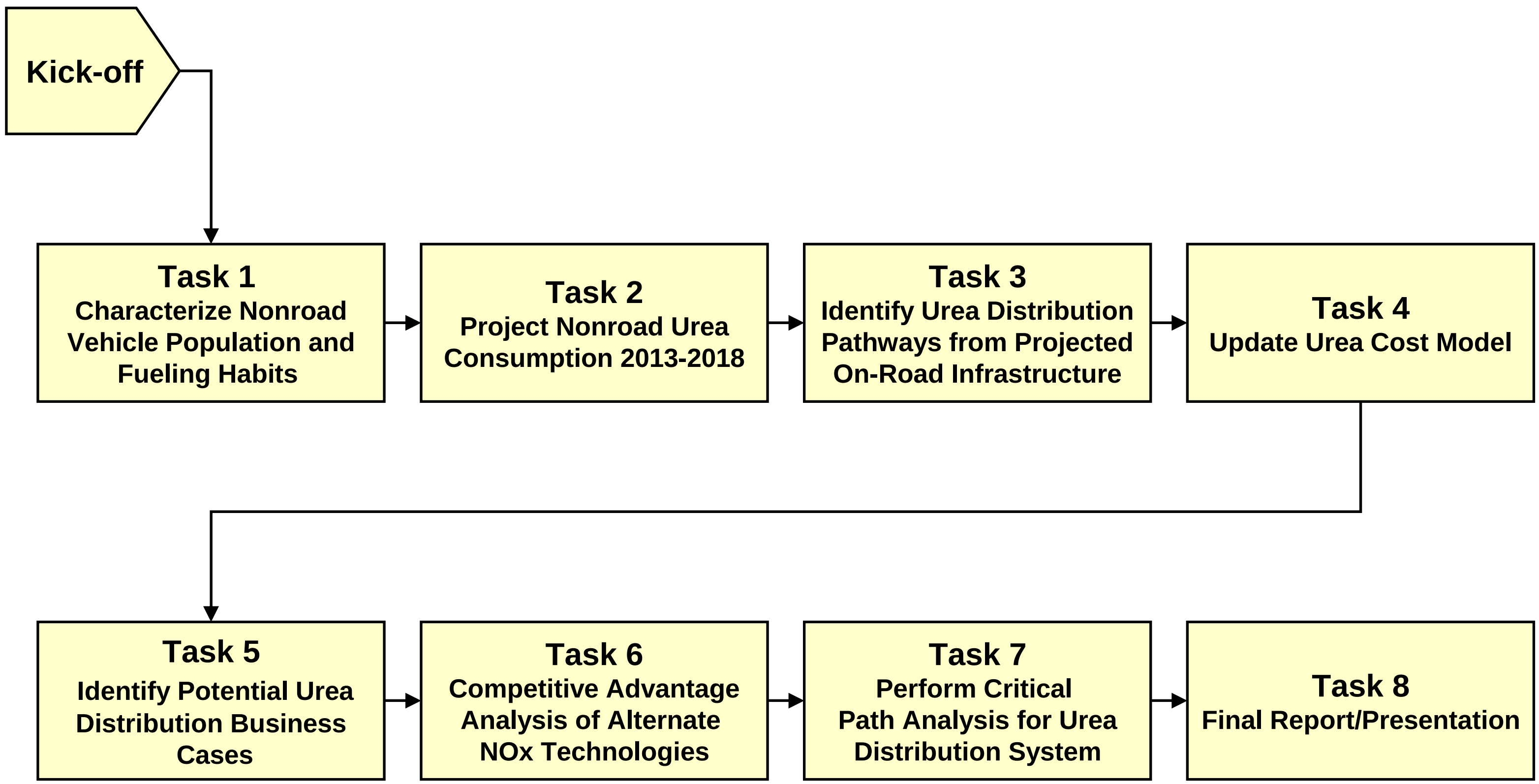
TIAX's previous studies on the feasibility of an SCR-urea infrastructure are used as a starting point for this analysis, and it is assumed that the on-road infrastructure developed in these reports will be complimented by a nonroad SCR-urea infrastructure

- "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)
- "SCR-Urea Implementation Strategies Update," June, 2006 for the Engine Manufacturers Association (EMA Study 2006)

Approach for Nonroad SCR-Urea Study

Work Breakdown Structure

Tasks



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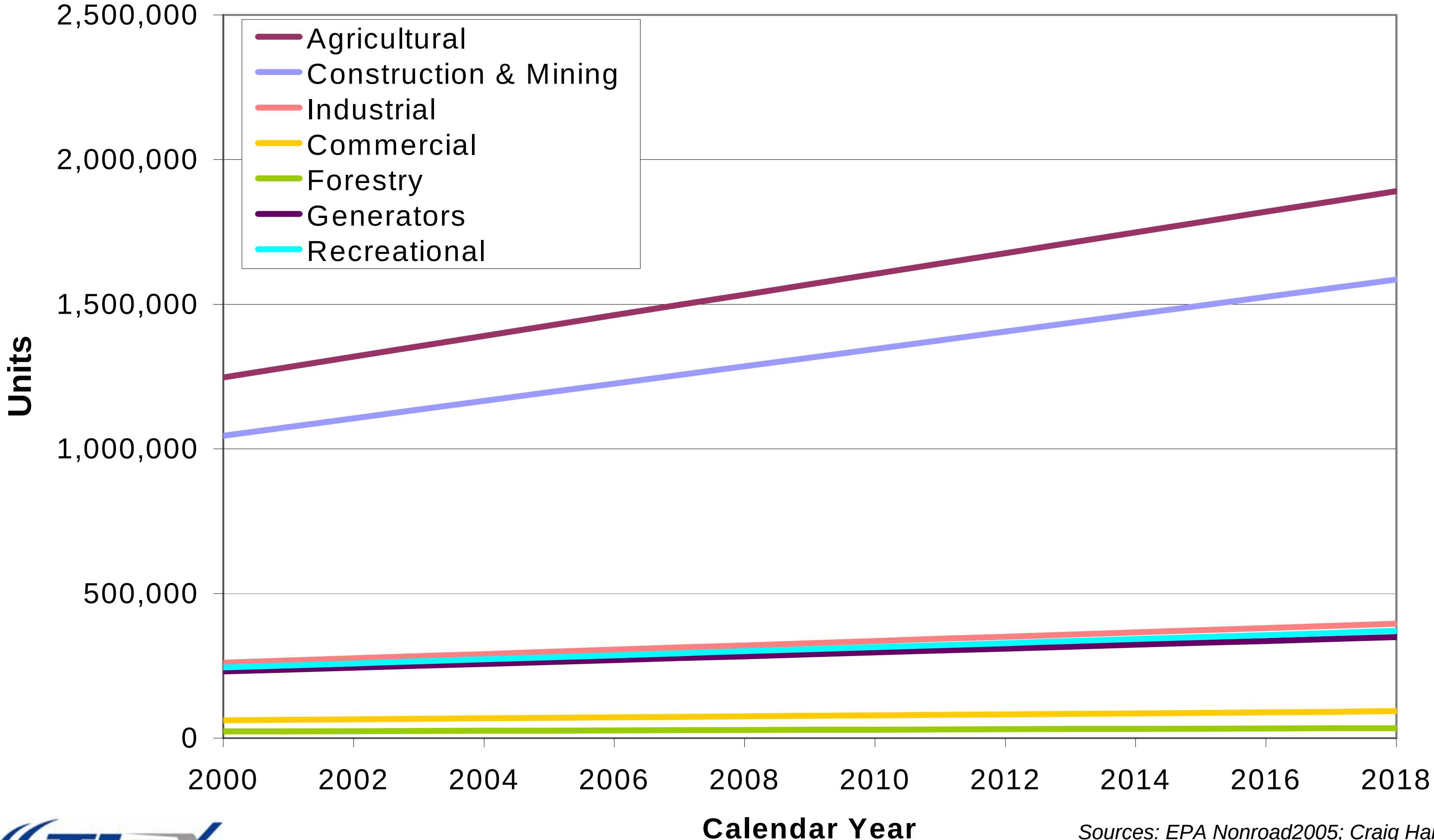
TIAX utilized EPA's modeled population of diesel equipment 75-750 hp and employed a segmentation to align with fueling practices.



Sources: EPA Nonroad2005; Craig Harvey, EPA

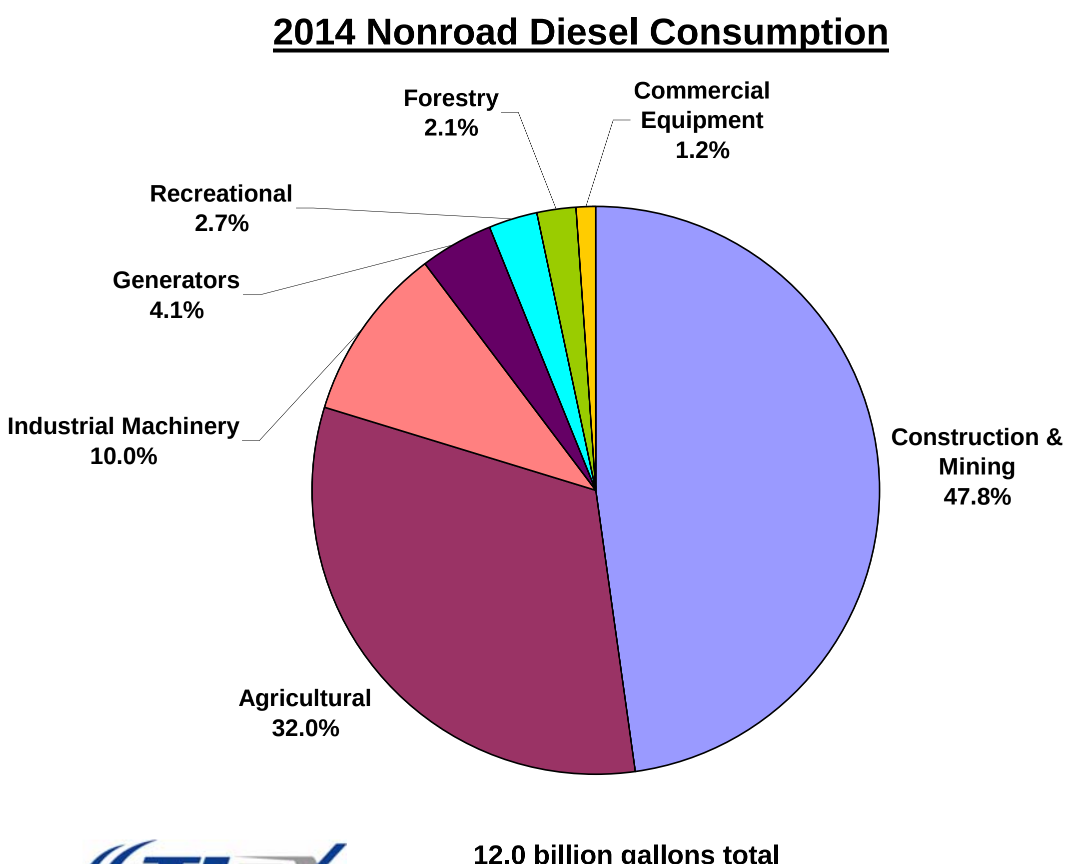
EPA's model also provided the population breakdown, average load factors, and the average annual hours of use for each equipment type

- NONROAD2005's technical documents provided equipment population in 2000
  - Population was segmented into 75-100 hp, 100-175 hp, 175-300 hp, 300-600 hp, and 600-750 hp
  - The percentage of equipment by hp bins was held constant over time in predicting future equipment populations
- Activity levels were identified using NONROAD2005
  - Annual hours were defined for each of the equipment type and horsepower bins, though activity level typically equivalent for each horsepower level, changing by equipment type only
  - Annual hours were identified in the technical documents for the year 2000 and these factors were held constant over time
- Load factors were identified using the NONROAD2005 technical documents
  - Load factor is the average amount of power used during operation over the rated power of the piece of equipment i.e., 100 hp average power from a 200 hp tractor = 0.5 load factor
  - Load factors for each of the equipment type and horsepower bins were identified, but again the factors are equivalent for each horsepower level, changing by equipment type only
- Brake specific fuel consumption factor also identified in HP bins
- Stationary prime generators are assumed to have the same activity level, load factor, and brake specific fuel consumption factor as mobile generators

Sources: EPA Nonroad2005; Craig Harvey, EPA

Using EPA's modeling guidelines, TIAX identified the nonroad diesel consumption distribution

- This results in diesel consumption volumes that are highly dependant on the equipment population and does not take into account efficiency gains



- In reality, efficiency gains are made in the equipment's powertrain, in applying more horsepower to a given task, and in work practices
- Work habit efficiency advancements in some sectors, like agriculture, are well documented but are not included in EPA's fuel consumption model
- Effect of a leveling off of diesel consumption in the agriculture sector would be 11% on overall urea consumption, which is within the range of our high and low urea consumption cases
- Therefore, we use EPA's modeled diesel consumption values to define our high consumption case

Sources: EPA Nonroad2005; Craig Harvey, EPA, ARB's Offroad Model

Fueling and maintenance practices were investigated for each market segment in order to identify the most likely urea distribution point

- Common Practices of Construction Equipment
  - Equipment is fueled once per day
  - Fluids (lube oil, hydraulic, coolant etc) are topped off when equipment is fueled
  - Wet hosing (fueling from mobile fueler) rather than fueling from storage tank is most common
  - On-site tanks not commonly used -- subject to vandalism and present a spill risk
  - Routine maintenance done on 200 hour intervals at construction site or in shop depending on where equipment is at time of service
  - Rental Companies
    - Leasee is responsible for fuel and sometimes fluids
    - Leasor performs routine maintenance (200 hr interval) and repairs
- Mining Operations Common Practices
  - Primarily open pit mining
  - Fuel is purchased directly from oil companies and delivered to on-site storage tanks
  - Owned fuel trucks wet hose mining equipment and top off fluids in the field
  - May place temporary skid mounted 10,000 gal fuel tanks in more remote areas of the mine
  - Routine maintenance and repairs are performed in-house

Fueling and maintenance practices characterization (continued)

- Common Practices of Agricultural Equipment
  - Have on-site diesel storage
  - Fuel delivered to on-site storage tanks (smart tanks, on demand, or fixed schedule)
  - Farmer’s fuel/lube truck wet hoses equipment and tops off fluids
  - Routine maintenance performed in-house
  - Ag Supply Co-op (diesel wholesaler) supplies fluids and sometimes fuel
- Industrial Machinery
  - Practices vary between the vocations, but on-site storage is typical throughout
  - Fuel delivered to on-site storage tanks (smart tanks, on demand, or fixed schedule)
    - Tank sizes vary greatly, somewhat proportional to fleet size
      - 100-250 gallon tank typical for Air compressors, pumps, welders
      - 10,000 - 20,000 gallon tanks for Airport GSE, Railway equipment
  - Owner/operator fuels, tops off fluids and performs routine maintenance/repairs
- Electric Power Generators
  - Mobile and prime stationary generators typically used in Construction, Mining, and Forestry or Industrial applications (oil fields)
  - Fueling practices tend to mirror the diesel equipment in the same vocation
    - Construction, Mining and Forestry generators would tend to be wet hosed
    - Industrial applications would tend to have on site fuel storage or separate tanks
  - Fluids topped off by owner/operator

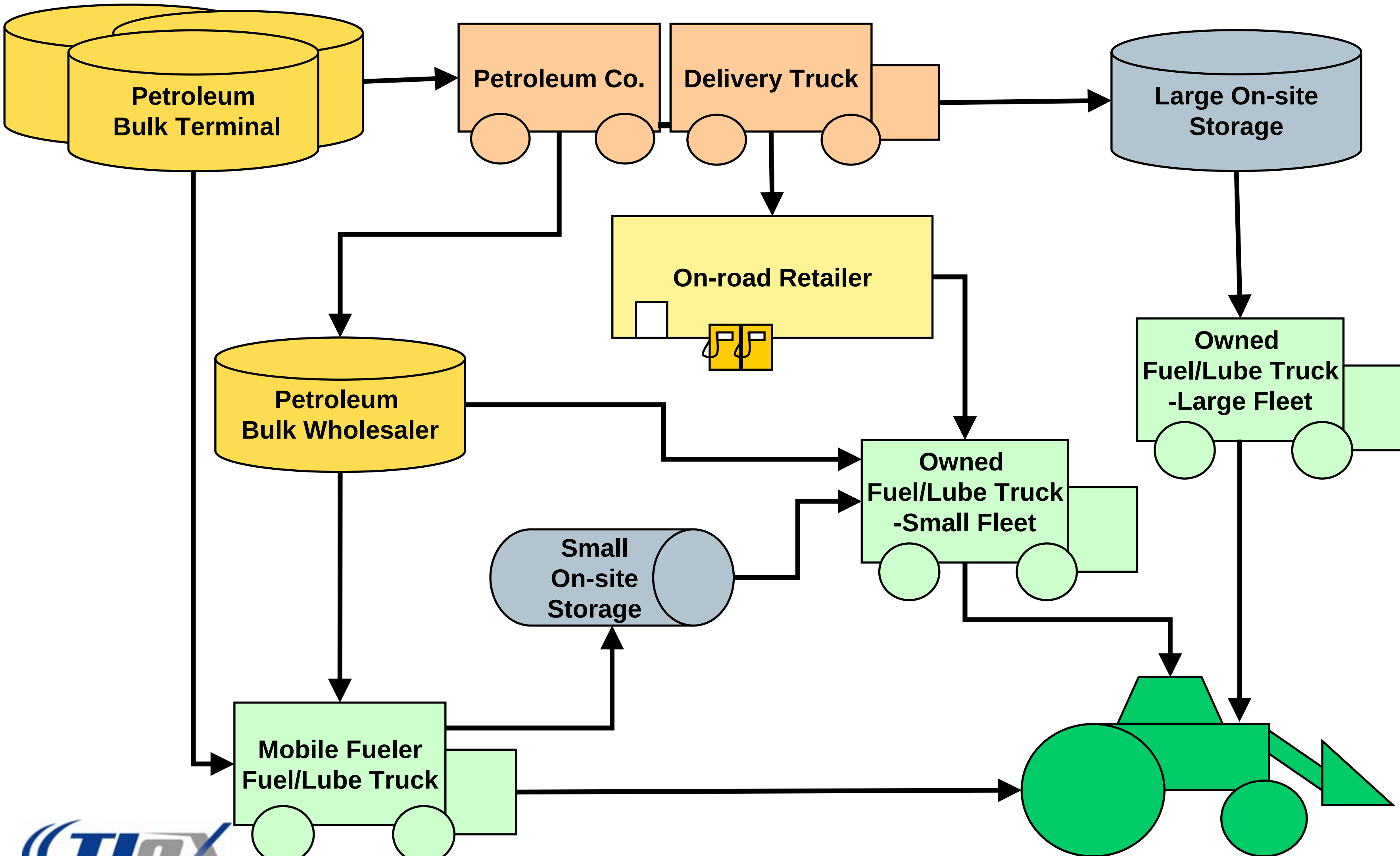
Fueling and maintenance practices characterization (continued)

- Common Practices of Forestry Equipment
  - Generally <10 pieces of equipment on-site at once
  - Fueling
    - Avoid storing large quantities of fuel on-site (fire safety)
    - Jobbers deliver fuel and fluids to home base
    - Equipment wet hosed either by in-house fuel truck or jobber
  - Fluids are topped off daily by in-house maintenance
  - Routine maintenance and repairs done in the field by own mechanics
- And, Commercial Equipment
  - Mainly fueled by owner/operator
    - Large chipper/grinders pulled behind road-crew and commercial landscaping trucks
    - Lawnmowers, turf equipment, snow blowers tend to use portable fuel tanks
    - Tends to use on-road diesel more than other segments
  - Fluids topped off by owner/operator
  - Routine maintenance performed by owner/operator or equipment repair and maintenance shop

Independent Mobile Fuelers, a.k.a. Jobbers, are a primary source of fluid replacement for many fleets

- 7,000 members of National Petroleum Marketer's Association
  - ~90% of Jobbers are members
- Typical practices
  - Utilize bobtail trucks with capacity of 2,500-5,000 gal
  - Fill once per day and dispense as much of it as possible
- Minimum company size is 3-5 million gal/yr ~ 2-4 trucks per jobber
- Jobbers operating in more remote areas own large storage tanks
  - National Petroleum Marketer's Assoc. estimates ~ 6000 tanks in U.S. owned by jobbers
- 10-15% of customers also contract for other fluids

A Fuel Flowchart is used to summarize nonroad fueling and maintenance fluid fill practices as identified through research



TIAX then estimated future nonroad fueling practices by percentage

- This step helps to align nonroad infrastructure needs with previously developed on-road infrastructure scenarios
- Previous on-road studies all started with a ‘follow the fuel’ methodology

Market Segment	**Nonroad Diesel Mobile Fueler**			**Nonroad Fleet On-site Storage**			**Onroad Diesel Infrastructure**		
	Small	**Medium**	**Large**	**Small**	**Medium**	**Large**	**Small**	**Medium**	**Large**
Construction & Mining	80%	80%	80%	10%	15%	20%	10%	5%	
Agricultural	10%	10%	10%	80%	85%	90%	10%	5%	
Industrial Machinery	10%	15%	20%	80%	80%	80%	10%	5%	
Generators	65%	65%	65%	25%	30%	35%	10%	5%	
Forestry	85%	80%	80%	10%	15%	20%	5%	5%	
Commercial Equipment	10%	10%	10%	30%	40%	50%	60%	50%	40%

Example, Small Commercial Equipment: 10% + 30% + 60% = 100%

Small	= Small Fleets; 10 and fewer units of equipment
Medium	= Medium Fleets; 11 to 50 units of equipment
Large	= Large Fleets; 51 units or more units of equipment

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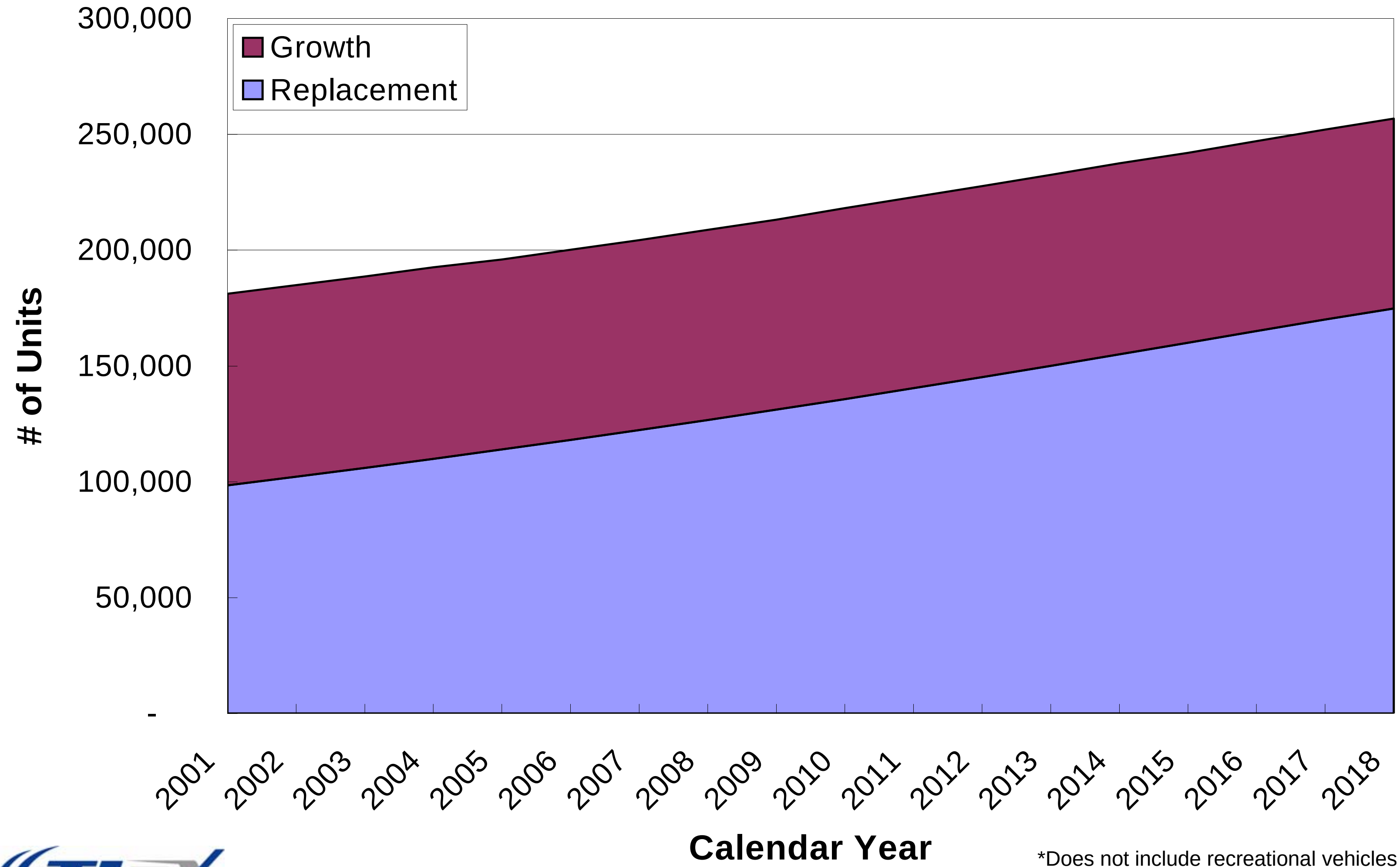
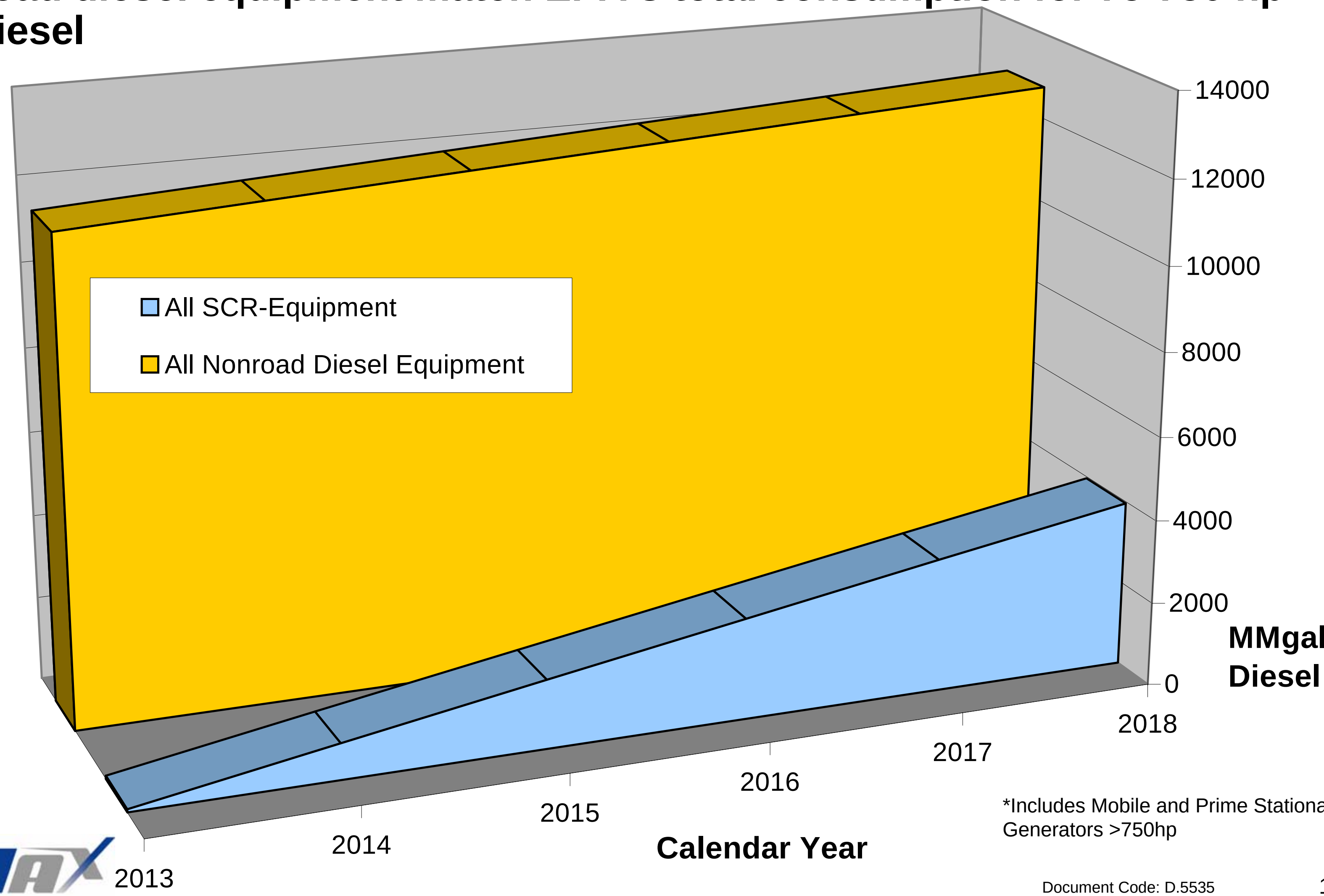
New equipment sales numbers were calculated using EPA's equipment population and lifetimes, with replacement equipment and new equipment in the inventory* identified



*Does not include recreational vehicles

Diesel consumption from SCR-equipment grows steadily as more and more equipment enter the inventory, while the consumption numbers for all nonroad diesel equipment match EPA's total consumption for 75-750 hp* NR diesel



*Includes Mobile and Prime Stationary Generators >750hp

Two urea demand scenarios are calculated using new equipment sales, fuel consumption rates, and estimated urea consumption ratios

- High urea demand scenario includes:
  - Equipment sales and diesel consumption based on EPA's Nonroad2005

  & 100% of the Final Tier 4 equipment from 75-750 hp employing urea-SCR

  & 2.0% urea consumption ratio = an average engine-out NOx emission rate of ~1.6 g/kWh

- Low urea demand scenario includes:
  - Equipment sales and diesel consumption based on EPA's Nonroad2005

  & 100% of the Final Tier 4 equipment from 75-750 hp employing urea-SCR

  & 1.0% urea consumption ratio = an average engine-out NOx emission rate of ~0.8 g/kWh

  -OR-
  - Equipment sales and diesel consumption based on EPA's Nonroad2005

  & 50% of the Final Tier 4 equipment from 75-750hp employing urea-SCR

  & 2.0% urea consumption ratio = an average engine-out NOx emission rate of ~1.6 g/kWh

- Possible realities that lie between our high and low scenarios include:
  - Engines below 100 hp, 33.4% of the equipment population, not employing urea-SCR
  - Diesel consumption flattening in some or all market segments from 2006 levels – about a 41% effect from all segments
  - Average engine-out NOx emissions rates between 0.8 and 1.6 g/kWh

Urea demand for each market segment is estimated for the calendar years 2013 to 2018 using equipment sales estimates and the high and low consumption scenarios

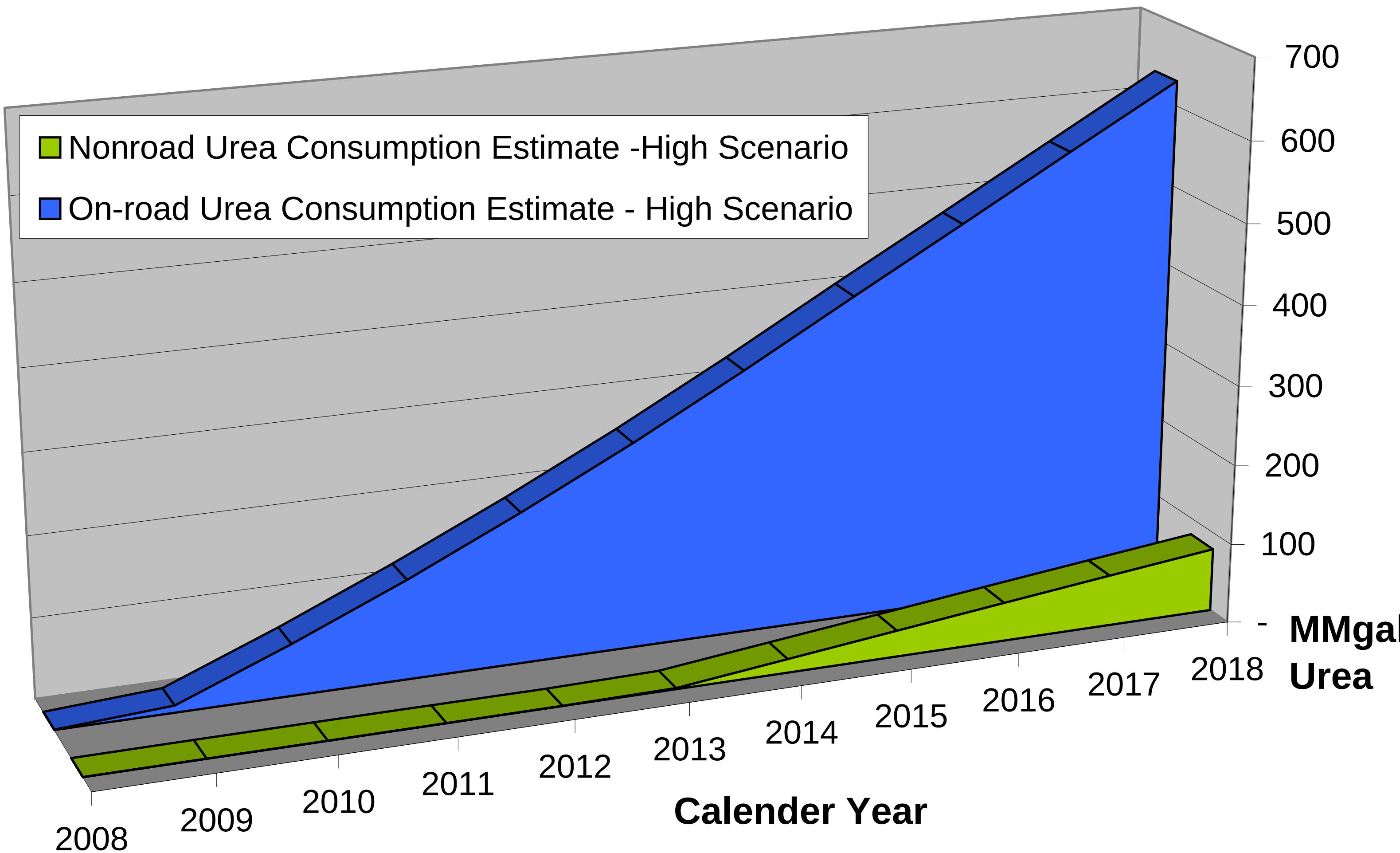
High Urea Demand by Calendar Year, MMGal

Market Segment	Calendar Year					
	2013	**2014**	**2015**	**2016**	**2017**	**2018**
Construction & Mining	0.83	9.20	17.35	25.32	33.09	40.64
Agricultural	0.47	5.28	10.13	15.03	19.99	24.99
Industrial Machinery	0.15	1.69	3.24	4.80	6.39	7.98
Generators	0.03	0.36	0.69	1.02	1.36	1.69
Forestry	0.03	0.35	0.68	1.01	1.34	1.67
Commercial Equipment	0.02	0.21	0.39	0.59	0.78	0.97
total	1.53	17.07	32.48	47.77	62.94	77.95

Low Urea Demand by Calendar Year, MMGal

Market Segment	Calendar Year					
	2013	**2014**	**2015**	**2016**	**2017**	**2018**
Construction & Mining	0.41	4.60	8.68	12.66	16.54	20.32
Agricultural	0.24	2.64	5.06	7.52	10.00	12.50
Industrial Machinery	0.08	0.84	1.62	2.40	3.19	3.99
Generators	0.02	0.18	0.34	0.51	0.68	0.85
Forestry	0.02	0.18	0.34	0.50	0.67	0.84
Commercial Equipment	0.01	0.10	0.20	0.29	0.39	0.49
total	0.76	8.54	16.24	23.88	31.47	38.98

Comparison between the nonroad urea high case consumption estimate* and the on-road high-case scenario shows a significant difference in urea demand for the analyzed years



*Stationary Generators >600hp are assumed to use existing stationary and on-road infrastructure prior to 2013

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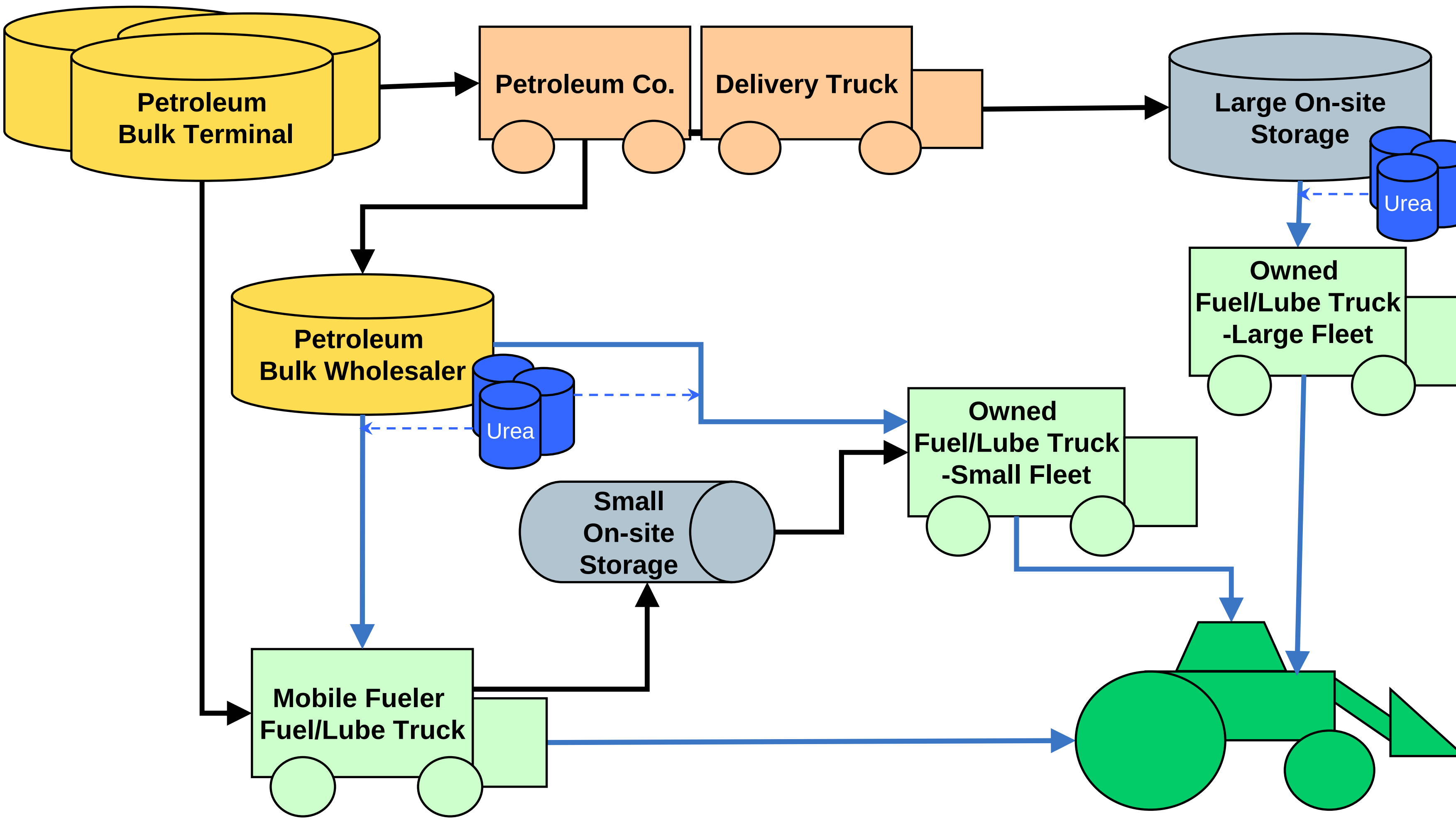
Identification of nonroad urea distribution points started by strategically adding distribution points along the Fuel Flowchart



In most cases, several SCR-equipped engines would be needed in order to have demand greater than 50 gal/month and make on-site storage viable

- TIAX calculated the average number of SCR-equipped engines by market segment and fleet size
- Large fleets will rapidly acquire multiple pieces of SCR equipment
- Medium-sized fleets have at least one piece of equipment early, but only heaviest consumers will require on-site storage
- On-storage for small fleets, where > 75% of the equipment will reside, is not feasible until well after 2018

Average Number of SCR-equipped Engines by Market Segment and Fleet Size

Market Segment	2014			2015			2016			2017			2018		
	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L
Construction & Mining	0.2	1.5	8.5	0.4	2.8	16.2	0.5	4.2	24.1	0.7	5.6	32.1	0.9	7.0	40.1
Agricultural	0.2	1.6	5.2	0.3	3.0	10.0	0.4	4.5	14.9	0.6	6.0	19.8	0.7	7.5	24.8
Industrial Machinery	0.1	1.2	4.8	0.3	2.4	9.3	0.4	3.5	13.8	0.5	4.7	18.3	0.7	5.8	22.9
Generators	0.1	0.5	3.6	0.2	1.0	7.0	0.2	1.5	10.4	0.3	2.0	13.8	0.4	2.6	17.2
Forestry	0.2	1.7	9.7	0.4	3.2	18.6	0.6	4.8	27.6	0.8	6.4	36.7	1.0	8.0	45.8
Commercial Equipment	0.2	1.1	5.7	0.4	2.1	11.0	0.7	3.2	16.4	0.9	4.2	21.8	1.1	5.3	27.2

S = Small Fleets; 10 & fewer units **M** = Medium Fleets; 11 to 50 units **L** = Large Fleets; greater than 50 units

Sources: EPA Nonroad2005; PSR's PARTSLINK™ database

Based on average monthly consumption, TIAX estimates what fraction of fleets will choose on-site urea storage

- Assume that both diesel wholesalers and on-road retailers will be able to offer urea at a lower price point (in $/gallon) than those storing small quantities
- Out of convenience, some fleets with < 50 gallons/month of urea consumption may purchase barrels and store on-site. This is most likely to occur in the agricultural sector where seasonal effects could result in the need for on-site storage during the high season while annual monthly average would be < 50 gal/month.
- Other retailers include on-road retail locations, nonroad equipment dealers and nonroad repair centers

Urea Distribution Preference by Fleet Demand

Urea Demand (gal/month)	Diesel Wholesaler	On-site Storage	Other Retail
< 25	40%	0%	60%
25 - 50	30%	25%	45%
50 - 95	15%	75%	10%
> 95	5%	90%	5%

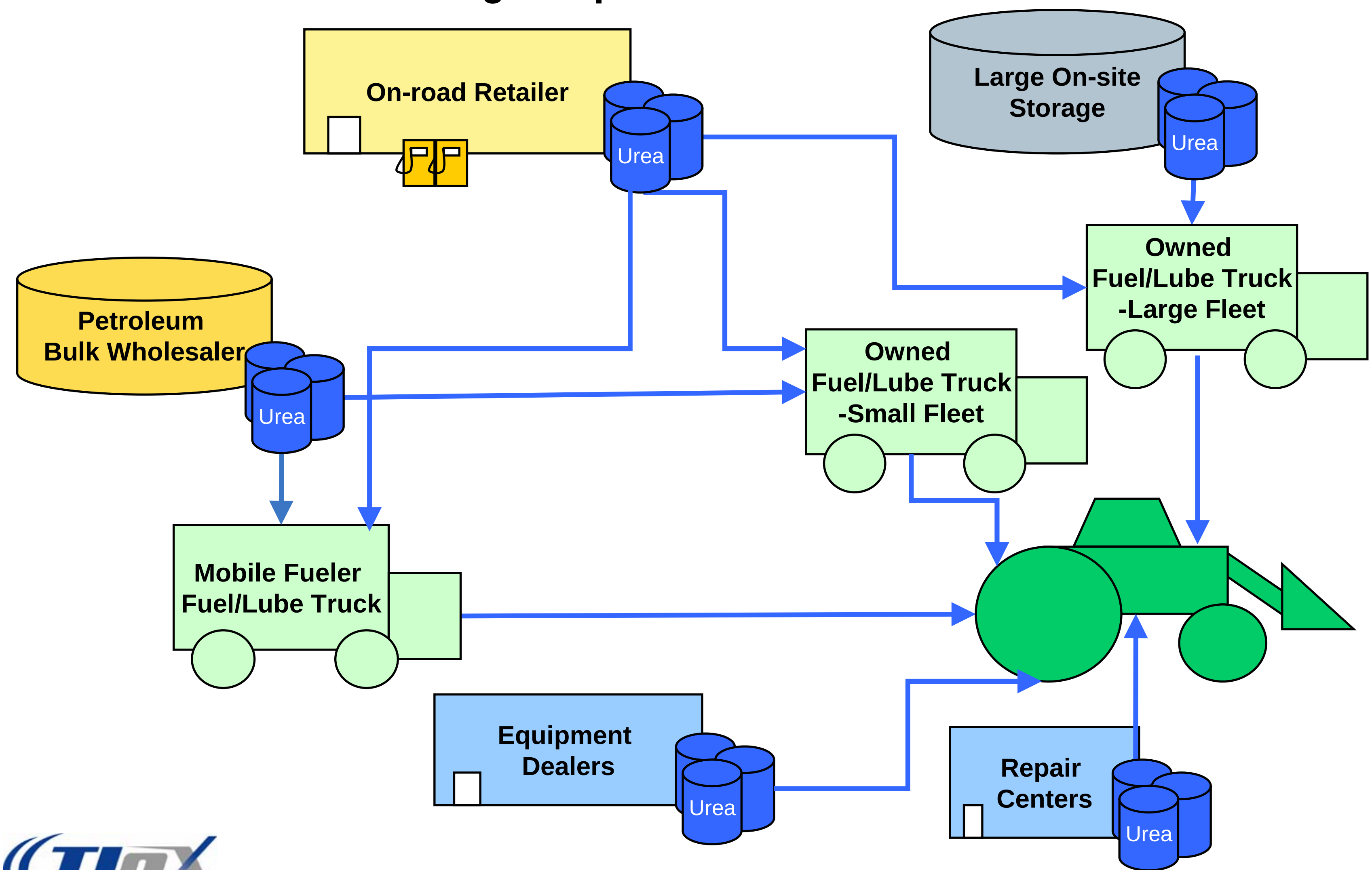
Next, we identify the urea distribution point for fleets that utilize an independent mobile fueler, a.k.a. jobber, for diesel delivery

- Assume that jobbers will primarily purchases urea from a diesel wholesaler
  - This pathway would tend to be the most convenient
  - On-road retail locations will continue to have a price advantage, because of their overall higher throughput levels
- Some fleets will receive fuel through the jobber but purchase fluids from another source
  - Filling a storage container on a maintenance truck or in the back of a pick-up
  - Low volume users will utilize lower-priced on-road retailers when convenient
- Estimate of jobber fleets using the diesel wholesaler as a urea source vs. other retail locations made independent of fleet size

Urea Distribution Preference by Fleets Utilizing Mobile Fueler

Fleets using Mobile Fueler	Diesel Wholesaler	Other Retail
	50%	50%

The addition of on-road and nonroad retail locations illustrates the distribution of urea through all points



The amount of nonroad urea distributed through equipment dealers, repair centers, and on-road retail is estimated by market segment and fleet size

- Nonroad equipment dealers will supply urea to new owner by filling urea tank and supplying take home containers
  - 2014: 10% for those equipment in small fleets, 5% for medium and large fleets
  - 2018: As nonroad infrastructure matures, market share for dealers is halved
- Nonroad repair centers would be the last to join retail chain
  - Industrial machinery and commercial equipment most likely to use repair centers
  - Estimates between are made for 2014, expected to double by 2018
  - Repair centers identified are in addition to the equipment dealer locations

2014 Nonroad Urea Market Share						
	NR Equipment Dealer			NR Repair Centers		
Market Segment	Small	Medium	Large	Small	Medium	Large
Construction & Mining	10%	5%	5%	5%		
Agricultural	10%	5%	5%	5%		
Industrial Machinery	10%	5%	5%	10%	10%	
Generators	10%	5%	5%	5%	5%	5%
Forestry	10%	5%	5%			
Commercial Equipment	10%	5%	5%	15%	15%	15%

- Remaining demand for each market segment / fleet size will be met by on-road retail locations

Overall urea demand for the nonroad sector is segmented among the distribution locations in the years 2014 and 2018

Nonroad Distribution Locations	% of Urea Sales for Nonroad Sector	
	2014	2018
Onroad Retail Locations	43.7%	41.9%
Nonroad Diesel Wholesalers	40.9%	39.4%
Nonroad Equipment Dealers	8.6%	4.3%
Nonroad Equipment Repair Center	4.1%	8.3%
Nonroad Fleet Locations	2.7%	6.2%

Urea demand for the non-road sector divided among all non-road distribution points yields low throughput levels through 2018

Nonroad Distribution Locations	Number of Locations		% of Urea Sales for Nonroad Sector		Monthly Urea Throughput from Nonroad Sector (gallons/location)			
					2014		2018	
	2014	2018	2014	2018	Low	High	Low	High
Onroad Retail Locations	47,757	57,725	43.7%	41.9%	7	13	24	48
Nonroad Diesel Wholesalers	6,800	8,000	40.9%	39.4%	43	87	162	324
Nonroad Equipment Dealers	7,798	9,174	8.6%	4.3%	8	16	15	31
Nonroad Equipment Repair Center	6,114	12,228	4.1%	8.3%	5	10	22	45
Nonroad Fleet Locations	731	3,396	2.7%	6.2%	26	53	60	121

- Estimated throughput levels would require only 1 to 2 totes per month in 2018 in the highest throughput locations

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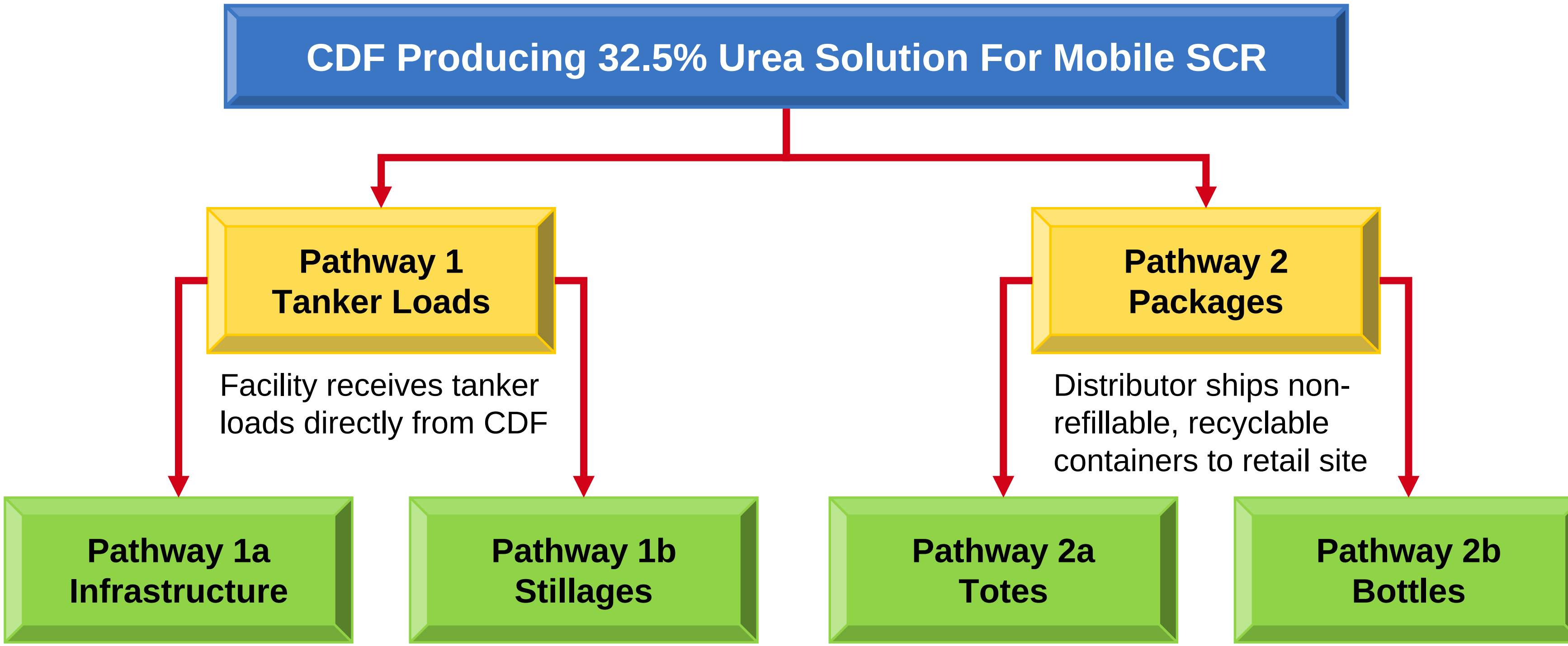
Key pathways for SCR-urea distribution identified in the on-road infrastructure study remain viable for nonroad applications



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 < 500 gal/month
- Retail site uses totes that are dropped off full, replaced when empty

Pathway 2b – Bottles
- Sales < 50 gal/month
- Retail site uses bottles and/or sells bottles to customers

Source: EMA Study 2006

U.S. urea consumption of all grades, including fertilizer, 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
- SCR-urea will likely need a separate and distinct supply chain from fertilizer grade urea
- 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]
Projected 2015 U.S. Nonroad Equipment	Urea Demand	0.05[3]

1. British Sulphur Consultants, CRU Group for 2005
2. Equivalent to 400 Million gallons 32.5% soln
3. Equivalent to 32.5 Million gallons 32.5% soln

Sources: British Sulphur Consultants, EMA Study 2006

Example Scenario:
Product packager equivalent to 5,000 gal/month retail station with a 5500 gal tank. Retail Service Station: 145 gal/month with 256 gal tote dispenser

Product Packager Storage & Dispensing

- The model assumes cost same as 5K/month retail station
- Previous on-road cost model build-up used
  - **Cost = $1.08/gal** urea solution **(A)**

Product Packaging

- Assume 256 gal heated* recyclable tote with pump
- **Cost = $0.20/gal** urea tote **(B)**
- **Expected packager profit mark-up =**
- **$1.02 to $1.17 per gal product urea (C)**

Transport To Retail

- Transportation of packaged urea to retailer
- **Cost = $0.16/gal** packaged urea **(D)**

Retail Station Storage & Marketing

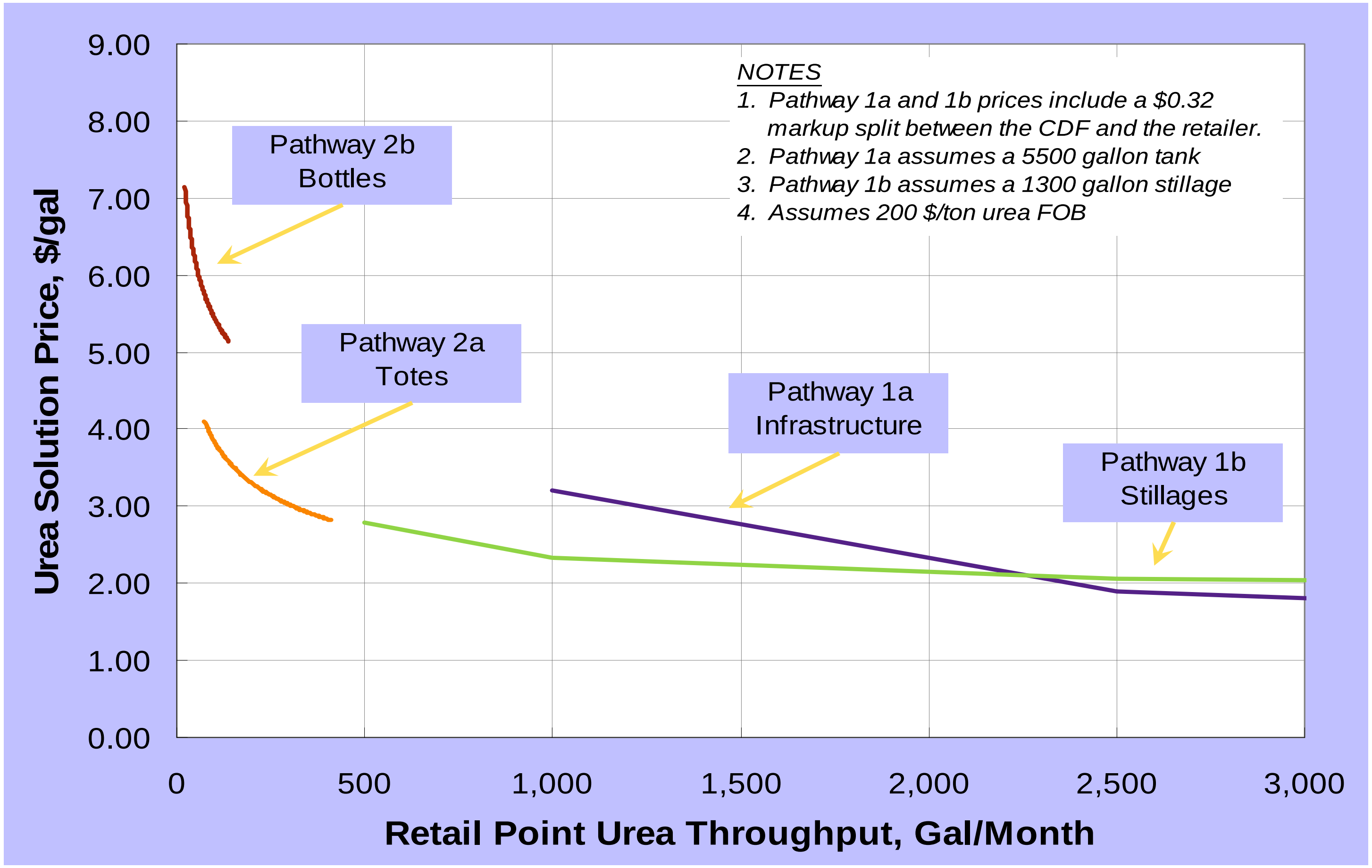
- Storage & marketing at a 145 gal/month station
- **Cost = $0.10/gal** product urea **(E)**
- **Expected retail profit mark-up = $ 0.59 to $0.72 per gal (F)**

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

Average Expected Price = (A) + (B) + (C) + (D) + (E) + (F) = 3.19 to 3.45 $/gal

* - Totes or barrels would likely be heated externally using a heated blanket or heating element and a constant recirculation pump in needed applications only

Projected prices and cross-over points previously identified show the need for stillages starting at 500 gal/month, with infrastructure not viable until 2,250 gal/month



Source: EMA Study 2006

Example Scenario:
Jobber purchasing urea from a diesel wholesaler with 145 gal/month throughput and 256 gal tote dispenser

Product Packager Storage & Dispensing
- The model assumes cost same as 5K/month retail station
- See previous cost model example for build-up
- **Cost = $1.08/gal** urea solution **(A)**

Product Packaging
- Assume 250-280 gal heated* recyclable tote with pump
- **Cost = $0.20/gal** urea tote **(B)**
- **Expected packager profit mark-up = $1.02 to $1.17 per gal product urea (C)**

Transport To Retail
- Transportation of packaged urea to retailer
- **Cost = $0.16/gal** packaged urea **(D)**

Retail Station Storage & Marketing
- Storage & marketing at a 145 gal/month station
- **Cost = $0.10/gal** product urea **(E)**
- **Expected retail profit mark-up = $ 0.59 to $0.72 per gal (F)**

Jobber Delivery to Equipment
- Rack to Retail Margins for less than 1,000 gal
- **Cost = $0.20/gal** product urea **(G)**
- **Expected jobber profit mark-up = $ 0.50 to $1.00 per gal (H)**

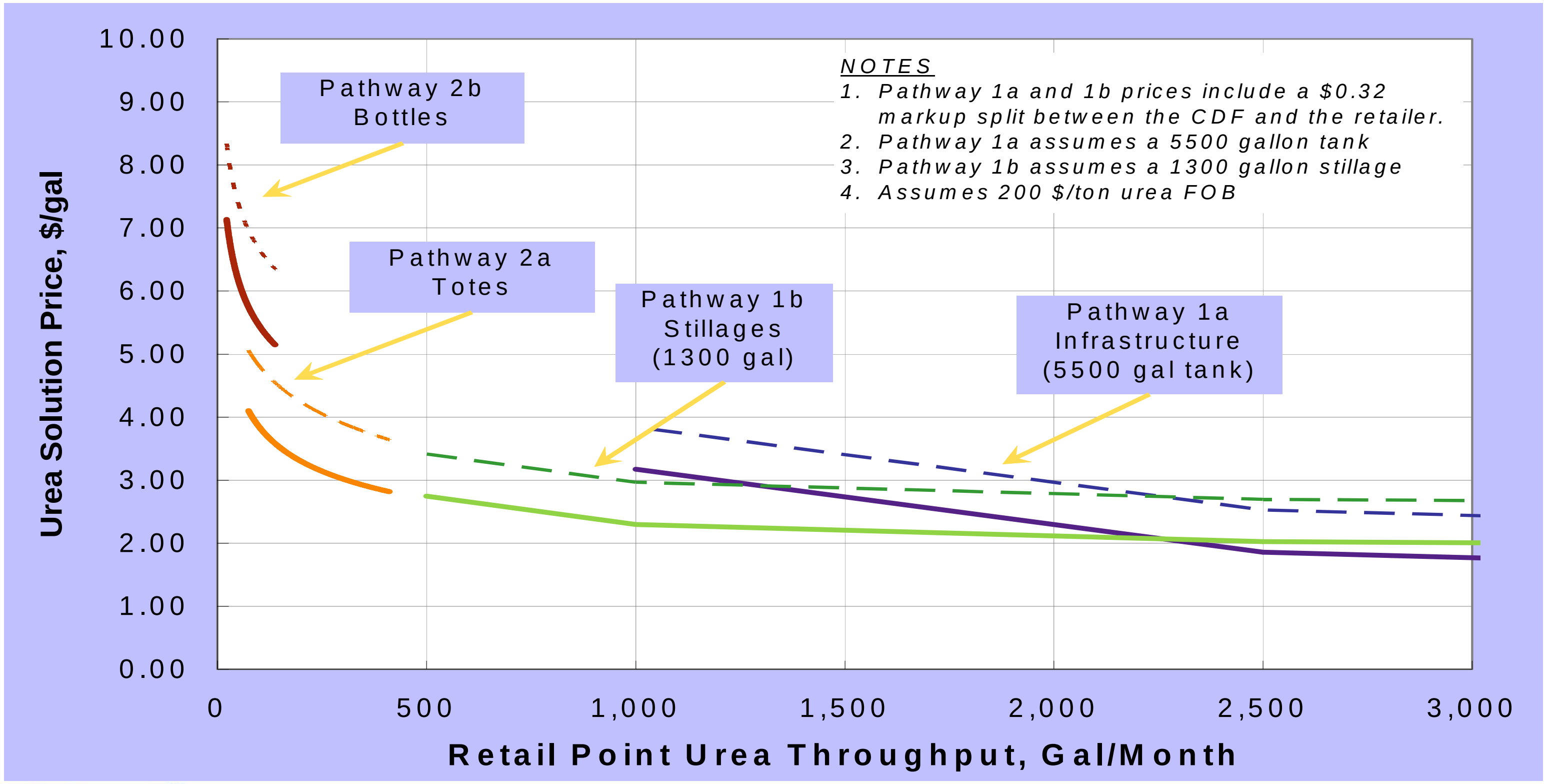
The cost model does not include mark-ups; mark-ups were added here for illustration

Average Expected Price = (A) + (B) + (C) + (D) + (E) + (F) + (G) + (H) = 3.89 to 4.65 $/gal

* - Totes or barrels would likely be heated externally using a heated blanket or heating element and a constant recirculation pump in needed applications only

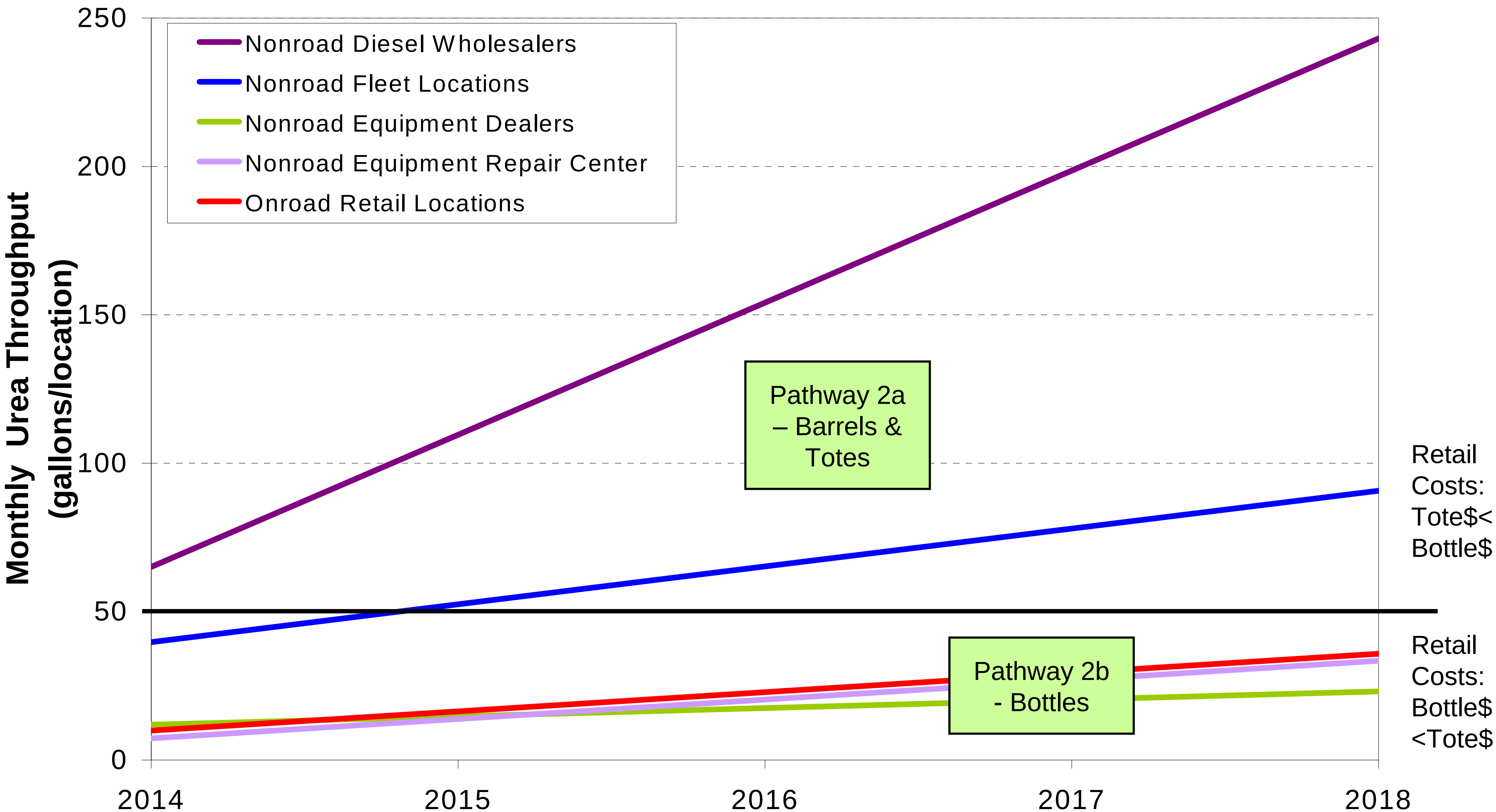
Projected price increase for fleets that will utilize a jobber is shown in the dashed lines for each distribution pathway

- Throughput at diesel wholesalers will support totes, so initial cost to jobbers will reflect low volume pathways without much room for mark-up
- As urea demand increases, jobbers will seek higher volume pathways for filling their intermediate containers to make urea delivery more profitable



A	Approach for the SCR-Urea Nonroad Study
1	Task 1 – Nonroad Population and Fueling Habits
2	Task 2 – Project NR Urea Consumption 2014-2018
3	Task 3 – Identify Urea Distribution Pathways
4	Task 4 – Update Urea Cost Model
5	**Task 5 – Identify Potential Business Cases**
6	Task 6 – Competitive Advantage Analysis
7	Task 7 – Critical Path Analysis

The average monthly throughput for each nonroad distribution location category is estimated to identify the likely distribution pathway



Potential urea volume for nonroad equipment is segmented among the pathways for projection of cost

- Throughput levels at nonroad equipment dealers and repair centers dictate that bottles would be used at these locations
- Barrels and totes are expected to be used at nonroad diesel wholesalers and for on site storage at the fleet locations
- Nonroad urea demand on the on-road infrastructure is not expected to make a significant impact on the throughput levels and therefore the cost at these locations

Year	Urea Scenario	Distribution of Nonroad Urea (million gallons/year)		
		On-road	Bottles	Barrels & Totes
2014	Low	3.8	1.1	3.8
	High	7.6	2.2	7.5
2018	Low	16.5	5.0	18.0
	High	33.1	9.9	36.0

Price comparison of on-road retail locations and nonroad retail locations shows the price advantage due to higher throughput levels

- On-road retail price range includes locations with tanks, stillages, totes/barrels, and bottles
- Non-road locations are expected to only employ totes/barrels and bottles in the 2014-2018 time period
- Weighted average price is based on the distribution method by volume

	Distributed Price ($/gallon)	
	On-road Retail Location	**Nonroad Location**
Range	**$1.10 - $7.50**	**$3.20 - $7.50**
Weighted Average	**$2.34**	**$4.25**

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The urea-SCR solution is projected to have an operating price advantage over alternative technologies that have a fuel economy penalty

- Annual cost analysis uses average population and use factors by market sector
- Assumes capital, replacement, and maintenance costs to be roughly equivalent
- 5% fuel economy difference estimated by TIAX

	Average Annual Cost Analysis					
	Agricultural Equipment	Construction and Mining	Industrial Machinery	Commercial Equipment	Forestry Equipment	Generators
Urea Consumption %	2% (High scenario consumption)					
Average Urea Cost $/gal	$2-34 - $4.25 (On-road retail average price vs. Nonroad average price)					
Projected Urea Cost $/year/equipment	$100 - $180	$230 - $410	$160 - $280	$120 - $220	$500 - $900	$100 - $180
Alternative Technology Fuel Economy Difference %	5 % (TIAX estimate)					
Ave. Diesel Cost $/gal	$1.89 - $2.94 (EIA projected price in 2014 vs. Today's price)					
Alternative Technology Cost $/year/equipment	$200 - $260	$460 - $600	$320 - $410	$240 - $320	$1000 - $1310	$190 - $260

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An estimation of the nonroad urea throughput levels and number of locations for all distribution points is identified

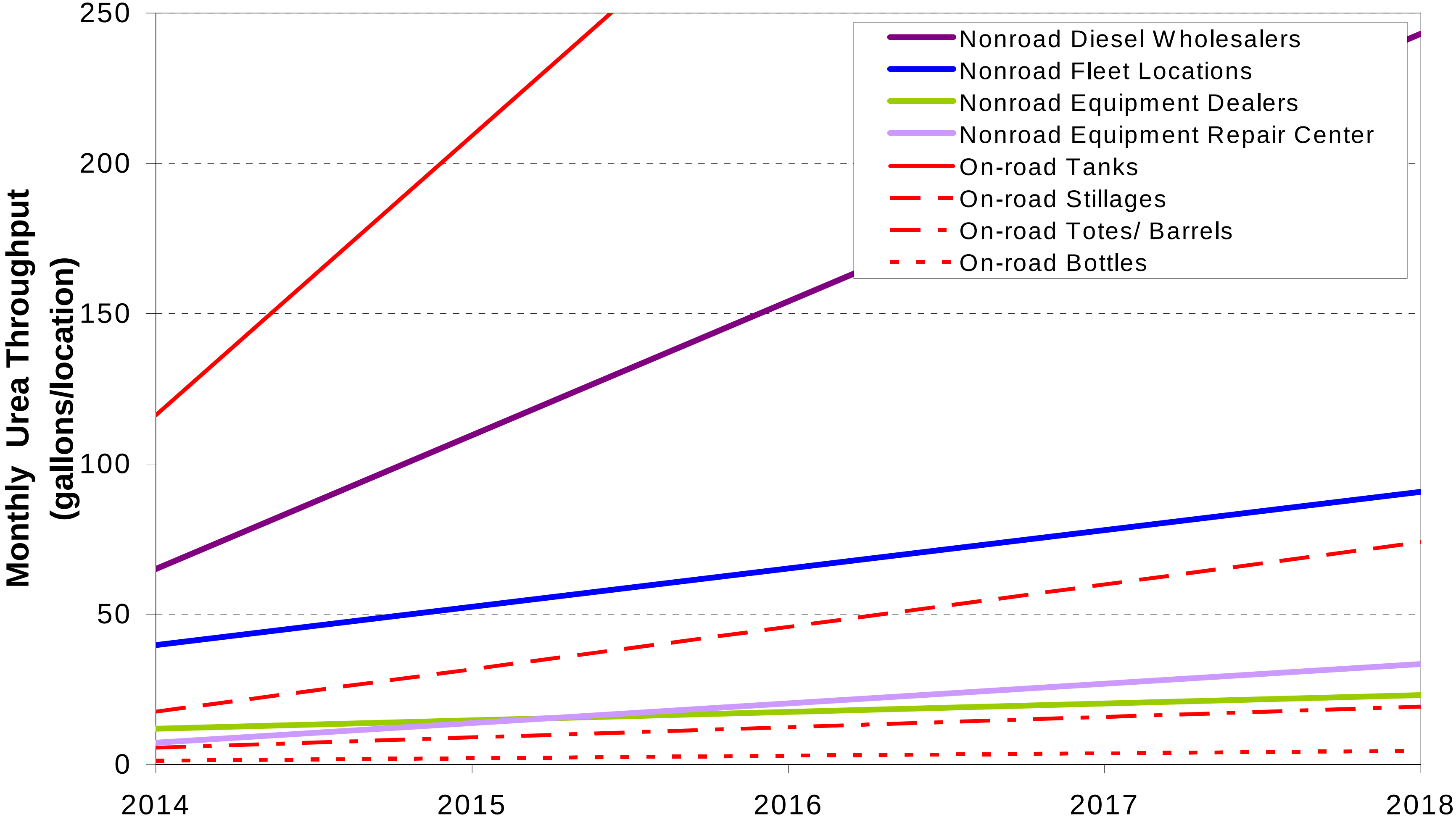
Nonroad Distribution Locations	Number of Locations	% of Urea Sales for Nonroad
	2014	
On-road Retail (ON)	47,757	43.7%
Diesel Wholesalers (DW)	6,800	40.9%
Equipment Dealers (ED)	7,798	8.6%
Repair Centers (RC)	6,114	4.1%
Fleet Locations (FL)	731	2.7%
	2018	
On-road Retail (ON)	57,725	41.9%
Diesel Wholesalers (DW)	8,000	39.4%
Equipment Dealers (ED)	9,174	4.3%
Repair Centers (RC)	12,228	8.3%
Fleet Locations (FL)	3,396	6.2%

Nonroad Urea Throughput (gal/month)	Number of Locations in 2014			
	Bottles	Totes/ Barrels	Stillages	Tanks
500 - 250				
250 - 50		6,800 DW 731 FL		2,328 ON
< 50	7,798 ED 6,114 RC 22,245 ON	24,724 ON	3,732 ON	
Total Sites	36,157	26,982	3,732	2,328

Nonroad Urea Throughput (gal/month)	Number of Locations in 2018			
	Bottles	Totes/ Barrels	Stillages	Tanks
500 - 250				2,423 ON
250 - 50		8,000 DW 2,512 FL	3,884 ON	
< 50	9,174 ED 1,228 RC 26,694 ON	24,724 ON		
Total Sites	48,096	36,120	3,884	2,423

Source: EMA Study 2006

The average nonroad urea monthly throughput for each distribution location is estimated to identify the potential impacts



Source: EMA Study 2006

The volume increase due to the nonroad demand at HD fueling stations should have no impact on the choice of infrastructure investment needed

- Extra-extra large (XXL), extra large (XL), and large (L) sized HD fueling stations will employ storage tanks for distribution of urea
  - 5,500 gal. tanks appear to be the most economic choice in all cases
  - Both above ground and below ground tanks will be used, dictated by the environmental conditions of the location and the pumping method
  - Average monthly throughput is greater than 4,000 gal in 2015 and 6,000 gal in 2018; average non-road volume increase is 115 gal in 2015 and 490 gal in 2018
- Medium large (ML), medium (M), and medium small (MS), sized HD fueling stations will employ stillages for distribution of urea
  - 1,300 gal stillages appear to be the most economic choice in all cases
  - Some ML stations may transition to tanks in the 2015 timeframe
  - Average monthly throughput is greater than 700 gal in 2015 and 1,000 gal in 2018; average non-road volume increase is 20 gal in 2015 and 75 gal in 2018
- Small (S) HD fueling stations will employ totes for distribution of urea
  - These stations may require addition totes or deliveries in order to meet increased demand of 20 gallons/month in 2018

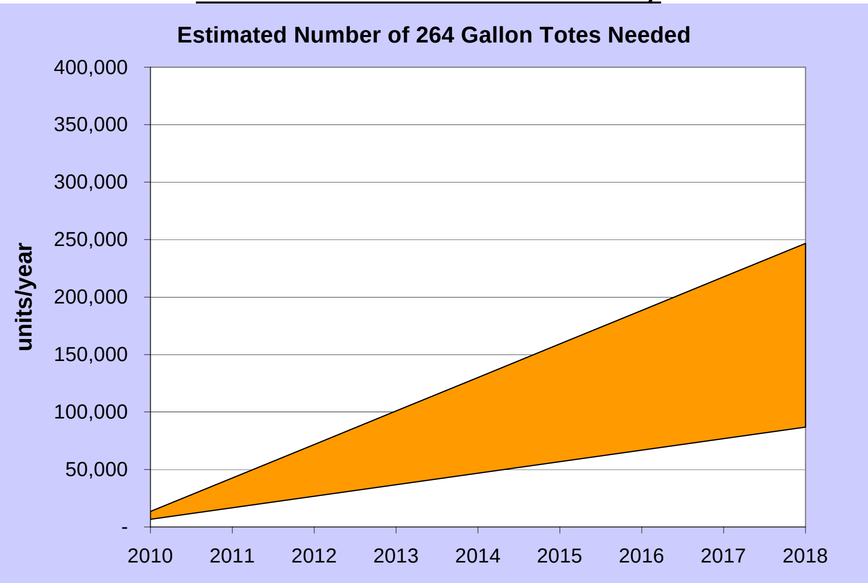
Nonroad urea demand at LD retail locations will need to be met with an increase containers at those locations.

- Chain service stations (e.g., Jiffy Lube) will compete with LD dealers for the oil change services to the new diesel vehicle and will therefore be first to distribute urea
  - Barrels and totes are most economical for these locations given the higher throughput than other LD locations
- Light-duty diesel fueling stations be an essential element in the infrastructure coverage requirement
  - 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
  - Smallest package possible (1 gallon bottles?) would be used at first because of shelf space, may transition to barrels or totes by 2014
- 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 Do-It-Yourself market segment that is being supplied (i.e., people filling up on their own)

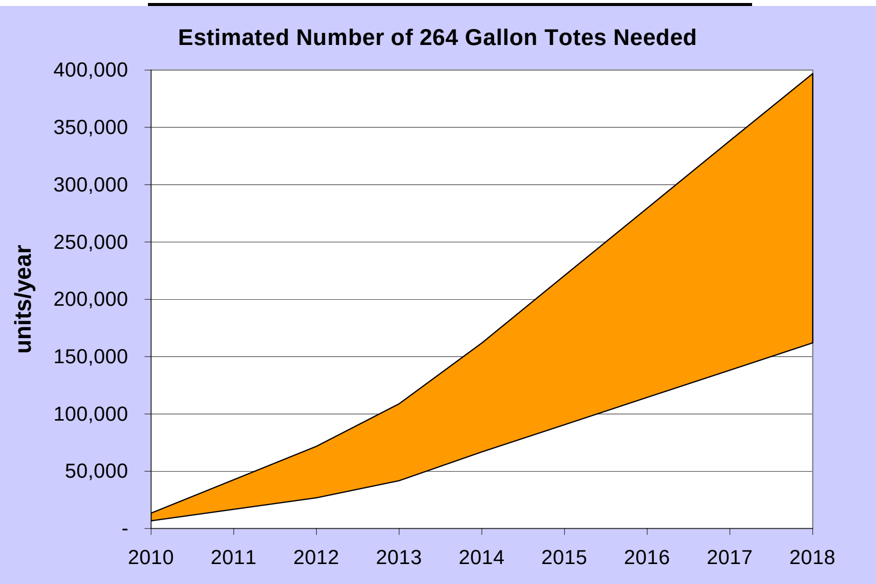
Tote and barrel manufacturers must be made aware of the expected increase in the number of totes needed to support the nonroad urea market

- Previously estimated range due to on-road urea demand
- Approximately 70% increase in number of totes needed in 2018 for all mobile equipment
- The number of totes is estimated by assuming a 50-50 split with barrels in 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

On-road Urea Demand Only



Urea Demand for All Mobile Sources



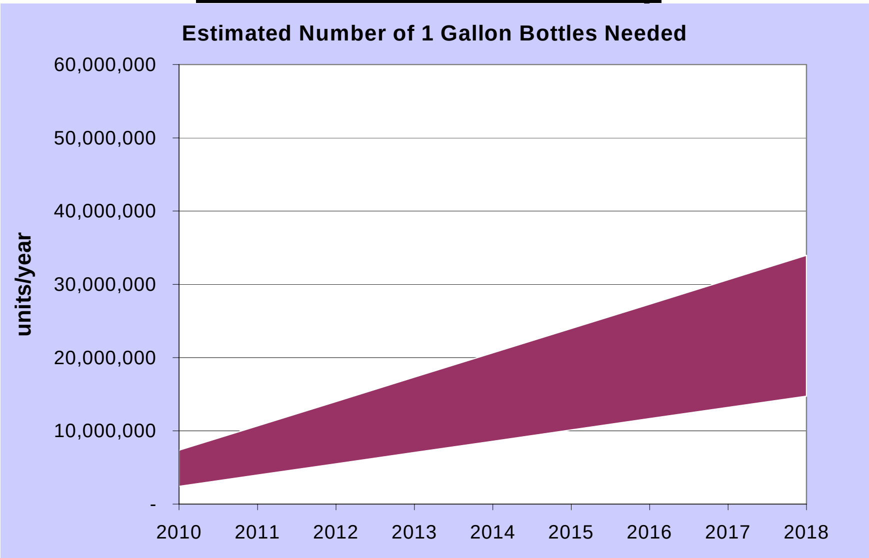
Note: 264 gallon (1000L) tote was used as estimate based on European experience, other sizes may be applicable to NA market

Source: EMA Study 2006

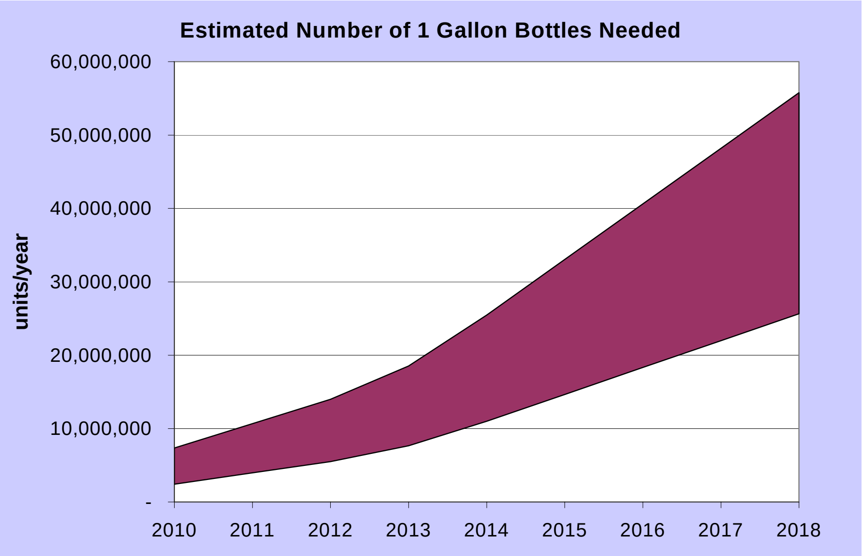
Bottlers will also need to be made aware of the expected increase in the number of bottles needed to support the nonroad urea market

- Approximately 70% increase needed in 2018 for all mobile equipment above previous demand for on-road urea
- The estimated number of bottles 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
- Increase in the number of bottles may have the most impact since they may tend to be recycled (or refilled) much less often than totes or barrels

On-road Urea Demand Only



Urea Demand for All Mobile Sources

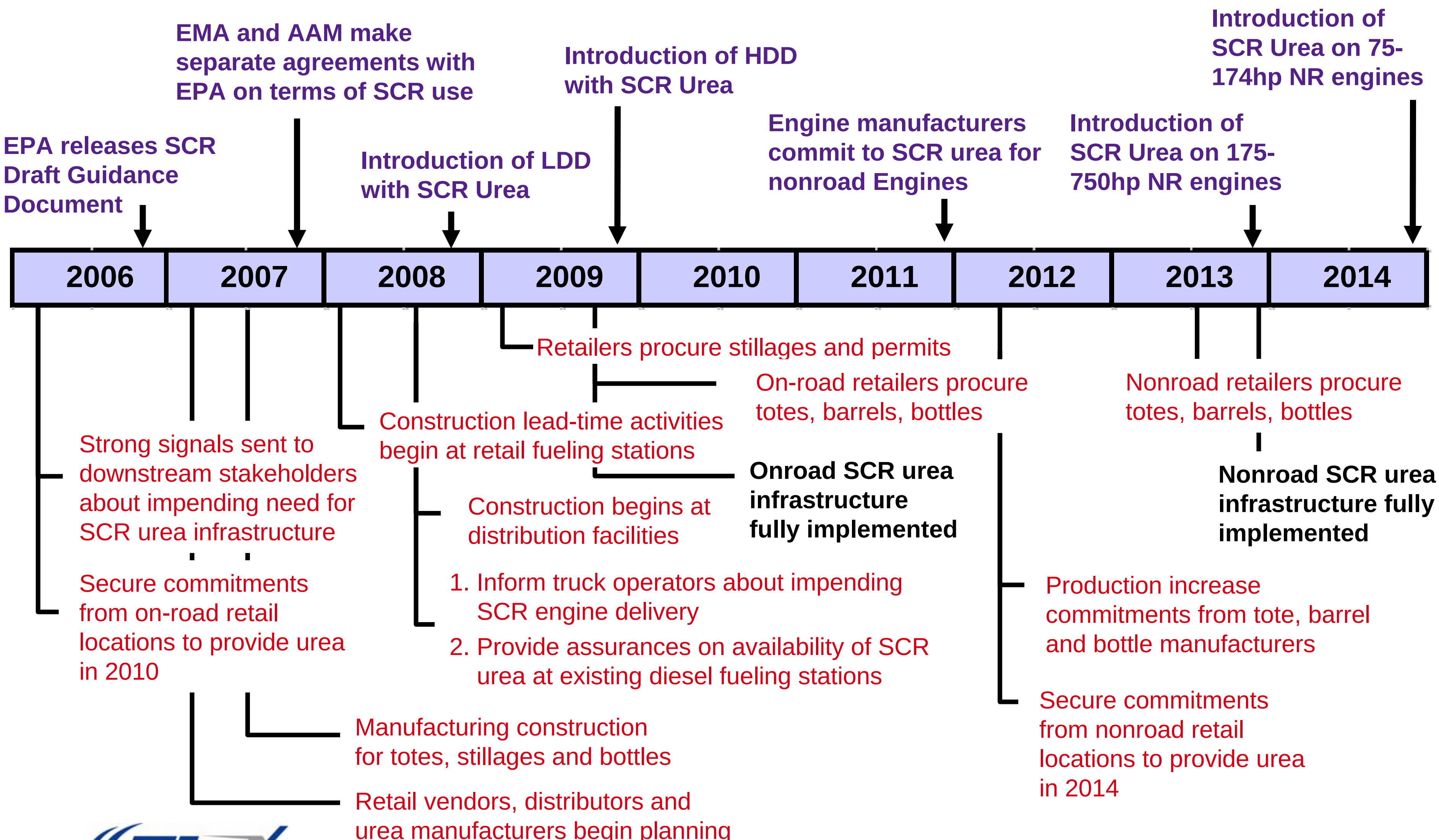


Source: EMA Study 2006

Intermediate storage containers, probably between 1-5 gallons, will likely be prevalent in the distribution of urea to the nonroad market

- Overall volume of bottles needed will depend on if or how often the bottles will be refilled by the equipment operator at a lower priced retail location, i.e. tank, stillage, tote, or barrel
- In all urea pathways other than the retail bottle, an intermediate container would likely be needed:
  - The large farmer with on-site storage will need to bring urea to the equipment from the tote or barrel back at the garage
  - The jobber (independent or company owned) will need to store urea on the fuel truck in a container smaller than a 55 gallon drum
  - The smaller fleet owner will need to transport urea from the point of purchase to the equipment
- Therefore, there might be a need for formal guidance on acceptable refillable containers for urea storage and transport

Milestones along the path to an SCR-urea infrastructure



The following acronyms are used throughout the report

- AAM – Alliance of Automotive Manufacturers
- ARB – California Air Resources Board
- UST/AST – Underground/Above-ground Storage Tank
- BSFC – Brake Specific Fuel Consumption
- CDF – Central Distribution Facility
- EIA – US Energy Information Administration
- EMA – Engine Manufacturers Association
- EPA – US Environmental Protection Agency
- FOB – Free On Board, delivered price
- GSE – Ground Support Equipment
- HD – Heavy Duty
- HDD – Heavy Duty Diesel
- HP -- Horsepower
- LD – Light Duty
- LDD – Light Duty Diesel
- MMgal – Million gallons
- NOx – Oxides of Nitrogen
- NR – Nonroad
- NREL – National Renewable Energy Laboratory
- PSR – Power Systems Research
- SCR – Selective Catalytic Reduction
- ULSD – Ultra Low Sulfur Diesel