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

1. **Task 1**: Update Urea Consumption Estimates
2. **Task 2**: Update Truck Segmentation
3. **Task 3**: Revise TIAAX SCR Urea Cost Model
4. **Task 4**: Analyze Potential Business Cases
5. **Task 5**: Perform Critical Path Analysis
6. **Task 6**: Final Report/Presentation
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

<table>
<thead>
<tr>
<th>Key Urea Manufacturing Companies in the U.S.</th>
<th>Capacity</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>2002¹</td>
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<td>Million TPY</td>
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<tr>
<td>Agrium</td>
<td>1.2</td>
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<tr>
<td>CF Industries</td>
<td>2.4</td>
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<tr>
<td>PCS Nitrogen</td>
<td>1.9</td>
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<tr>
<td>Terra Industries</td>
<td>1.4</td>
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<td>Other</td>
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</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>10.1</strong></td>
</tr>
</tbody>
</table>

¹.  w w w .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
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

<table>
<thead>
<tr>
<th>All Urea Grades</th>
<th>Million short tons/year</th>
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<tr>
<td><strong>WORLD</strong></td>
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<td>Production</td>
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<td>Capacity</td>
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<td><strong>DOMESTIC (U.S.)</strong></td>
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<tr>
<td>Demand</td>
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<tr>
<td>Production</td>
<td>6.0</td>
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<tr>
<td>Capacity</td>
<td>8.2</td>
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<tr>
<td><strong>Projected 2015 U.S. On Road Diesel Vehicle</strong></td>
<td>0.6 (^2)</td>
</tr>
</tbody>
</table>

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

- 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

CDF Producing 32.5% Urea Solution For On-Road SCR

Pathway 1
Tanker Loads
Facility receives tanker loads directly from CDF

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 2
Packages
Distributor ships non-refillable, recyclable containers to retail site

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.

NOTES
1. Pathway 1a and 1b prices include a $0.32 markup split between the CDF and the retailer.
2. Pathway 1a assumes a 5500 gallon tank
3. Pathway 1b assumes a 1300 gallon stillage
4. Assumes 200 $/ton urea FOB
**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)**

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

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

*The cost model does not include mark-ups; mark-ups were added here for illustration*
For stations selling less than 10,000 gal/month, retailer costs dominate the end of pipe urea cost...

- All costs except retailer storage & dispensing cost are independent of throughput.
- For 5000 gal/month case, costs are:
  - Urea ~26%
  - CDF cost ~ 11%
  - Total transport ~22%
  - Retail Dispensing ~ 41%
- Insensitive to Urea FOB cost (NG)
• 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

<table>
<thead>
<tr>
<th>Heavy-duty Station Size Designation</th>
<th>Number of Stations</th>
<th>% of Urea Sales in HD Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>XXL</td>
<td>310</td>
<td>17%</td>
</tr>
<tr>
<td>XL</td>
<td>1,128</td>
<td>44%</td>
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<tr>
<td>L</td>
<td>515</td>
<td>11%</td>
</tr>
<tr>
<td>ML</td>
<td>262</td>
<td>2%</td>
</tr>
<tr>
<td>M</td>
<td>2,436</td>
<td>14%</td>
</tr>
<tr>
<td>MS</td>
<td>1,115</td>
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### Light-duty Retail Location

<table>
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<th>Light-duty Retail Location</th>
<th>Number of Retail Sites</th>
<th>% of Urea Sales in LD Vehicles</th>
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<tbody>
<tr>
<td>Dealers (D)</td>
<td>17,252</td>
<td>21%</td>
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<tr>
<td>Service Stations (SS)</td>
<td>1,400</td>
<td>19%</td>
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<tr>
<td>Fueling Stations (FS)</td>
<td>6,000</td>
<td>8%</td>
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<tr>
<td>Auto Parts Stores (AP)</td>
<td>2,696</td>
<td>1%</td>
</tr>
<tr>
<td>Mass Merchants (MM)</td>
<td>3,978</td>
<td>1%</td>
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### Urea Throughput (gal/month)

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• 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*

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*Source: Air Improvement Inc. Study 2005*
In most cases, infrastructure decisions made for 2010 urea volumes allow for the increased throughput projected in 2015.

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<td>31%</td>
</tr>
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<td>Service Stations (SS)</td>
<td>7,000</td>
<td>30%</td>
</tr>
<tr>
<td>Fueling Stations (FS)</td>
<td>12,000</td>
<td>17%</td>
</tr>
<tr>
<td>Auto Parts Stores (AP)</td>
<td>10,784</td>
<td>6%</td>
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<td>Mass Merchants (MM)</td>
<td>15,910</td>
<td>6%</td>
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<tr>
<td>Total Retail Sites</td>
<td>26,694</td>
<td>40,205</td>
<td>3,551</td>
<td>2,215</td>
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</tbody>
</table>

- 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*

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*Source: Air Improvement Inc. Study 2005

Document Code: D5498
Bulk of Pathway 1 installations are needed for 2010, number of additional tanks and stillages between 2010 and 2015 is small

*Estimated Pathway 1 Dispenser Quantities*

- 1,300 gal. Stillages
- 5,500 gal. Tanks
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.

Estimated Number of 264 Gallon Totes Needed

- 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

<table>
<thead>
<tr>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
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<tr>
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</table>

EMA and AAM make separate agreements with EPA on terms of SCR use as a control strategy

Introduction of LDD with SCR Urea

Introduction of HDD with SCR Urea

Send strong signals to downstream stakeholders about impending need for SCR urea infrastructure

Retail vendors, distributors and urea manufacturers begin planning

Construction lead-time activities begin at retail fueling stations

Construction begins at distribution facilities

Retailers procure stillages and permits

Retailers procure totes, barrels and bottles

1. Inform truck operators about impending SCR engine delivery

2. Provide assurances on availability of SCR urea infrastructure at existing diesel fueling stations

Secure commitments from retail fueling stations to provide urea in 2010

Manufacturing construction for totes, stillages and bottles

SCR urea infrastructure full implementation
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<td>1</td>
<td>Approach for the SCR-Urea Update</td>
</tr>
<tr>
<td>2</td>
<td>Task 1 – Update Urea Consumption Estimates</td>
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<tr>
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  - Slow growth rate of market could inhibit the economic feasibility of urea infrastructure

- **Projected sales volumes of SCR-urea vehicles increased**
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  - 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, 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

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

- “Vehicle Inventory and Use Survey (VIUS) 2002,” U.S. Census Bureau, Issued December 2004
- 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 health 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...
A two-step process is utilized to manufacture urea, an environmentally benign chemical.

**Urea Classifications**

<table>
<thead>
<tr>
<th>Agency Listing</th>
<th>Hazardous</th>
<th>Carcinogenic</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPA</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>OSHA</td>
<td>Yes²</td>
<td>Yes¹</td>
</tr>
<tr>
<td>DOT</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Federal Hazardous Waste Regulations¹</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

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**

<table>
<thead>
<tr>
<th>Metric</th>
<th>Unit</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urea Concentration</td>
<td>wt%</td>
<td>31.8</td>
<td>33.2</td>
</tr>
<tr>
<td>Density at 20°C</td>
<td>kg/cm³</td>
<td>1087</td>
<td>1093</td>
</tr>
<tr>
<td>Refractive Index at 20°C</td>
<td>1.3814</td>
<td>1.3843</td>
<td></td>
</tr>
<tr>
<td>Alkalinity as NH₃</td>
<td>wt%</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>Biuret</td>
<td>wt%</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>Aldehyde</td>
<td>mg/kg</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Insolubles</td>
<td>mg/kg</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Phosphate</td>
<td>mg/kg</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Calcium</td>
<td>mg/kg</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Iron</td>
<td>mg/kg</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>mg/kg</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td>mg/kg</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>Chromium</td>
<td>mg/kg</td>
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<tr>
<td>Nickel</td>
<td>mg/kg</td>
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<tr>
<td>Aluminum</td>
<td>mg/kg</td>
<td>0.5</td>
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</tr>
<tr>
<td>Magnesium</td>
<td>mg/kg</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Sodium</td>
<td>mg/kg</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Potassium</td>
<td>mg/kg</td>
<td>0.5</td>
<td></td>
</tr>
</tbody>
</table>

Sources: NREL Study 2002
Approach for TIAX SCR-Urea Update Study

Work Breakdown Structure

**Tasks**

- **Kick-off**
- **Task 1** Update Urea Consumption Estimates
- **Task 2** Update Truck Segmentation
- **Task 3** Revise TIAX SCR Urea Cost Model
- **Task 4** Analyze Potential Business Cases
- **Task 5** Perform Critical Path Analysis
- **Task 6** Final Report/Presentation


**SCR-Urea Implementation Strategies Update**

**Agenda**

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
Approach for TIAx SCR-Urea Update Study  Work Breakdown Structure

**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

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

- **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**
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.

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

* AAM diesel sales estimate includes cars
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.

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

*- AAM diesel sales estimate includes cars
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.
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.

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

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.

EMA sales estimates for all classes is used for the low urea consumption scenario, along with VIUS VMT and FE data, 100% market penetration, and 1% urea consumption ratio.

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.
Update Urea Consumption Estimates  Task 1

Urea Consumption Analysis

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...

Previous MY2007 implementation scenario consumption projection nearly three times the current projection

New is higher than previous MY2010 implementation scenario, because of increased market penetration rates and consideration of all classes

Previous MY2010 implementation scenario numbers for Heavy-heavy duty vehicles only
Update Urea Consumption Estimates  Task 1  Urea Consumption Analysis

...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%
<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Approach for the SCR-Urea Update</td>
</tr>
<tr>
<td>2</td>
<td>Task 1 – Update Urea Consumption Estimates</td>
</tr>
<tr>
<td>3</td>
<td>Task 2 – Update Truck Segmentation</td>
</tr>
<tr>
<td>4</td>
<td>Task 3 – Revise TIAX SCR-Urea Cost Model</td>
</tr>
<tr>
<td>5</td>
<td>Task 4 – Analyze Potential Business Cases</td>
</tr>
<tr>
<td>6</td>
<td>Task 5 – Perform Critical Path Analysis</td>
</tr>
</tbody>
</table>
**Task 2**

**Update Truck Segmentation**

**Inputs**

- 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

**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

**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
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.
Update Truck Segmentation  Task 2

Projected 2007 Diesel Trucks; Population: 7,350,000

Light Classes 1-2
< 10,000 lb
L 36.8%  MR 1.8%  LR 1.2%

Medium Classes 3-5
10,001 - 19,500 lb
L 7.4%  MR 0.8%  LR 1.0%

Light-Heavy Classes 6-7
19,501 - 33,000 lb
L 14.9%  MR 1.4%  LR 2.4%

Heavy Class 8
> 33,001 lb
L 21.1%  MR 5.4%  LR 6.6%

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

L = Local; < 200 miles
MR = Medium Range; 200 - 500 miles
LR = Long Range; > 500 miles

Σ = 23.6%
Σ = 3.6%
Σ = 71.4%

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

<table>
<thead>
<tr>
<th></th>
<th>Light; Class 1-2</th>
<th>Medium; Class 3-5</th>
<th>Light-Heavy; Class 6-7</th>
<th>Heavy; Class 8</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 10,000 lb</td>
<td>10,001 - 19,500 lb</td>
<td>19,501 - 33,000 lb</td>
<td>&gt; 33,000 lb</td>
</tr>
<tr>
<td></td>
<td>Local</td>
<td>Medium</td>
<td>Long</td>
<td>Local</td>
</tr>
<tr>
<td>Fuel Economy, mpg</td>
<td>13.48</td>
<td>13.48</td>
<td>13.48</td>
<td>9.75</td>
</tr>
<tr>
<td>Average Miles/Yr</td>
<td>12,500</td>
<td>20,000</td>
<td>40,000</td>
<td>10,000</td>
</tr>
<tr>
<td>Central company-owned fueling facility</td>
<td>607,182</td>
<td>47,278</td>
<td>50,242</td>
<td>135,996</td>
</tr>
<tr>
<td>Single contract fueling facility located off-site</td>
<td>78,917</td>
<td>11,533</td>
<td>12,739</td>
<td>17,624</td>
</tr>
<tr>
<td>Public fueling stations</td>
<td>1,804,217</td>
<td>130,105</td>
<td>194,841</td>
<td>402,919</td>
</tr>
<tr>
<td>Other</td>
<td>19,759</td>
<td>7,954</td>
<td>10,368</td>
<td>4,413</td>
</tr>
<tr>
<td>Total</td>
<td>2,510,075</td>
<td>196,876</td>
<td>268,190</td>
<td>560,552</td>
</tr>
</tbody>
</table>

*Source: VIUS 2002*

*Fuel Economy for the In-use diesel fleet is used here to estimate the total fuel consumption.*
Projected 2007 On-Road Diesel Consumption: 26.5 billion gal

Light Classes 1-2
< 10,000 lb

\[ L = 9.2\% \]
\[ MR = 0.7\% \]
\[ LR = 0.2\% \]

\[ CF = 2.3\% \]
\[ SC = 0.3\% \]
\[ P = 6.8\% \]
\[ O = 0.1\% \]

Medium Classes 3-5
10,001 - 19,500 lb

\[ L = 2.1\% \]
\[ MR = 0.1\% \]
\[ LR = 0.2\% \]

\[ CF = 0.5\% \]
\[ SC = 0.1\% \]
\[ P = 1.5\% \]
\[ O = 0\% \]

Light-Heavy Classes 6-7
19,501 - 33,000 lb

\[ L = 6.2\% \]
\[ MR = 0.3\% \]
\[ LR = 0.3\% \]

\[ CF = 1.6\% \]
\[ SC = 0.1\% \]
\[ P = 4.9\% \]
\[ O = 0\% \]

Heavy Class 8
> 33,001 lb

\[ L = 0.4\% \]
\[ MR = 0.4\% \]
\[ LR = 45.1\% \]

\[ CF = 3.4\% \]
\[ SC = 0.9\% \]
\[ P = 10.4\% \]
\[ O = 1.7\% \]

\( \Sigma = 21.5\% \)
\( \Sigma = 4.4\% \)
\( \Sigma = 71.2\% \)

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

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 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

For Hire
(53% Revenue Share, R.S.)

Private
(47% R.S.)

Truck Load
(37% R.S.)

Less than Truck Load
(16% R.S.)

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

Fueling Habits - Percent of Fuel Consumption
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

Fueling Habits - Percent of Fuel Consumption
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.

A bimodal distribution as shown here, was developed to profile the truck stops. $0.78F_1 + 0.22F_2 = 290,000$ gal/month where $F_1$ and $F_2$ are average throughputs for each segment.

**Monthly Diesel Fuel Throughput (gallons/station)**

<table>
<thead>
<tr>
<th>Fuel Throughput Range</th>
<th>Number of Stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>2,000,000</td>
<td>1,300,000</td>
</tr>
<tr>
<td>1,300,000</td>
<td>1,000,000</td>
</tr>
<tr>
<td>1,000,000</td>
<td>300,000</td>
</tr>
<tr>
<td>300,000</td>
<td>200,000</td>
</tr>
<tr>
<td>200,000</td>
<td>140,000</td>
</tr>
<tr>
<td>140,000</td>
<td>80,000</td>
</tr>
<tr>
<td>80,000</td>
<td>10,000</td>
</tr>
<tr>
<td>10,000</td>
<td>100</td>
</tr>
<tr>
<td><strong>Total Number of Stations</strong></td>
<td><strong>32,509</strong></td>
</tr>
</tbody>
</table>
The urea consumption numbers from Task 1 were then distributed among diesel fueling stations using the diesel throughput percentages

<table>
<thead>
<tr>
<th>Monthly Diesel Fuel Throughput (gallons/station)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
</tr>
<tr>
<td>2,000,000</td>
</tr>
<tr>
<td>1,300,000</td>
</tr>
<tr>
<td>1,000,000</td>
</tr>
<tr>
<td>300,000</td>
</tr>
<tr>
<td>200,000</td>
</tr>
<tr>
<td>140,000</td>
</tr>
<tr>
<td>80,000</td>
</tr>
<tr>
<td>10,000</td>
</tr>
</tbody>
</table>

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).

<table>
<thead>
<tr>
<th>Heavy-duty Station Size Designation</th>
<th>Monthly Urea Throughput (gallons/station)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of Stations</td>
</tr>
<tr>
<td></td>
<td>High</td>
</tr>
<tr>
<td>XXL</td>
<td>310</td>
</tr>
<tr>
<td>XL</td>
<td>1,128</td>
</tr>
<tr>
<td>L</td>
<td>515</td>
</tr>
<tr>
<td>ML</td>
<td>262</td>
</tr>
<tr>
<td>M</td>
<td>2,436</td>
</tr>
<tr>
<td>MS</td>
<td>1,115</td>
</tr>
<tr>
<td>S</td>
<td>2,491</td>
</tr>
<tr>
<td>XS</td>
<td>24,251</td>
</tr>
</tbody>
</table>
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
SCR-Urea Implementation Strategies Update

**Agenda**

1. Approach for the SCR-Urea Update
2. Task 1 – Update Urea Consumption Estimates
3. Task 2 – Update Truck Segmentation
4. Task 3 – Revise TIAAX SCR-Urea Cost Model
5. Task 4 – Analyze Potential Business Cases
6. Task 5 – Perform Critical Path Analysis
**Approach for TIAx SCR-Urea Update Study**  
**Work Breakdown Structure**  

**Task 3**

**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

**Outputs**

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

- 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
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

<table>
<thead>
<tr>
<th>Key Urea Manufacturing Companies in the U.S.</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2002¹</td>
</tr>
<tr>
<td></td>
<td>Million TPY</td>
</tr>
<tr>
<td>Agrium</td>
<td>1.2</td>
</tr>
<tr>
<td>CF Industries</td>
<td>2.4</td>
</tr>
<tr>
<td>PCS Nitrogen</td>
<td>1.9</td>
</tr>
<tr>
<td>Terra Industries</td>
<td>1.4</td>
</tr>
<tr>
<td>Other</td>
<td>3.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>10.1</strong></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>All Urea Grades</th>
<th>Million short tons/year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WORLD</strong>¹</td>
<td>Demand: 137</td>
</tr>
<tr>
<td></td>
<td>Production: 138</td>
</tr>
<tr>
<td></td>
<td>Capacity: 162</td>
</tr>
<tr>
<td><strong>DOMESTIC</strong> (U.S.)¹</td>
<td>Demand: 12.4</td>
</tr>
<tr>
<td></td>
<td>Production: 6.0</td>
</tr>
<tr>
<td></td>
<td>Capacity: 8.2</td>
</tr>
<tr>
<td><strong>Projected 2015</strong> U.S. On Road Diesel Vehicle</td>
<td>Urea Demand 0.6²</td>
</tr>
</tbody>
</table>

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.
Domestic and imported urea is shipped to a central distribution facility, blended and transported to the retailer.
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

CDF Producing 32.5% Urea Solution For On-Road SCR

Pathway 1
Tanker Loads
Facility receives tanker loads directly from CDF

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 2
Packages
Distributor ships non-refillable, recyclable containers to retail site

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

- 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
  - 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

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

- 11,000 Gal Infrastructure
- 5,500 Gal Infrastructure
- 2,500 Gal Infrastructure
- 5,500 Gal Stillage
- 1,300 Gal Stillage
- 11,000 Gal with 11,000 gal delivery

- 200 $/ton urea FOB
- 5200 gal tanker deliveries
- Average of melt and granular costs
- Costs amortized over 3 yrs at 12%

Dashed line shows impact for 11,000 gal tanker delivery (not done in U.S.)
The model assumes 200 $/ton urea FOB discounted 20% for melt.

- **Cost = $0.24/gal** product urea (A)

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)

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)

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)

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

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.
**Pathway 1b Infrastructure Example**

**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)

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

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

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

<table>
<thead>
<tr>
<th>AdBlue Retail Containers</th>
<th>Container Volume</th>
<th>Price of AdBlue ($/gal)(^c)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stillages(^b)</strong></td>
<td>15,000-L (3,963-gal)</td>
<td>2.12</td>
</tr>
<tr>
<td></td>
<td>3,000-L (793-gal)</td>
<td>2.52</td>
</tr>
<tr>
<td><strong>Totes</strong></td>
<td>1,000-L (264-gal)</td>
<td>2.78</td>
</tr>
<tr>
<td><strong>Bottles</strong></td>
<td>18-L (4.8-gal)</td>
<td>4.30</td>
</tr>
<tr>
<td></td>
<td>10-L (2.6-gal)</td>
<td>4.63</td>
</tr>
<tr>
<td></td>
<td>5-L (1.3-gal)</td>
<td>5.30</td>
</tr>
</tbody>
</table>

\(^a\) 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 system².
  - Trucks registered after Oct 2007 will have tank level sensors³. 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 rates¹,³:
  - 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

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

* 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.

**Sources:** AAM Study 2004

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

- **Dealers** 24%
- **Quick Lubes & Chain Service Stations** 27%
- **Others, 4%**
- **Fuel Stations** 3%
- **Auto Parts Stores** 18%
- **Mass Merchants** 24%
- **DIFM, 55%**
- **DIY, 45%**

- 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.

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Sources: AAM Study 2004

---

\(a\) Derived from the following sources:
(1) 2003 Aftermarket Business Survey Report
(3) Various other trade reports
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.
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.

**NOTES**
1. Pathway 1a and 1b prices include a $0.32 markup split between the CDF and the retailer.
2. Pathway 1a assumes a 5500 gallon tank
3. Pathway 1b assumes a 1300 gallon stillage
4. Assumes 200 $/ton urea FOB
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.
**SCR-Urea Implementation Strategies Update**

**Agenda**

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
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

<table>
<thead>
<tr>
<th>Heavy-duty Station Size Designation</th>
<th>Monthly Urea Throughput (gallons/station)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of Stations</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>XXL</td>
<td>310</td>
</tr>
<tr>
<td>XL</td>
<td>1,128</td>
</tr>
<tr>
<td>L</td>
<td>515</td>
</tr>
<tr>
<td>ML</td>
<td>262</td>
</tr>
<tr>
<td>M</td>
<td>2,436</td>
</tr>
<tr>
<td>MS</td>
<td>1,115</td>
</tr>
<tr>
<td>S</td>
<td>2,491</td>
</tr>
<tr>
<td>XS</td>
<td>24,251</td>
</tr>
</tbody>
</table>
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.

### Monthly Urea Throughput (gallons/station)

<table>
<thead>
<tr>
<th>Station</th>
<th>Monthly Urea Throughput</th>
</tr>
</thead>
<tbody>
<tr>
<td>XXL</td>
<td>310</td>
</tr>
<tr>
<td>XL</td>
<td>1,128</td>
</tr>
<tr>
<td>L</td>
<td>515</td>
</tr>
<tr>
<td>ML</td>
<td>262</td>
</tr>
<tr>
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<td>2,436</td>
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<td>MS</td>
<td>1,115</td>
</tr>
<tr>
<td>S</td>
<td>2,491</td>
</tr>
<tr>
<td>XS</td>
<td>24,251</td>
</tr>
</tbody>
</table>

### Pathways

- **Pathway 1a**: 5,500 gal Tank
- **Pathway 1b**: 1,300 gal Stillage

Station Costs:
- Tank$ < Stillage$
- Stillage$ < Tank$

3-year projection from 2010 to determine strategy

3-year projection from 2015 to determine strategy
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

<table>
<thead>
<tr>
<th>Light-duty Retail Location</th>
<th>Number of Locations</th>
<th>% of Urea Sales in LD Vehicles</th>
<th>Monthly Urea Throughput (gallons/location)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2010</td>
<td>2015</td>
<td>2010</td>
</tr>
<tr>
<td>Dealers (D)</td>
<td>17,252</td>
<td>18,714</td>
<td>21.0%</td>
</tr>
<tr>
<td>Service Stations (SS)</td>
<td>1,400</td>
<td>7,000</td>
<td>19.0%</td>
</tr>
<tr>
<td>Fueling Stations (FS)</td>
<td>6,000</td>
<td>12,000</td>
<td>8.0%</td>
</tr>
<tr>
<td>Auto Parts Stores (AP)</td>
<td>2,696</td>
<td>10,784</td>
<td>0.5%</td>
</tr>
<tr>
<td>Mass Merchants (MM)</td>
<td>3,978</td>
<td>15,910</td>
<td>0.5%</td>
</tr>
</tbody>
</table>

- 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 dependent 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.

Pathway 2a - Barrels & Totes

Pathway 2b - Bottles

Retail Costs:
Tote$ < Bottle$

Retail Costs:
Bottle$ < Tote$
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

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

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

<table>
<thead>
<tr>
<th>Urea Throughput (gal/month)</th>
<th>Bottles</th>
<th>Barrels &amp; Totes</th>
<th>Stillages</th>
<th>Tanks</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,000 - 5,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5,000 - 2,500</td>
<td>310 XXL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2,500 - 1,000</td>
<td>1,128 XL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,000 - 500</td>
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<td></td>
<td></td>
</tr>
<tr>
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<td></td>
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</tr>
<tr>
<td>250 - 100</td>
<td>1,400 SS</td>
<td>2,436 M</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 100</td>
<td>17,252 D</td>
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<td>1,115 MS</td>
<td>2,491 S</td>
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<td></td>
</tr>
<tr>
<td>2,491 S</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- 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

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

<table>
<thead>
<tr>
<th>Urea Throughput (gal/month)</th>
<th>Bottles</th>
<th>Barrels &amp; Totes</th>
<th>Stillages</th>
<th>Tanks</th>
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</thead>
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<td>10,000 - 5,000</td>
<td></td>
<td></td>
<td></td>
<td>310 XXL, 1,128 XL</td>
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<td>5,000 - 2,500</td>
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<td></td>
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</tr>
<tr>
<td>2,500 - 1,000</td>
<td></td>
<td></td>
<td>2,436 M</td>
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</tr>
<tr>
<td>1,000 - 500</td>
<td></td>
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<td>250 - 100</td>
<td></td>
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<td>7,000 SS</td>
<td></td>
</tr>
<tr>
<td>&lt; 100</td>
<td>10,784 AP</td>
<td>15,910 MM</td>
<td>18,714 D</td>
<td>12,000 FS</td>
</tr>
<tr>
<td>Total Retail Sites</td>
<td>26,694</td>
<td>40,205</td>
<td>3,551</td>
<td>2,215</td>
</tr>
</tbody>
</table>

- 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.
- 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.

<table>
<thead>
<tr>
<th>Year</th>
<th>Urea Scenario</th>
<th>Distribution of Urea (million gallons/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>LD OEM</td>
</tr>
<tr>
<td>2010</td>
<td>Low</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>9.3</td>
</tr>
<tr>
<td>2015</td>
<td>Low</td>
<td>3.1</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>9.3</td>
</tr>
</tbody>
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<td></td>
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</tr>
<tr>
<td>2015</td>
<td>Low</td>
<td>3.1</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>9.3</td>
</tr>
</tbody>
</table>
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
Analyze Potential Business Cases  Task 4

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

<table>
<thead>
<tr>
<th>Light: Class 1-2</th>
<th>Light-Heavy: Class 6-7</th>
<th>Heavy: Class 8</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Local</td>
<td>Medium Range</td>
</tr>
<tr>
<td>&lt; 10,000 lb</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 200 miles</td>
<td>17.64</td>
<td></td>
</tr>
<tr>
<td>&gt; 500 miles</td>
<td>12.59</td>
<td></td>
</tr>
<tr>
<td>Average Miles/Yr</td>
<td>13,100</td>
<td>25,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Urea Consumption %</th>
<th>1% - 2% (TIAX estimate)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Average Urea Cost $/gal</th>
<th>$4.97 (Pathway 2 Average Price)</th>
<th>$1.99 (Pathway 1 Average Price)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ave. Diesel Cost $/gal</td>
<td>$1.82 - $2.94 (EIA projected price in 2010 vs. Today's price)</td>
<td></td>
</tr>
</tbody>
</table>

Sources: VIUS 2002, EIA AEO2006
SCR-Urea Implementation Strategies Update

**Agenda**

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
Approach for TIAX SCR-Urea Update Study  
Work Breakdown Structure  

Task 5

**Task 5**
Perform Critical Path Analysis

Perform 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

**Inputs**
Potential Business Cases: Task 4

**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.

- Light Duty Manufacturers Commit to SCR for MY 2009
- Engine Manufacturers Commit to SCR for MY 2010 (HDD)
- Engine Manufacturers Submit Plans to EPA
- EPA Formally Approves SCR Plans
- Final Light-Duty Certification
- Final Heavy-Duty Certification
- SCR Equipped LDD Vehicle Sales
- SCR Equipped HDD Vehicle Sales
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\textsuperscript{TM} 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\textsuperscript{TM} product name
    - Air1\textsuperscript{TM} 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.

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

Vendors already selling SCR urea solution in totes. Must signal to them that they need to prepare for increased volume.
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 of 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.

![Graph](image)

**Estimated Number of 1 Gallon Bottles Needed**

- 2010: 5,000,000 units/year
- 2015: 10,000,000 units/year
Vendors will need to set up bottling production to handle projected demand for bottled urea.

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

Alert Urea Suppliers/Distributors

Distributors Bottle SCR Urea

Setup Bottling

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

Assume 1 gallon bottles

2.4-7.4 Million Bottles

10-24 Million Bottles

Bottles In-Use
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.
Summary of key issues for the major urea production and distribution stakeholders

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Urea Manufacturers</td>
<td>Urea specification completed, no issues</td>
<td>No special issues</td>
<td>None</td>
<td>- Will require strong signals from distributor and retail level stakeholders</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- Timeline: minimum 1 year from planning to higher volume production</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- UST/AST installation - 0.5 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- Operating &amp; construction permits 0.5 years</td>
</tr>
<tr>
<td>Urea Distributors (CDFs)</td>
<td>No special issues</td>
<td>- UST/AST installation - 0.5 years</td>
<td>Operating &amp; construction permits 0.5 years</td>
<td>- Strong signals from truck operators and upwards such as engine manufacturers</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- Timeline: 1.5 - 2 years from planning to installation</td>
</tr>
<tr>
<td>Equipment &amp; Systems Manufacturers</td>
<td>- Storage systems: no special issues</td>
<td>- Manufacturing: 1 - 1.5 years lead time - Some dispensing units already being produced</td>
<td>None</td>
<td>- Strong signals from engine manufacturers, truck manufacturers, distributors and retailers</td>
</tr>
<tr>
<td></td>
<td>- Dispensing system will be developed using European experience</td>
<td></td>
<td></td>
<td>- Development in the US will be accelerated by European experience</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Timeline: 1 - 1.5 years from planning through production</td>
</tr>
</tbody>
</table>
## Summary of key issues for the major urea production and distribution stakeholders

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

*Critical Path Analysis Task 5*
Milestones along the path to an on-road SCR-urea infrastructure

EMA and AAM make separate agreements with EPA on terms of SCR use as a control strategy

Introduction of LDD with SCR Urea

Introduction of HDD with SCR Urea

Send strong signals to downstream stakeholders about impending need for SCR urea infrastructure

EMA and AAM make separate agreements with EPA on terms of SCR use as a control strategy

Retail vendors, distributors and urea manufacturers begin planning

Retailers procure stillages and permits

Manufacturing construction for totes, stillages and bottles

Retailers procure totes, barrels and bottles

Construction lead-time activities begin @ retail fueling stations

Construction begins @ distribution facilities

SCR urea infrastructure full implementation

Retailers procure stillages and permits

Send strong signals to downstream stakeholders about impending need for SCR urea infrastructure

Retailers procure totes, barrels and bottles

Retail vendors, distributors and urea manufacturers begin planning

Manufacturing construction for totes, stillages and bottles

Stillages, totes and bottles

1. Inform truck operators about impending SCR engine delivery
2. Provide assurances on availability of SCR urea infrastructure at existing diesel fueling stations

Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4
We would like to thank the following people for their valuable insights and the information of their industries that contributed to this study

- EMA SCR-urea committee members
- Mr. Barry Lonsdale, Terra Industries
- Mr. Jerry Kroon, Agrium
- Mr. Chris Haynes, GreenChem-AdBlue
- 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 für 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