Distributing Urea for the On-Road Vehicle Market

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Distributing Urea for the On-Road Vehicle Market

Agenda

1. Introduction
2. Estimated Urea Consumption
3. Urea Distribution Pathways
4. Estimated Urea Costs/Prices
5. Infrastructure Requirements
6. Operating Costs
7. Concluding Remarks
Will an Urea Infrastructure Developed if Engine Manufacturers Chose SCR for 2010 NOx Control?

- What vehicle applications will use SCR Urea?
- How much urea will be required for these applications?
  - NOx reduction needed
- How will urea be manufactured and supplied for the on-road market?
  - Urea specification
  - Aqueous urea: 32.5 % (vol) with deionized water
  - Trucked to large station users
  - Packaged/bottle and shipped to retail outlets
    - Totes
    - Barrels
    - Bottles
- What’s the cost and possible business case for manufacturing and distributing urea?
Several Light- and Heavy-Duty Engine/Vehicle Manufacturers Have Selected SCR as Their NOx Control Strategy

• On road SCR systems will use aqueous urea—on road specification at 32.5% mixed with deionized water

• For light-duty vehicles to meet Tier 2, Bin 5 NOx standards urea will require 2% aqueous urea (urea volume to diesel volume)

• For heavy-duty vehicles to reduce engine out NOx emissions from 1.2 g/bhp-hr to 0.2 g/bhp-hr will require 1% aqueous urea

• On-board urea storage depends on vehicle packaging, weight, and range considerations

Sources: NREL Study 2002
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**Estimated Urea Consumption**

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

- Consumption estimates were calculated for each vehicle class: LDV (1-5) and HDV (6,7) and HHDV (8)

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

- Sales estimates obtained from
  - Alliance of Auto Manufactures and EMA for LDVs (13.4% to 4.4%)
  - EMA for HDVs (consistent with Wards Sales data)

- Urea Consumption varying sales estimates and urea consumption used to provide range of estimates
  - Low range: 4.4% LDD sales (with 2% urea) and 1% urea in HDVs
  - High range: 13.4% AAM LDD sales and 2% urea in HDVs

Source: VIUS 2002

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Estimated Urea Consumption

Urea Consumption Estimates

<table>
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<tr>
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<td>Low Estimate</td>
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<td>High Urea Consumption Scenario Class 1-5</td>
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</table>

Sources: EMA, AAM Study 2004, VIUS 2002

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Urea Distribution Pathways

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

- Domestic Urea Producers
- Central Distribution Facility (CDF) Blenders
- Imported Dry Urea
- Agriculture Operations
- Industrial Users
- Stationary Urea SCR
- On-Road Urea SCR
  - Truck Stops
  - Fleet Refueling
  - Retail Stations
  - Other Retail

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**Urea Distribution Pathways**

**Urea Manufacturing and Specification**

**Catalytic Steam Reformer**

- Natural Gas
- Steam

**Catalyst Bed**

- H₂
- CO₂

**High Temp High Pressure Reactor**

- NH₃
- N₂

Ammonia Production

Urea Production

**Concentrated Urea Solution**

(Melt)

\[(NH_2)₂CO + H₂O\]

**Urea Classifications**

<table>
<thead>
<tr>
<th>Agency Listing</th>
<th>Hazardous</th>
<th>Carcinogenic</th>
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</thead>
<tbody>
<tr>
<td>EPA</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>OSHA</td>
<td>Yes²</td>
<td>No</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>
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</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></th>
<th>Unit</th>
<th>Min</th>
<th>Max</th>
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<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>
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<tr>
<td>Refractive Index at 20°C</td>
<td></td>
<td>1.3814</td>
<td>1.3843</td>
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<tr>
<td>Alkalinity as NH₃</td>
<td>wt%</td>
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<tr>
<td>Biuret</td>
<td>wt%</td>
<td>0.3</td>
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<tr>
<td>Aldehyde</td>
<td>mg/kg</td>
<td>5</td>
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<tr>
<td>Insolubles</td>
<td>mg/kg</td>
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<tr>
<td>Phosphate</td>
<td>mg/kg</td>
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<tr>
<td>Calcium</td>
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<tr>
<td>Iron</td>
<td>mg/kg</td>
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<tr>
<td>Sodium</td>
<td>mg/kg</td>
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<td></td>
</tr>
<tr>
<td>Potassium</td>
<td>mg/kg</td>
<td>0.5</td>
<td></td>
</tr>
</tbody>
</table>

Sources: NREL Study 2002
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Urea Distribution Pathways

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

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

Urea Tank Range Analysis

Fuel Economy: The fuel economy for light-duty cars is 29.60 mpg, for light heavy-duty trucks is 8.45 mpg, and for heavy heavy-duty trucks is 6.51 mpg.

Average Miles/Yr: The average miles driven in a year are 12,227 for light-duty cars, 12,974 for light heavy-duty trucks, and 41,500 for heavy heavy-duty trucks.

Urea Consumption %: The urea consumption percentage is 2.0% for light-duty cars, 1.0% for light heavy-duty trucks, and 1.0% for heavy heavy-duty trucks.

Urea Tank Size: The urea tank size is 7.5 gallons for light-duty cars and light heavy-duty trucks, and 20 gallons for heavy heavy-duty trucks.

Urea Tank Range: The urea tank range is 11,100 miles for light-duty cars, 16,901 miles for light heavy-duty trucks, and 13,025 miles for heavy heavy-duty trucks.

Diesel Tank Size: The diesel tank size is 13 gallons for light-duty cars, 100 gallons for light heavy-duty trucks, and 300 gallons for heavy heavy-duty trucks.

Diesel Tank Range: The diesel tank range is 385 miles for light-duty cars, 845 miles for light heavy-duty trucks, and 1,954 miles for heavy heavy-duty trucks.

Diesel Fills/Urea Fills: The ratio of diesel fills to urea fills is 28.85 for light-duty cars, 20.00 for light heavy-duty trucks, and 6.67 for heavy heavy-duty trucks.

Long Maint. Interval: The long maintenance interval is 7,500 miles for light-duty cars, 15,000 miles for light heavy-duty trucks, and 25,000 miles for heavy heavy-duty trucks.

Miles Short for Maint.: The miles short for maintenance are 0 for all vehicle classes.

Urea Gallons Needed: The urea gallons needed between maintenance intervals are 0.00 for light-duty cars, 0.00 for light heavy-duty trucks, and 18.39 for heavy heavy-duty trucks.
Characteristics of Private and Commercial Truck Fueling

Class 8

- Total: 73%
- Centrally Fuel: 22%
- Cardlock Station: 5%
- Public Station: 0%

Percent of Diesel Fuel Consumed
Heavy Duty Truck Fueling Occurs at Truck Stops, Cardlocks, and Central or Fleet Fueling

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

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

* Derived from the following sources
  (1) 2003 Aftermarket Business Survey Report
  (3) Various other trade reports

Sources: AAM Study 2004

Document Code: D5498

11
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
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**Urea Distribution Pathways**

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>
</table>
| Stillages\(^b\)          | 15,000-L (3,963-gal)  
                          | 3,000-L (793-gal)    | 2.12  
                          |                  | 2.52 |
| Totes                    | 1,000-L (264-gal)  | 2.78 |
| Bottles                  | 18-L (4.8-gal)     | 4.30 |
|                          | 10-L (2.6-gal)     | 4.63 |
|                          | 5-L (1.3-gal)      | 5.30 |

\(^a\) Pictures of Air1 are shown as an example and do not imply an endorsement of the product  

\(^b\) Stillages are covered under Pathway 1 in this analysis  

\(^c\) Prices are shown without applicable taxes.

Sources: AAM Study 2004
Retailer Costs Dominate Urea Costs for Underground Tanks Selling Less Than 10,000 gal/month*

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

Projected Urea Prices for Various Retail Distribution Strategies

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 Solution Price, $/gal

Retail Point Urea Throughput, Gal/Month
Methodology for Estimating Urea Infrastructure

- For pathway 1 segmented diesel fueling into station sizes and then assigned urea volume
  - Station size, number of stations, and percentage of diesel throughput
  - For each station size determined urea throughput based on percentage of diesel throughput
  - Determine type and number of urea dispensing systems needed to meet urea demand
    - Type based on infrastructure costs (function of urea throughput)
    - Above ground or underground tank systems for large throughputs, stillages for medium, and totes for small throughputs

- For pathway 2 assigned remaining urea demand among a widely distributed supply system that provides coverage within 20 miles to a high percent of U.S. population
  - Dealers, service stations, fueling stations, auto parts stores, and mass merchants (~30,000 sites throughout the U.S.)
  - Barrels and totes, and bottles
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**Infrastructure Requirements**

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

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

**Tanks/Dispensers In-Use**

- ~1,950 Tanks
- ~2,220 Tanks
- 17-34 Mgal/yr
- 116-262 Mgal/yr
- 72% of HD Fleet

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

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

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

Alert Urea Suppliers/Distributors

Vendors Supply Stillages

Stillage Manufacture

Retailers Install Stillages

Permits

Procure

Install

Stillages In-Use

1,300 gal Stillage throughput range: 100 to 2,000 gal/month
For Pathway 2A, Vendors Already Sell Urea in Totes for Stationary SCR Use but Will Need Significant Jump in Volume by 2010

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.

264 gal totes or barrels throughput range: 60 to 240 gal/month
Services both HD and LD Market
Vendors will need to set up bottling production to handle projected bottled urea demand.

Alert Urea Suppliers/Distributors

Setup Bottling

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

Bottles In-Use

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

- Dealers: 21%
- Service Stations: 19%
- Fueling Stations: 8%
- Auto Parts Stores: 1%
- Mass Merchants: 1%
Operating Costs for Urea are Lower than Fuel Penalty Costs of Other Alternatives for 2010 NOx Compliance

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

<table>
<thead>
<tr>
<th></th>
<th>Light Duty Class 1-2</th>
<th>Heavy Duty Class 8</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Local &lt;200 miles</td>
<td>Medium 200-500 miles</td>
</tr>
<tr>
<td>Fuel Economy (mpg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VMT (mi/yr)</td>
<td>13,100</td>
<td>25,000</td>
</tr>
<tr>
<td>Urea Consumption</td>
<td>1%</td>
<td>2%</td>
</tr>
<tr>
<td>Urea Price ($/gal)</td>
<td>4.97</td>
<td></td>
</tr>
<tr>
<td>Diesel Price ($/gal)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5% FE Penalty ($/yr)</td>
<td>$68 - $109</td>
<td>$129 - $208</td>
</tr>
<tr>
<td>Urea Costs ($/yr)</td>
<td>$37 - $74</td>
<td>$70 - $141</td>
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</tbody>
</table>
Concluding Remarks

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

- Clear signal from vehicle manufacturers is needed by 2007
  - Urea manufacturers
  - Urea distributors (CDFs)--some construction lead time
  - Urea Retailers--permitting and construction lead times
  - Equipment and system manufacturers—manufacturing lead times

- European experience will help U.S. infrastructure development
  - Vendors with product already developed for stillages, totes, and bottles
  - U.S. numbers not overwhelming according suppliers of dispensing equipment

- Margins make a reasonable business case based on “averages”, but detail planning will be required to achieve these margins
  - Need to meet urea demand but not strand infrastructure investment
  - Easiest for large volume stations harder for small volume stations
Thank You For Your Attention

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

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

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