Fabricio Cardoso
Lead Analyst, Emissions
Integer Research, Ltd.

The Market Outlook for Diesel Exhaust Fluid
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Savannah, Nov 18 - 20, 2014
2014 Fertilizer Outlook & Technology Conference
FROM AIR QUALITY STANDARDS TO DEF
The relationship between air quality, emission standards and DEF

PM – particulate matter, HC – hydrocarbons, CO – carbon monoxide, NOx – nitrogen oxide, CO2 – carbon dioxide

Source: Integer
NOx and PM levels have been dramatically reduced since the first standards.

Source: Integer, EPA, NHTSA
Demand driver: why ammonia/urea?

The combustion trade-off:
- Injection timing, Exhaust Gas Recirculation

NOx:
- High temperatures
  - SCR & alternatives
    - Ammonia or urea reductant

Particulates / soot:
- Incomplete combustion
  - Filters
    - Expensive maintenance
Several aftertreatment technologies are available to reduce NOx levels.

**Aftertreatment technologies to reduce NOx levels**

- **Exhaust Gas Recirculation (EGR)**
- **Lean NOx Trap (LNT)**
- **Selective Catalytic Reduction (SCR)**

**Selective Catalytic Reduction (SCR)**

- AUS 32 (urea solution, 32.5 wt%)
- DEF

NO, NO₂ (NOₓ) from combustion

Ceramic catalyst (Vanadium, Iron, Copper)

N₂, H₂O

SCC TECHNOLOGY USES AMMONIA TO REDUCE NOₓ TO ELEMENTAL NITROGEN AND WATER.
The EPA has regulated heavy-duty diesel engine emissions since its inception in 1970, but GHG and fuel economy requirements have just been introduced.

<table>
<thead>
<tr>
<th>NOx limit (g/bhp-hr)</th>
<th>Fleet-wide CO\textsubscript{2} compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td>EPA ‘98</td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td>2002</td>
</tr>
<tr>
<td>EPA ‘04</td>
<td></td>
</tr>
<tr>
<td>1.2</td>
<td>2007</td>
</tr>
<tr>
<td>EPA ‘07</td>
<td></td>
</tr>
<tr>
<td>0.2</td>
<td>2010</td>
</tr>
<tr>
<td>EPA ‘10</td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td></td>
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<tr>
<td>2017</td>
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<td>2020</td>
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<tr>
<td>2021</td>
<td></td>
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<tr>
<td>2025</td>
<td></td>
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</tbody>
</table>

Navistar adopts SCR, last OEM to do so.

SCR used by all but one truck OEM. Navistar uses high-flow EGR and credits.

Truck-makers use EGR technology, fuel efficiency drops.

OEMs circumvent emission standards, EPA introduces strict test procedures and Not-To-Exceed limits.

Source: Integer, EPA, NHTSA
If SCR requires ammonia, why urea?

- Ammonia is technically more suitable for use in every application

- However: storing, transporting, dispensing and using ammonia has challenges due to its pungent smell and safety-related issues

- **Urea is therefore used as an ammonia carrier.** It must first be converted back to ammonia before it can be used to destroy NOx

- Other options were considered, including aqueous ammonia and ammonium formate and more recently solidly methods for storing ammonia. None have yet reached commercial acceptance.
  - Absorbed on a salt matrix: Amminex
  - As ammonium bicarbonte: Tenneco
Urea fluid standardised globally

- 32.5% urea solution – allows freezing of vehicle tank
- Names: AdBlue / Diesel Exhaust Fluid (DEF) / ARLA-32

- ISO 22241 standard defines the quality requirements
  - biuret and formaldehyde limits mean that fertilizer urea cannot be used
  - water must be de-ionised
- This standard was originally defined by truck industry in discussion with catalyst suppliers and urea producers, then adopted by non-road equipment and car manufacturers.

- 40% urea solution for marine applications because tank freezing is not an issue
VEHICLE, SCR AND DEF FORECAST
While the majority of commercial vehicles in North America are equipped with a diesel engine, the share of diesel passenger cars and light-duty vehicles is still small compared to other regions.

<table>
<thead>
<tr>
<th>Category</th>
<th>Diesel</th>
<th>Non-Diesel</th>
<th>Total (Million Vehicles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDV</td>
<td>95.7%</td>
<td>4.3%</td>
<td>8.9</td>
</tr>
<tr>
<td>PC</td>
<td>1.4%</td>
<td>98.6%</td>
<td>8.3</td>
</tr>
<tr>
<td>MDV/HDV</td>
<td>93.0%</td>
<td>7.0%</td>
<td>0.4 million</td>
</tr>
</tbody>
</table>

Source: Integer, WardsAuto, ACT
The commercial vehicle SCR fleet is expected to be six times bigger in 2025 compared to 2013.

Source: Integer
More than 11 million passenger cars and light-duty vehicles are forecast to be on the road in North America by 2025.
Our base-case scenario shows DEF consumption is expected to reach 1 billion gallons in North America by 2019.

Source: Integer Research
DEF MARKET, CURRENT AND OUTLOOK
DEF logistics: It’s all about the water

- 67.5% of AdBlue/DEF is water
- Supply chain options account for transport optimisation:
  - End-user prices reflect supply chain requirements
About 65% of total DEF consumption in 2013 originated from domestic urea production.
DEF production from urea plants in North America totalled 147 million gallons in 2013.
Midwest, Gulf Coast and Canada have the highest shares of DEF coming from domestic urea plants.
What to expect for 2020?

• Urea plants coming online – domestic DEF production will remain strong

• More efficient logistics – urea plants producing more concentrate solution and distributing to solutionizing & dilution plants across the country and closer to the main consumption markets

• Prilled urea imports – likely to maintain an important growth, specially in California, where the gap between supply and demand will increase
Thank you!
Fabricio.cardoso@integer-research.com
Our nitrogen publications

Nitrogen
Cost and Profit Margin Service
An extensive business-focused analysis of the global nitrogen fertilizer industry

Focus Report
The Chinese urea industry: addressing the global impact
The first report of its kind to comprehensively analyse the China urea cost curve

Industry Insight
Navigating the North American Nitrogen Market