Ensuring the Availability and Reliability of Urea Dosing For On-Road and Non-Road

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PURPOSE

"We need assurance that urea is available nationwide and the engine maker must ensure you can't operate the engine without urea"

Quote by Jeff Holmstead, Assistant Administrator US EPA taken from the Diesel Fuel News, June 23, 2003

The purpose of this presentation is to address these two important issues

EXPERIENCE

Terra Industries

- One of the largest producers of ammonia with annual revenues >$1Billion
- 6 nitrogen manufacturing plants in NA and 2 in UK
- 2 methanol manufacturing facilities in NA
- www.terraindustries.com

Hilite International

- Multinational corporation with facilities in US, Germany, and France; annual revenues $400M
- Supplier of valves for engines & transmissions incl. diesel fuel systems
- Manufacturer of urea dosing units for SCR
- www.hilite-ind.com

A. D. Little Report – 2001

In August 2001, A.D.Little released a report on "Supplying Urea for the On-Road Vehicle Market"

- **The report concluded: "Urea is a viable reductant for using SCR technology in diesel vehicles"**
- **The report identified the establishment of a urea distribution infrastructure as a major issue with many open questions**

These findings prompted additional study

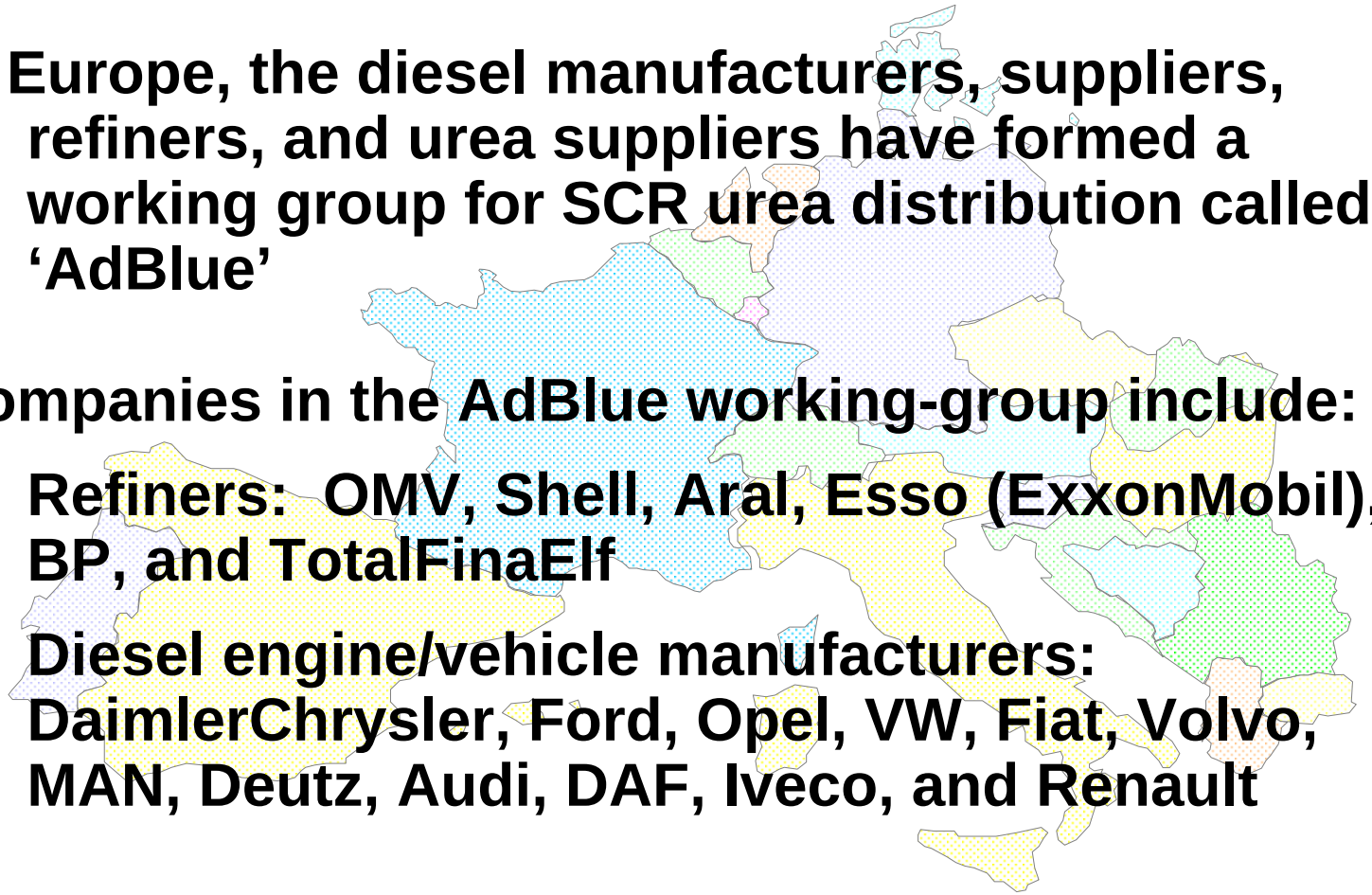
TIAX Report - 2003

TIAX released a study analyzing possible business cases for a viable urea infrastructure in the US

- **The study identified key stakeholders as engine & truck manufacturers, truck operators, urea manufacturers and distributors, and diesel fuel retailers**
- **The study identified potential business models to support profitable distribution of urea for SCR**
- **The study identified potential distribution pathways utilizing existing pathways and equipment**
- **The study concluded infrastructure can be in place by 2007**

We will further address these issues today

European Urea Distribution Plans



In Europe, the diesel manufacturers, suppliers, refiners, and urea suppliers have formed a working group for SCR urea distribution called 'AdBlue'

Companies in the AdBlue working-group include:

- **Refiners: OMV, Shell, Aral, Esso (ExxonMobil), BP, and TotalFinaElf**
- **Diesel engine/vehicle manufacturers: DaimlerChrysler, Ford, Opel, VW, Fiat, Volvo, MAN, Deutz, Audi, DAF, Iveco, and Renault**

European Urea Distribution Plans

AdBlue's goal is to resolve potential problems with urea supply, distribution, and handling

- **AdBlue developed a standard for SCR quality urea**
- **The group is currently developing standards for urea nozzles and urea tank filler necks**
- **Refiners will open SCR urea facilities this year**
- **Negotiating with commercial fleet operators on installation of urea resupply centers at terminals**
- **AdBlue expects distribution to facilities to begin with private trucking company terminals, then move to commercial fleet card locks & truck stops, and then to public diesel fueling stations as demand grows**

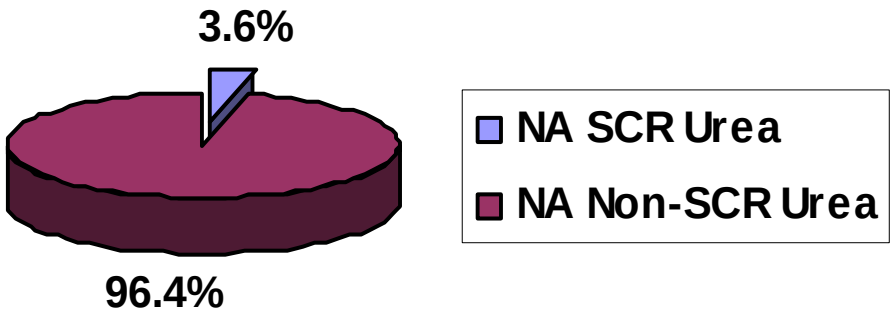
NA SCR Urea Demand/Supply

The US demand for 32.5%wt SCR quality urea for new Class 8 trucks has been estimated as:

- **200 - 350 million gallons in 2007**
- **600 - 1100 million gallons by 2015**

*** Reference TIAX LLC .**

NA urea production in 2007 is projected to be: 13,700,000 tonnes (equivalent to 9.7 billion gallons of 32.5%wt urea)

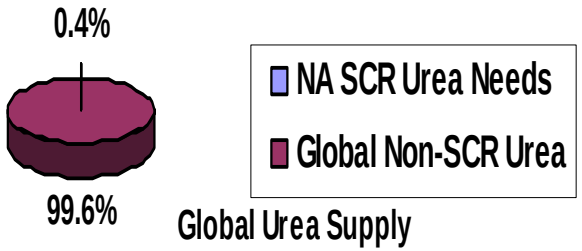


2007 NA Urea Production

NA SCR Urea Demand/Supply

2007 Global urea production is estimated to be greater than 124 million tonnes

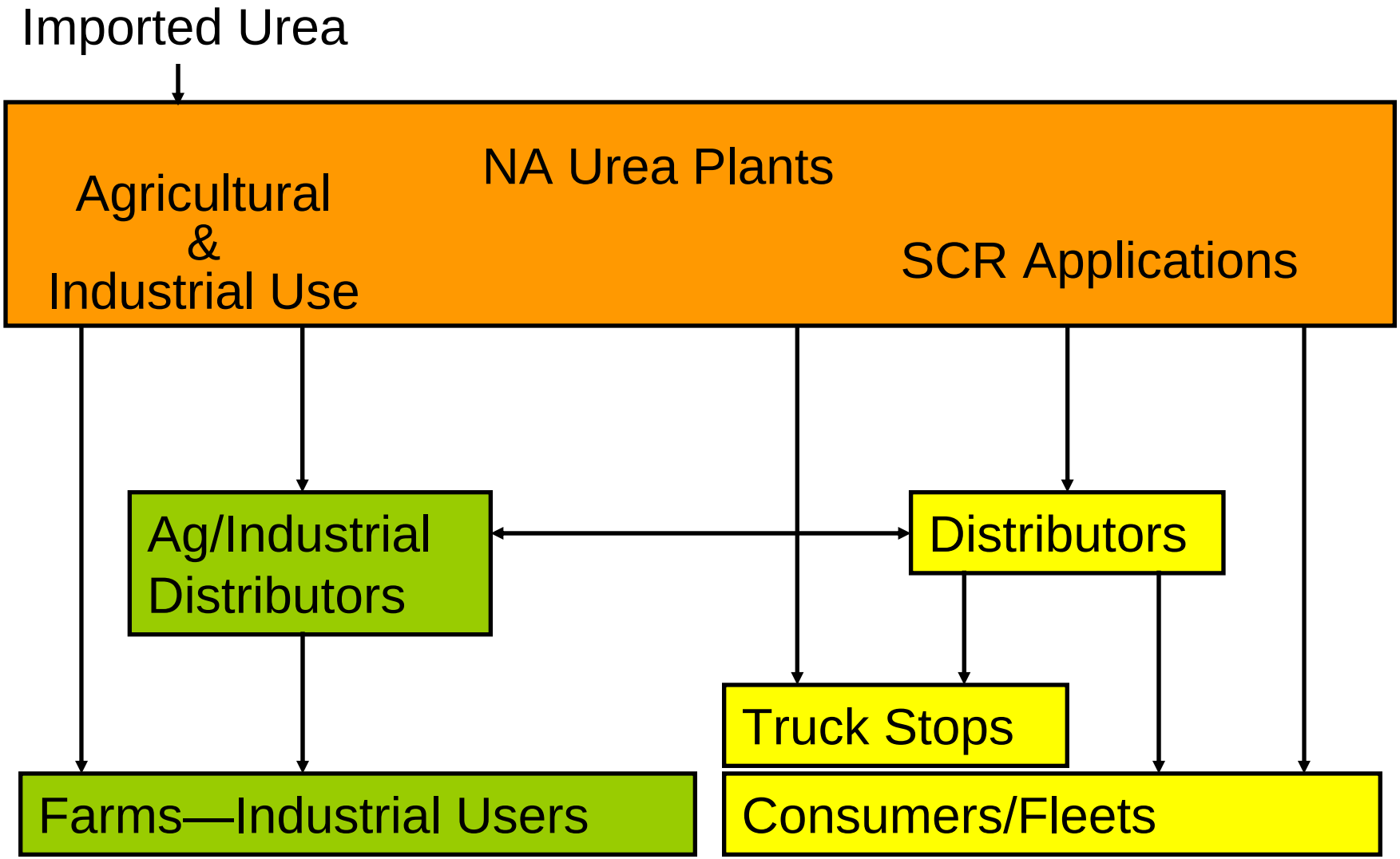
- **NA urea needs for SCR would be less than ½% of urea supply**



By 2007 more than 30 million tonnes of urea will be available on the global export market

- **The additional demand created by NA SCR would be less than 2% of current projected global urea export supplies**

Urea Distribution Pathways



Urea Distribution Pathways

Initial transport from the urea plant could be in the form of solid urea or concentrated liquid urea 70%wt and diluted later in the distribution chain

- More efficient/cost effective transport

Due to purity, cleanliness, and ease of dilution and handling in distribution we recommend liquid urea

- A simple process at the distribution center to dilute the liquid urea with distilled water to the desired concentration is all that would be needed

Imported urea would best be used to supplement supplies for agricultural use and domestic supply used for SCR due to cleanliness and purity

Distribution Phase-In

Long-term distribution would be through distribution networks similar to diesel fuel – using rail cars and tankers to deliver to distributors, truck stops, and commercial stations - or directly to fleets

In the interim while demand and distribution is ramping up, a variety of distribution methods could be used:

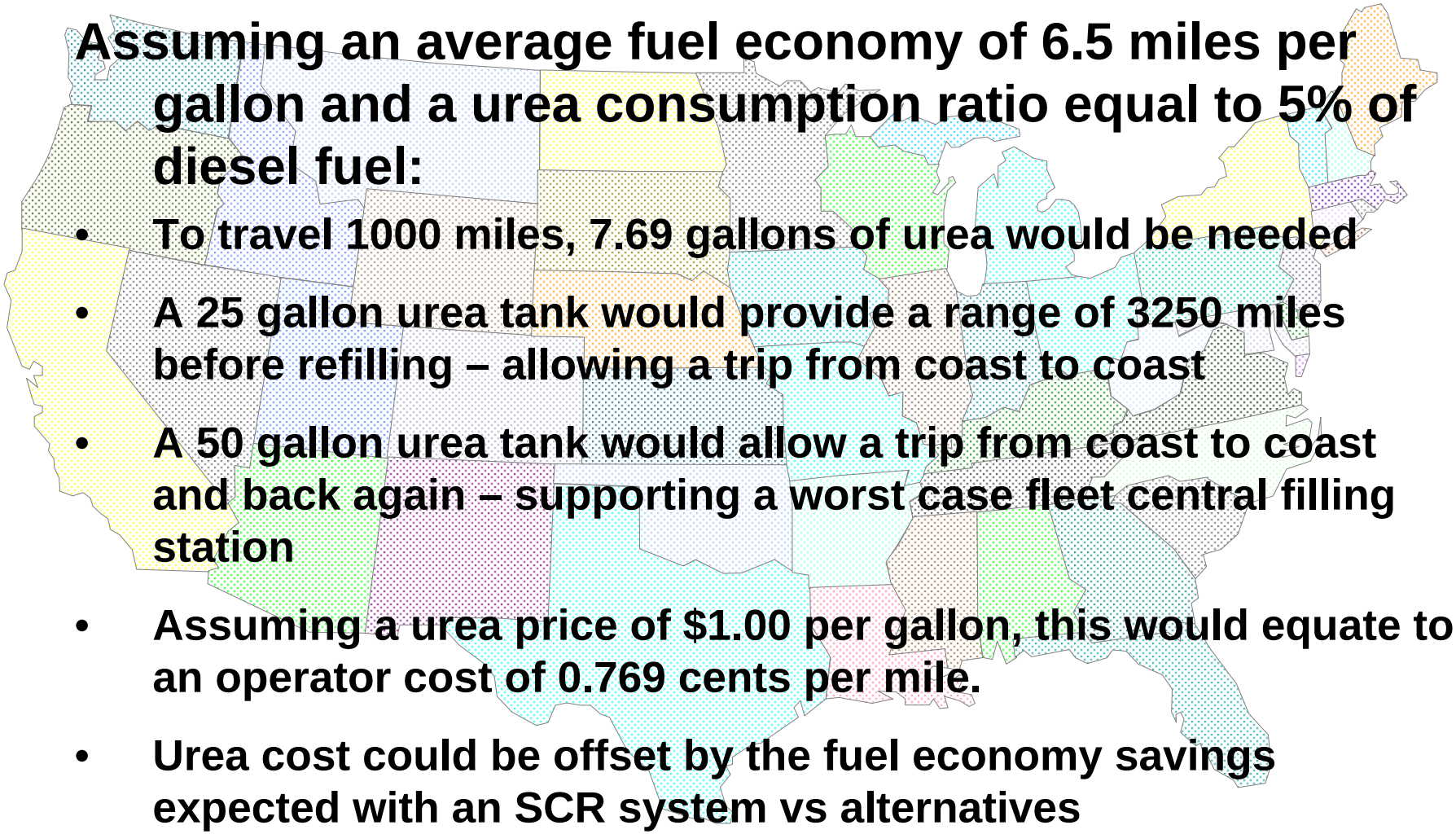
- **For sites with large demand and throughput, concentrated urea could be delivered by rail car or tanker at low cost and diluted on site for distribution**
- **For sites with moderate demand, 32.5%wt urea could be delivered by tanker to storage tanks for distribution**
- **For sites with low demand, 32.5%wt urea could be delivered in 200 gallon totes or 55 gallon drums**

Urea Cost

The urea cost to the end customer would be dominated by distribution costs

- **The material cost for urea coming out of the NA plants would be low – approximately 41 cents/gallon (32.5%wt equivalent) with a natural gas cost of $5.40/ MMBtu.**
- **Natural gas price fluctuations would primarily effect only the material cost and even large fluctuations in natural gas prices would cause only fluctuations of a few cents in urea prices**
- **The urea price to the customer would be highly effected by the throughput at the distribution point**
- **Urea prices to the end user assuming reasonable demand and throughput at the distribution points should be in the range of $1.00/ gallon.**

Impact on Consumer



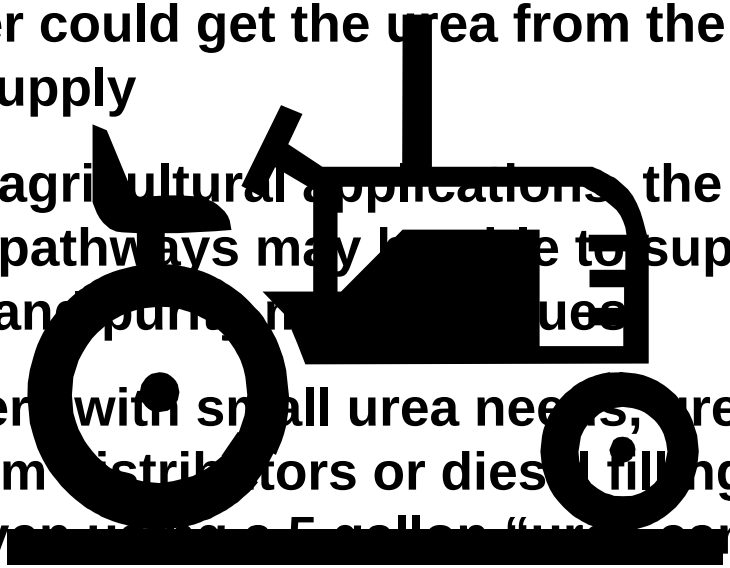
Assuming an average fuel economy of 6.5 miles per gallon and a urea consumption ratio equal to 5% of diesel fuel:

- **To travel 1000 miles, 7.69 gallons of urea would be needed**
- **A 25 gallon urea tank would provide a range of 3250 miles before refilling – allowing a trip from coast to coast**
- **A 50 gallon urea tank would allow a trip from coast to coast and back again – supporting a worst case fleet central filling station**
- **Assuming a urea price of $1.00 per gallon, this would equate to an operator cost of 0.769 cents per mile.**
- **Urea cost could be offset by the fuel economy savings expected with an SCR system vs alternatives**

Non-Road Supply

Urea distribution for non-road diesel applications could be supported in a number of ways

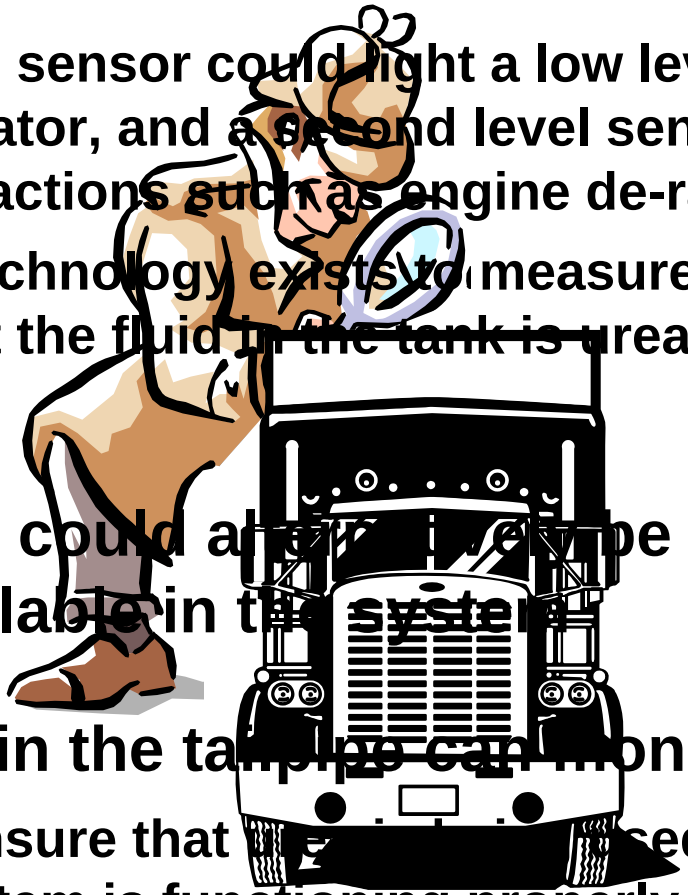
- **The end-user could get the urea from the same source used for diesel fuel supply**
- **In non-road agricultural applications, the agricultural urea distribution pathways may be able to support urea supplies – cleanliness and purity issues**
- **For customers with small urea needs, urea could be made available from distributors or diesel filling stations in 55 gallon drums, or even through a 5 gallon "urea can" that could be refilled at a filling station or truck stop as necessary**



Ensuring Urea is Used during Operation

Urea level in the tank could be monitored with sensors

- **The tank level sensor could light a low level warning light to alert the operator, and a second level sensor could trigger enforcement actions such as engine de-rate or shutdown**
- **The sensor technology exists to measure urea concentration to ensure that the fluid in the tank is urea of acceptable concentration**



An NH_3 sensor could also be used to ensure urea is available in the system

A NOx sensor in the tailpipe can monitor full function

- **This would ensure that the system is used as needed and that the entire system is functioning properly**

NOx Sensors

NOx sensors are currently available with performance necessary to support SCR system operation and monitoring

- **Accurate in the low range necessary to measure compliance (+/- 20ppm)**
- **Response time approximately 750ms (future target of 500ms)**
- **Currently have 120,000 mile life for HD and expected to be capable of at least 150,000 miles by 2007**
- **NOx sensors are currently in production in Europe for passenger car applications**

Bosch Diesel Car Sensor NOx Sensor

NOx Sensor from Denso

Monitoring and Enforcement

A monitoring system similar to On Board Diagnostics (OBD) could support actions such as:

- **Warn the operator when urea tank levels are low (level sensor)**
- **Trigger enforcement action if urea tank is empty or near empty (level sensor)**
- **Trigger warning and enforcement action if fluid other than urea is filled into urea tank (urea concentration or ammonia sensor)**
- **Warn the operator and/or trigger enforcement action if NOx level exceeds limits (NOx sensor)**
  - **Enforcement actions of increasing severity could be triggered depending upon duration of high NOx level**
  - **NOx level monitoring would also accomplish monitoring of the presence of urea in system**

Monitoring and Enforcement

Enforcement actions could include:

- Light a warning light or Malfunction Indicator Light (MIL)
- De-rating engine performance to encourage corrective action if initial warnings are ignored
- Engine shutdown or blocking engine restart after shutdown if system faults exist and corrective actions are not being pursued in a timely manner
- Vehicles found to have a MIL light on and/or fault codes due to emission system faults that have not been corrected could be subject to fines
- More discussion is needed between industry and government groups to determine the best enforcement options, but the technology and processes necessary are available today

Summary

Urea availability and distribution

- NA urea production can support SCR needs for HD trucks
- Existing distribution methods, pathways, and technology could be utilized for urea supply – no new invention required
- Urea usage and storage capacity on vehicles would support long distances between tank refill – SCR could be initially rolled out with a limited infrastructure
- Urea price should be less than diesel fuel and urea SCR should have a fuel economy advantage over competing technologies – urea SCR should have lowest lifetime cost
- Infrastructure can be in place by 2007

Summary

Urea monitoring and enforcement

- Sensor technology exists to monitor urea tank level and verify that the fluid in the tank is urea
- NOx sensors are available to monitor tailpipe NOx, ensuring the entire SCR system is functioning properly, and inferring that urea is in the system
- The monitoring system could be used to monitor compliance, record faults, and initiate enforcement actions as necessary
- The monitoring system could initiate actions to encourage compliance such as:
  - light warning lamps or chimes
  - De-rate engine performance
  - Shut down engine under certain circumstances
  - These actions are already used in HD for other reasons

Conclusion

Solutions exist to resolve the major issues that are obstacles to the implementation of urea SCR technology for HD Trucks

But… the trucking, diesel, urea, and petroleum industries must organize and begin taking action now if urea SCR is to be ready for 2007