Supplying Urea for the On-Road Vehicle Market

7th Diesel Engine Emissions Reduction (DEER) Workshop
Fuels and Lubricants Section

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- Introduction
- Urea Impurities
- Urea Production
- Urea Pathways
- Urea Demand
- Summary

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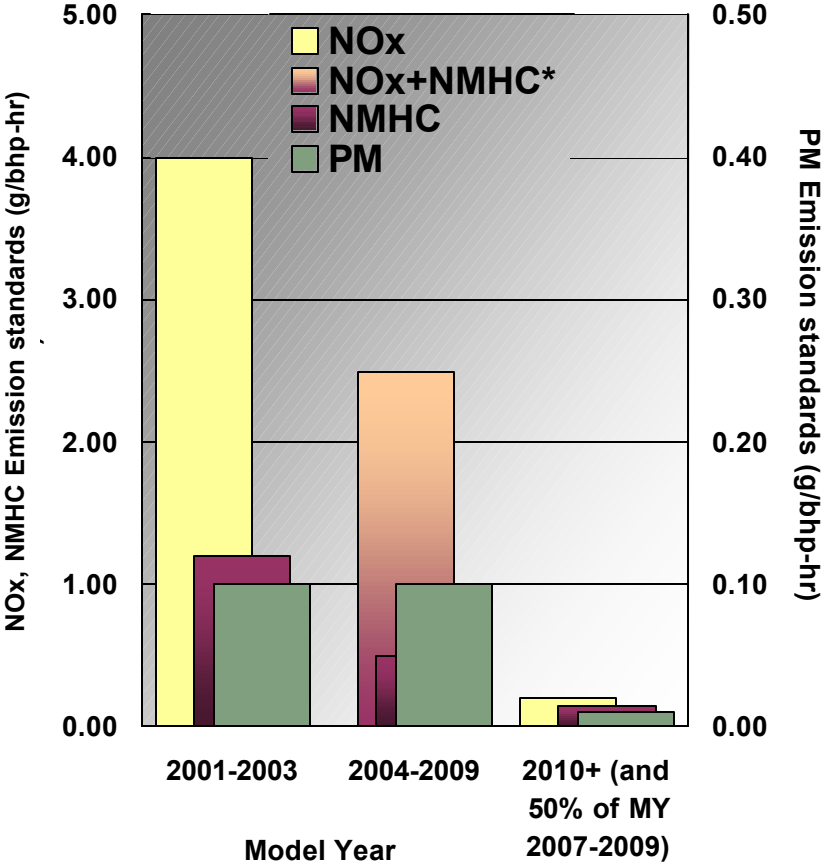
Project Background and Objectives

- DOE is interested in assessing viable exhaust after-treatment technology for heavy-duty and light-duty diesel engines. SCR is one technology that is being developed to reduce NOx emissions to meet 2007 emissions standards. A key component of SCR technology is the supply and distribution of urea which is typically dissolved in water at 32.5% (wt).
- Determine SCR infrastructure requirements for diesel vehicles:
  - Determine pathways for the manufacture and distribution of urea-water solutions
  - Estimate reductant consumption
  - Estimate capital requirements and retail costs
  - Assess environmental impact of spills
  - Estimate life-cycle greenhouse gas emissions
- Provide assessment of potential hurdles or possible roadblocks in the supply and distribution of urea for SCR systems used on heavy- and light-duty vehicles.

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 will meet MY2004 standards starting October 2002
  - MY2010 low-emission standards applies to 50% of MY2007-2009 sales, and all of MY2010+ sales
- Potential technologies to meet new requirements:
  - Exhaust Gas Recirculation (EGR)
  - Diesel Particulate Filters (DPF)
  - NOx adsorbers
  - SCR systems



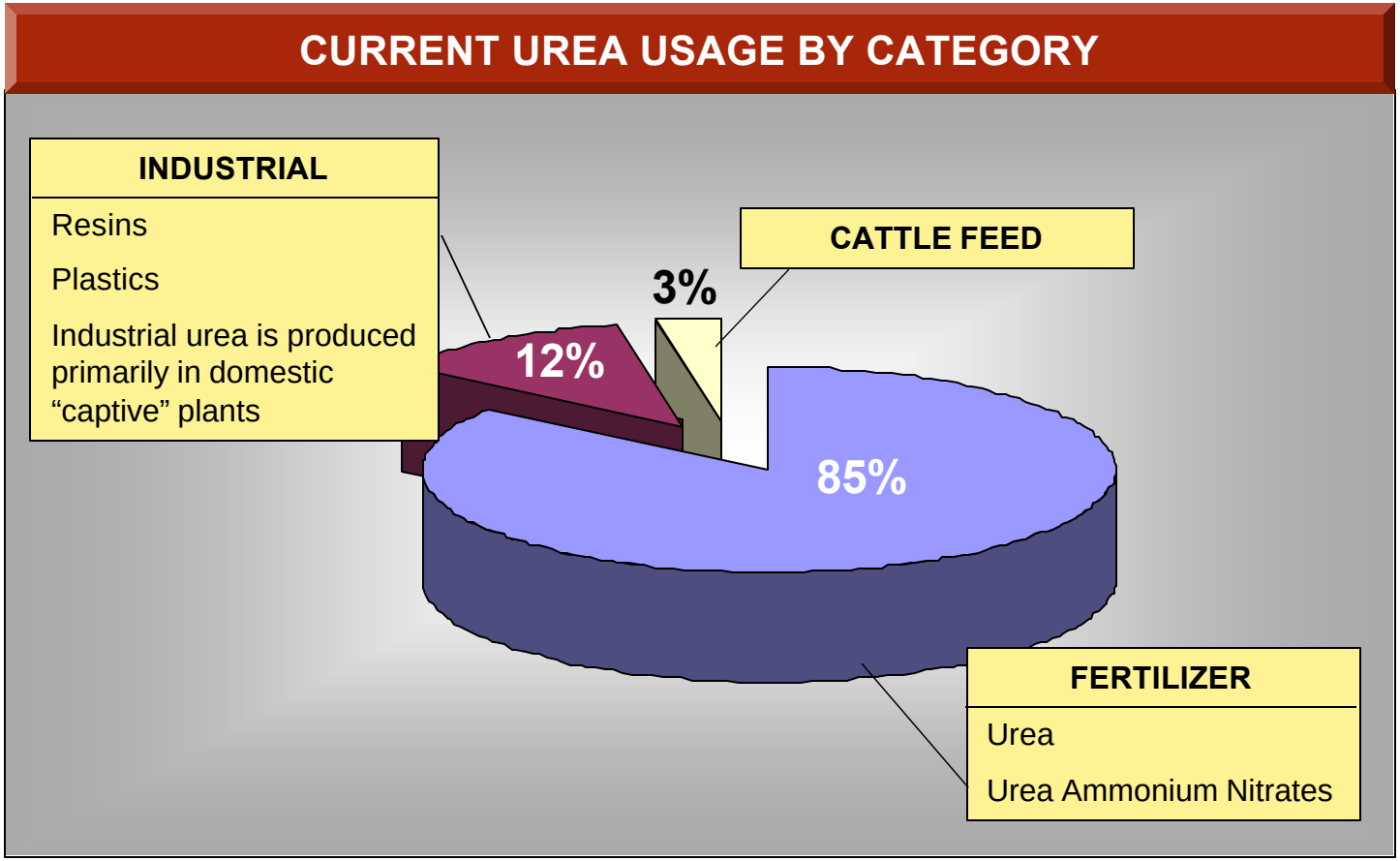
*Engine manufacturers may substitute a NOx+NMHC engine certification standard of 2.4 g/bhp-hr in place of the MY 2004-2009 independent NOx+NMHC and NMHC standards.

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 heath 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 experience

SCR Catalyst

Urea dosing Unit and Integrated Urea/Diesel Tank



Average U.S. Urea Usage: 9 to 10 million tons* per year

*"tons" refers to short tons throughout this presentation

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Urea quality specifications for SCR systems will depend upon the contaminant thresholds of the emission control systems

- Grades of urea available:
  - Agricultural (solid)
  - Industrial grade (solid or liquid)
  - High-quality/reagent grade (solid or liquid)
- Agricultural and industrial urea contain conditioners added to enhance end-use application
- SCR systems and other emissions reduction equipment (oxidation catalysts, diesel particulate filters) may not tolerate impurity levels found in some grades of urea

	Agricultural Grade	Industrial Grade
Form	Granular	Granular
Total Nitrogen (%)	46.0	46.0
Biuret Content (%)	1.2 - 1.4	1.3
Conditioner (%)	0.3 - 0.5	1.5
Free Ammonia (ppm)	NA	120
Ash (ppm)	50	60
Iron Content (ppm)	1 - 2	3

High-purity urea is also readily available, should emissions control systems require low contaminant levels

- Emission control systems used in tandem with SCR may require high-quality grade urea in order to avoid contamination
- Urea is typically manufactured first as high-purity grade — conditioning agents are added later in the process stream to produce other grades
- Any of these grades could be produced in sufficient quantity to meet SCR demand

High-Purity Grade	
Form	Crystals
Biuret Content (%)	0
Iron Content (ppm)	<0.5
Copper (ppm)	<0.5
Lead (ppm)	<0.5
Chloride (ppm)	<5.0
Sulfate (ppm)	<100
Urea Assay (%)	>99.5
Melting Point (°C)	132 - 135

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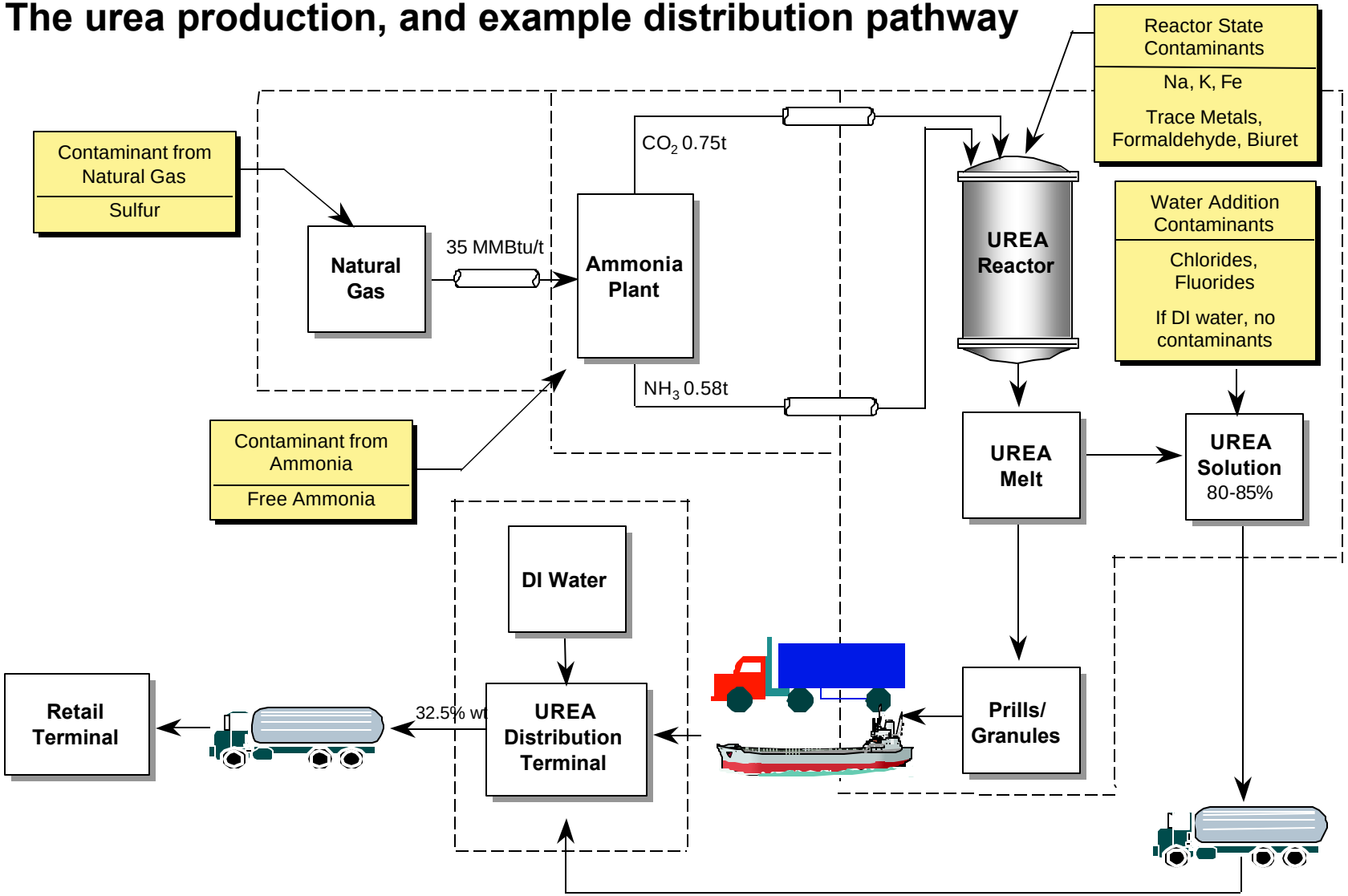
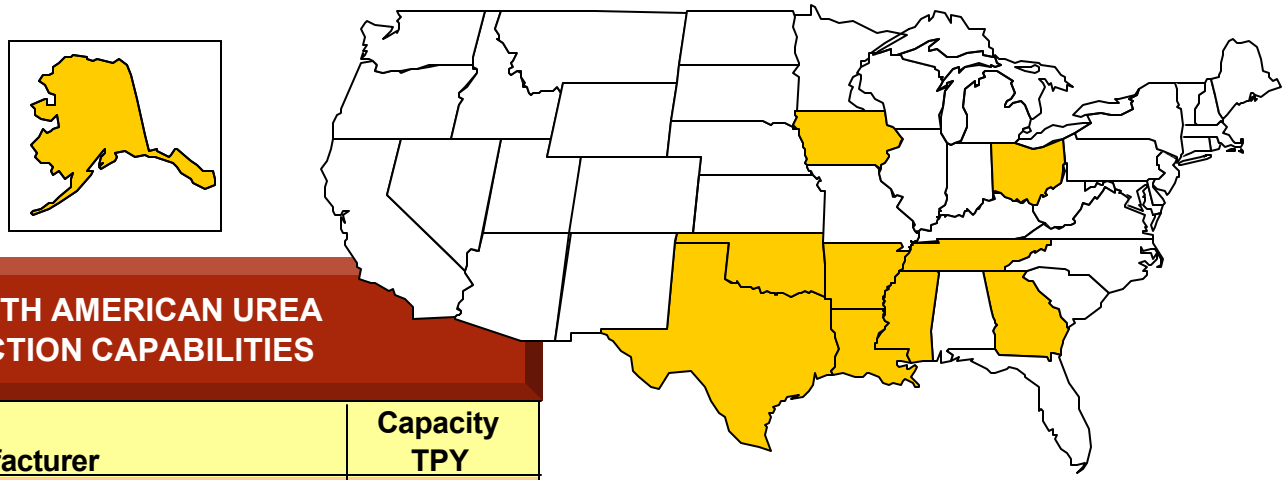
The urea production, and example distribution pathway



Major Urea Producing States in the United States



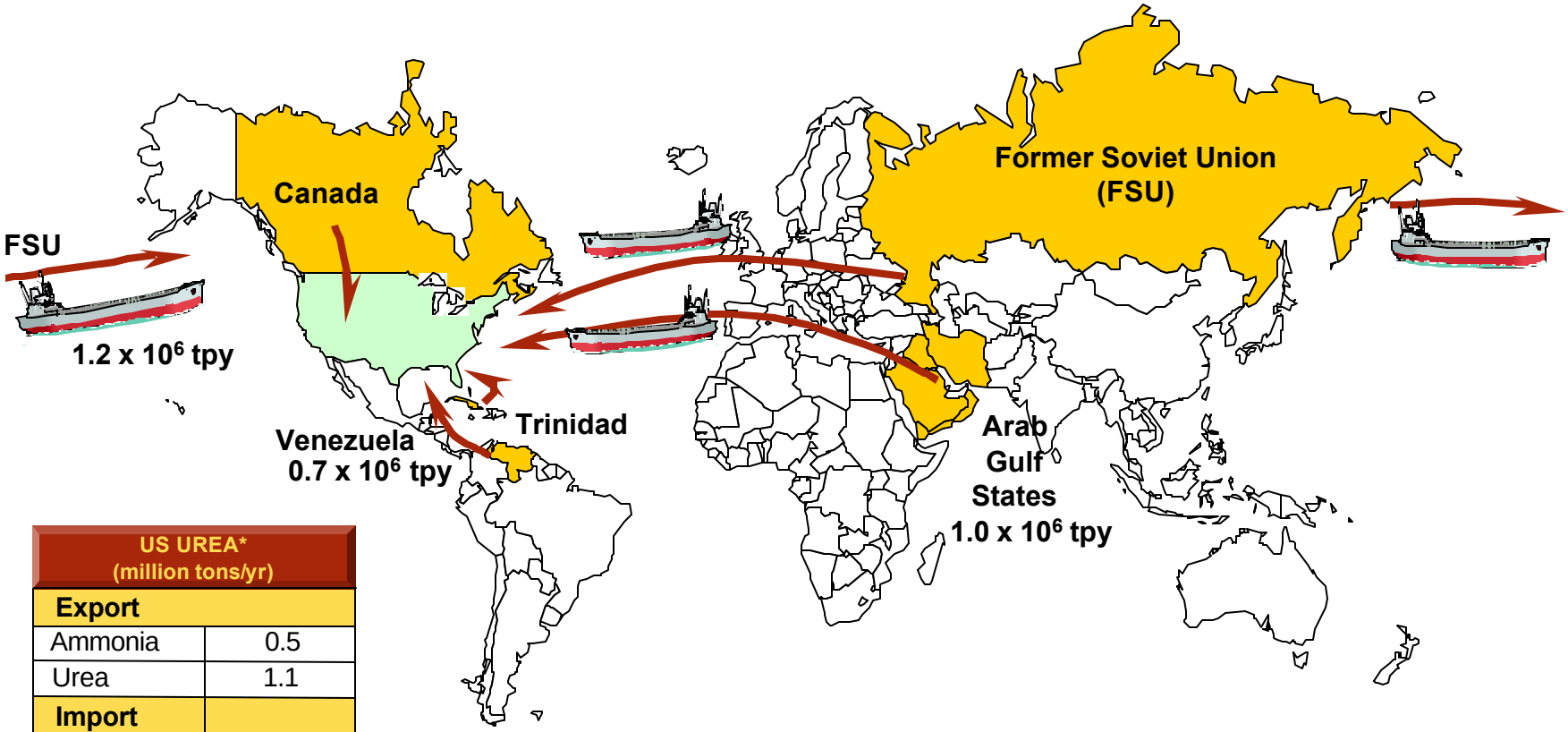
KEY NORTH AMERICAN UREA PRODUCTION CAPABILITIES

Manufacturer	Capacity TPY
PCS Augusta, GA; Geismar, LA; Lima, OH; Memphis, TN; Trinidad	**1,826,000**
CFI Donaldsonville, LA	**1,700,000**
Farmland*	**2,670,000**
Terra Industries Courtright, Ontario; Woodward, OK; Blytheville, AR; Port Neal, IA	**715,000**
Agrium Carseland, Calgary; Borger, TX; Ft. Saskatchewan, Saskatoon; Kenai, AK	**2,279,000**
Mississippi Chemicals Yazoo City, MS; Donaldsonville, LA	**838,000**
Total	**10,028,000**

*Most of the Urea produced is converted to UAN fertilizers at the Farmland factories

- Rising Domestic natural gas prices, cheaper imported urea, supply/demand instability, and an production capacity comprised predominantly of older, inefficient urea plants have resulted in 50% utilization for current domestic urea production
- There are well-developed fertilizer distribution channels

Major Urea Exporters to the United States



US UREA* (million tons/yr)	
Export	
Ammonia	0.5
Urea	1.1
Import	
Ammonia	3.3
Urea	2.9
Net	
Ammonia	-2.8
Urea	-1.8

*Average, 5 years: 1995-1999

- Majority of urea is exported to U.S. manufacturing plants and large terminals as solid urea. Agricultural additives are introduced at these points
- Most imported urea is granular urea

FACTORS INFLUENCING U.S. UREA IMPORTS

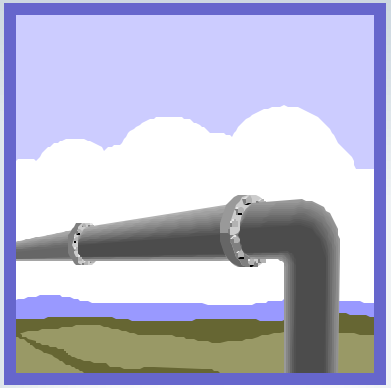
In the short term, urea imports are inevitable!

- **High domestic natural gas prices**
- **Increased supply of low-priced urea from foreign markets. Low-prices are enabled by cheap natural gas (< 1 $/MMBtu), new generation urea plants, lower operating costs and governmental support**

Average Natural Gas Costs, Y2000	$/MMBtu
FSU	0.90
Arab Gulf States	0.55
Venezuela	0.50
USA	4.00

- **The cost of manufacture can be as low as 17 - 33 $/ton of urea overseas at the above prices**
- **In contrast, the cost of manufacture in the U.S. at a natural gas price of $4/MMBtu is around 120 $/ton**

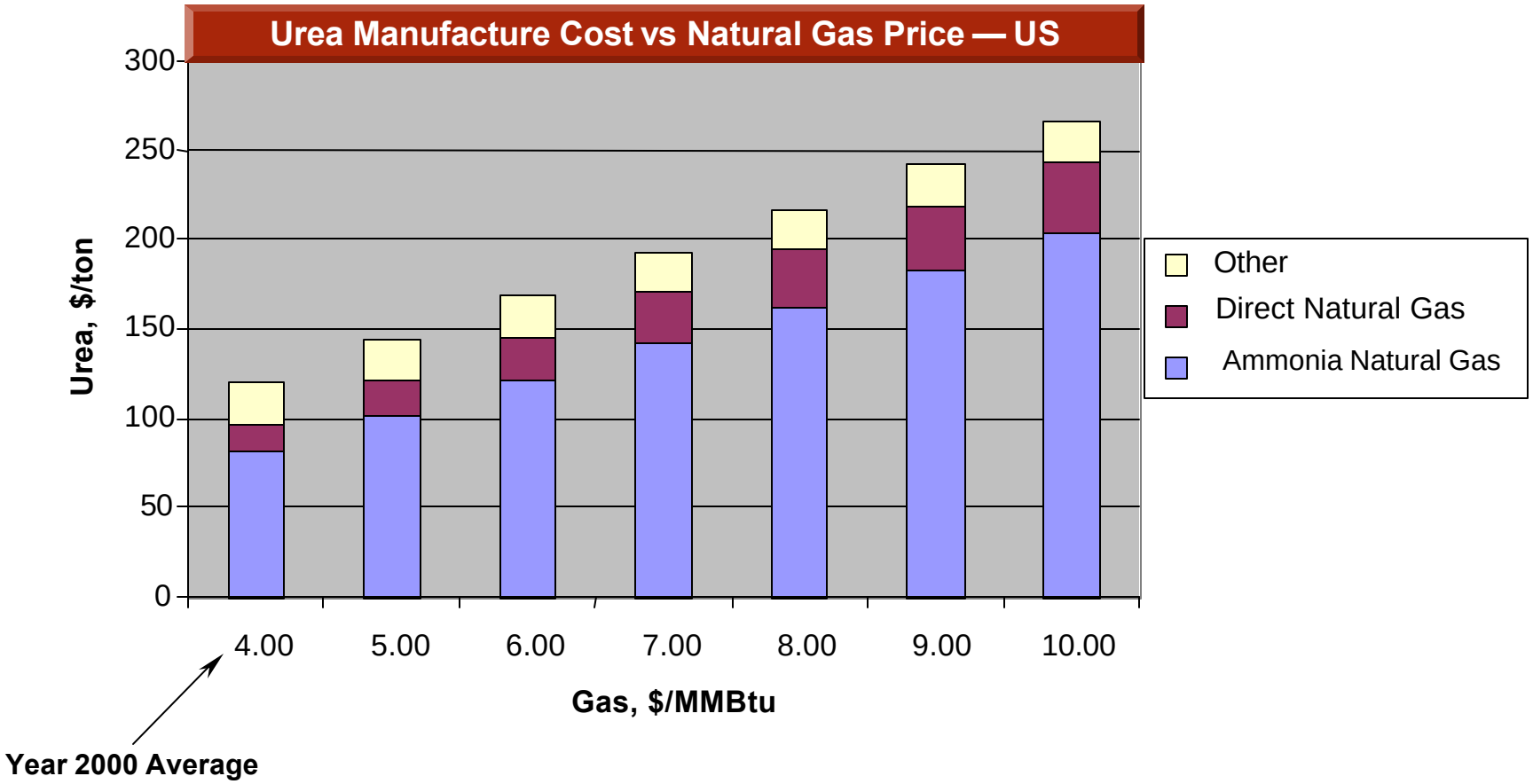
MAJOR FACTORS CURRENTLY AFFECTING THE PRICE OF UREA



PRICE OF NATURAL GAS

AGRICULTURAL DEMAND

UREA PRICE


Urea Manufacture Cost vs Natural Gas Price — US
Urea, $/ton
300
250
200
150
100
50
0
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Gas, $/MMBtu
Other
Direct Natural Gas
Ammonia Natural Gas
Year 2000 Average

UREA AVAILABILITY

		Million tons/Year
Current Annual Average U.S. Demand		9 to 10
Projected Additional Demand with SCR Usage	2007	0.2
	2010	1
Current U.S. Production Capacity		10
Current U.S. Production		6 to 7
Average U.S. Imports		3 to 4
Current World Production		110
Current World Aggregate Surplus of Urea — Stockpiles		4 to 6
Production Loss Due to Recent U.S. Plant Shut Downs, Since June 1999		1.2

The additional demand for SCR Urea is not likely to alter the dynamics of U.S. and world urea markets

Whether the SCR Urea will be manufactured in the U.S. or imported will primarily depend on the price of natural gas in the U.S.

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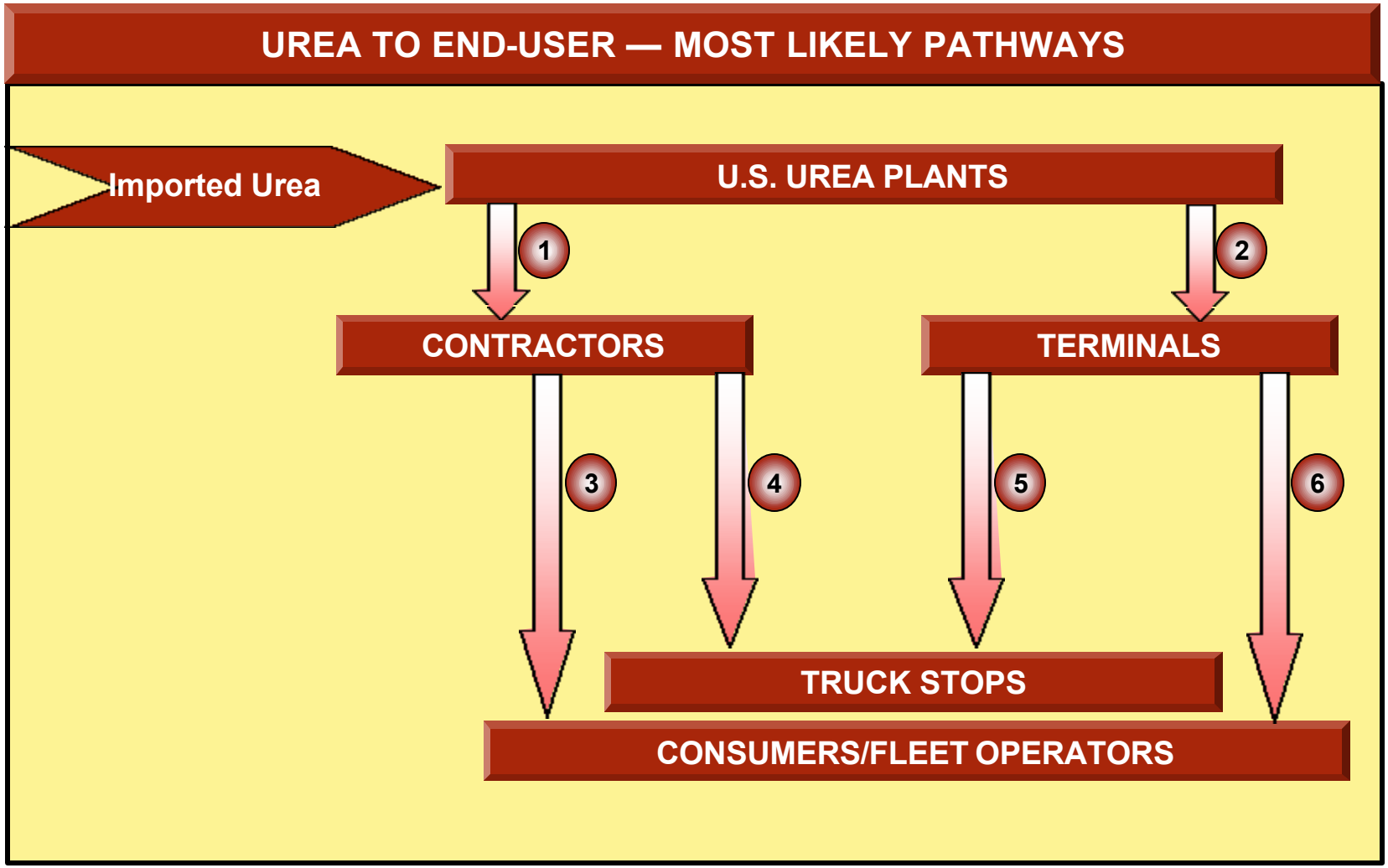
UREA TO END-USER — MOST LIKELY PATHWAYS
Imported Urea
U.S. UREA PLANTS
1
2
CONTRACTORS
TERMINALS
3
4
5
6
TRUCK STOPS
CONSUMERS/FLEET OPERATORS

Issues surrounding pathway selection

- Urea Imports may be the most likely short-term scenario. Majority of imported urea will likely be channeled through existing domestic manufacturers/plants.
- The existing petroleum products (e.g., lube-oil) and fertilizer distribution channels are best positioned for handling the transportation demand for SCR urea
- Independent terminal operators and contractors have expressed interest in distribution of SCR-urea and will be the most likely candidates in the short term
- A number of distribution scenarios are possible. But the most likely pathways in the short term include movement of urea from the plants to intermediate terminals by independent contractors and terminal operators followed by distribution from the terminals to the retail points.
- No new or specialized technology will need to be developed to distribute SCR-grade urea to retail market

Issues surrounding pathway selection

- Additional storage and dispensing equipment will be required by the dispensing station, and may require development of specialized dispensing technology
- SCR-grade urea could be distributed as a solid or as urea liquor (a concentrated solution of urea in water). The distribution costs associated with each will dictate the preferable form.
- Urea-liquor transportation and storage for SCR will have special heating requirements. Currently bulk movement of urea-liquor is in the form of 50 to 70% liquor and is transported in heated containers (~135˚F). Most urea liquor is used for non-agricultural purposes.
- Solid urea transport for SCR distribution to final destinations (terminals, fleet depots, truck stops) could occur in existing delivery quantities — 50 lb bags, 200 lb bags, and ton containers
- Solid urea and urea-liquor need to be blended to 32.5% solution before dispensing. Blending with de-ionized (DI) water can occur at the terminals, container sites, or at the final retail points (truck-stops and/or fleet depots).

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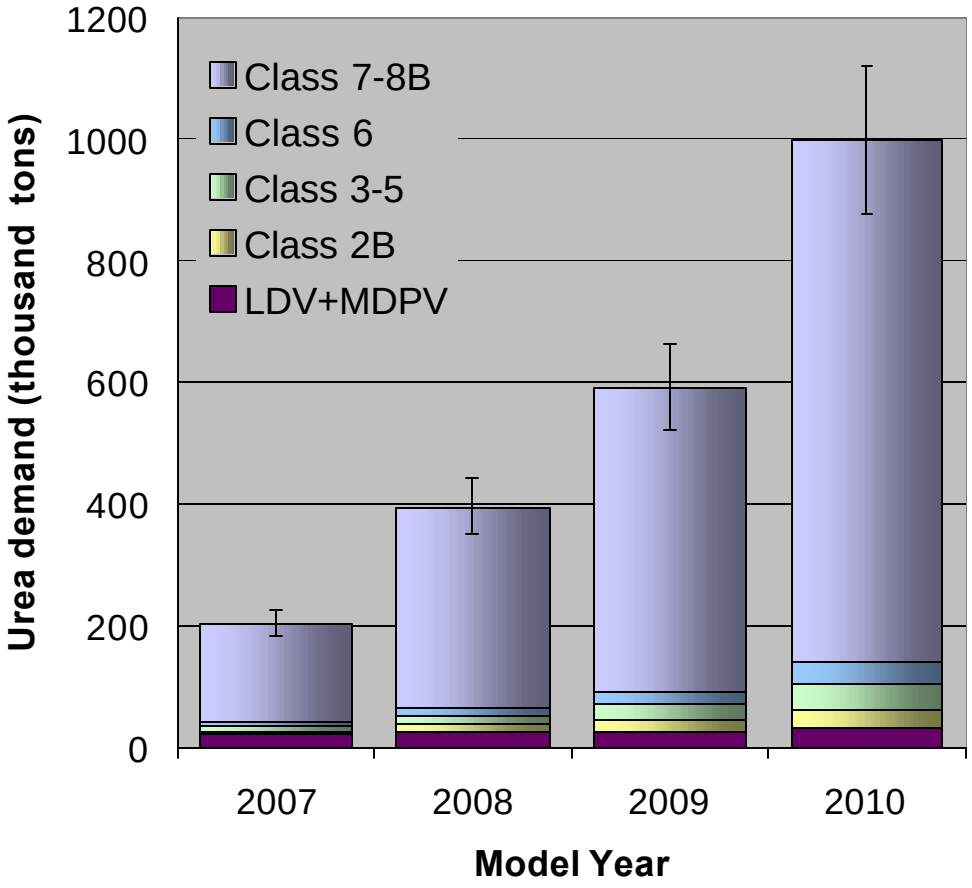
Urea demand for on-road SCR systems estimated from vehicle miles traveled, historical diesel consumption rates, and estimated vehicle sales

- U.S. highway diesel consumption as reported by states' fuel tax reports ('92-'99):
  - Represents total in-use consumption.
  - Assumed to grow linearly nationally as well as within each region considered
- Vehicle miles traveled as provided by U.S. Census Bureau ('92 and '97):
  - Assumed linear growth in vehicle miles for each weight class
  - Assumed constant distribution of fuel economy within each vehicle class
  - Results in linear growth projected for fuel consumption
- Vehicle population projections obtained from EPA MOBILE model estimates
  - Assumed percentage of diesel vehicles within each vehicle class remains constant
  - For each class, assumed annual growth in vehicle sales between 2 and 8% year
  - Determined new diesel vehicle fuel consumption by applying fraction of new vehicles in each class to corresponding projected fuel consumption. If fuel economy improves in new vehicles (and other parameters follow projections as stated) this will lead to a overstatement of fuel demand.

Urea demand from on-road SCR could be met by using the current production capacity of U.S. urea manufacturers

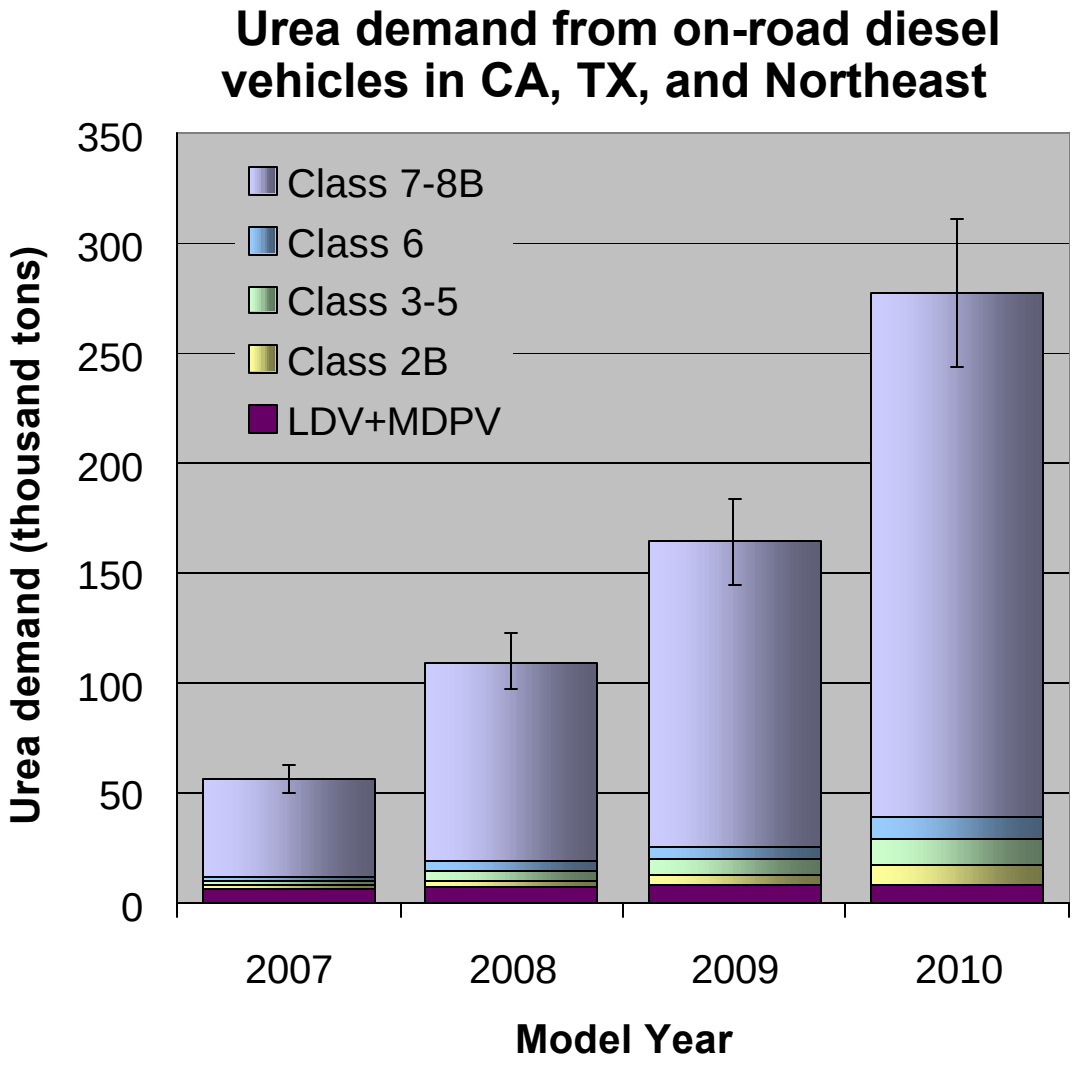
- The following assumptions were made to determine urea demand from vehicle SCR:
  - Vehicle sales rates will not rise or drop significantly due to introduction of SCR technology
  - Linear growth in diesel fuel consumption for all vehicle classes consistent among U.S. geographic regions
  - Urea consumption rate consistent with rate achieved in demonstration programs (1 gallon of 32.5%wt urea solution per 18 gallons of diesel fuel)

Urea demand from new on-road diesel vehicles



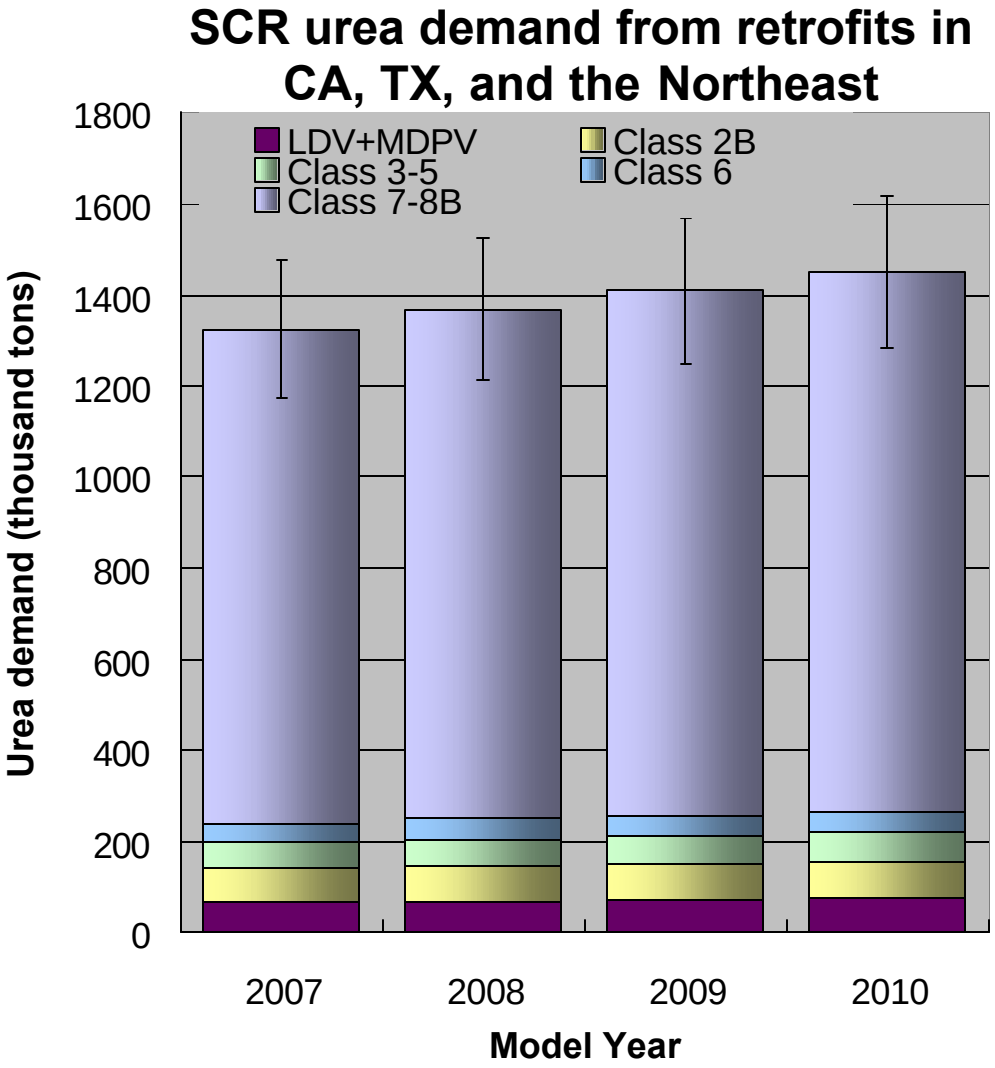
Urea demand from on-road vehicles

- Virtually all of urea demand will come from heavy-duty commercial diesel vehicles
- Heavy-heavy duty diesel (class 7 to 8B) vehicles require the most urea
- One million tons nationwide SCR urea demand is well within the unused capacity of U.S. urea manufacturers
- Regional demand could be met by regional urea manufacturers



Urea demand if existing vehicles were required to implement SCR retrofit

- High-demand scenario: regions needing additional emissions reduction may require SCR retrofits of existing diesel vehicles.
- If retrofits were required of all existing diesel vehicles, the SCR urea demand would reach more than five times the projected demand from new vehicles alone.



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Urea is a viable reductant for using SCR technology in diesel vehicles

- Urea production and import levels are heavily influenced by natural gas prices
- The contaminant thresholds of the SCR and complement emission control systems will dictate quality of urea needed. Urea of various quality grades is readily available.
- SCR urea demand can be readily met by U.S. producers given projected urea supply
- Existing pathways could be used to perform SCR urea distribution

Future work

- Estimation of the capital requirements and retail cost of various distribution pathways
- Environmental impact assessment of urea spills at all points along each distribution pathway
- Life-cycle greenhouse gas emissions assessment for each pathway of SCR urea production and distribution

Distribution issues that will need to be resolved

- Potential barriers to urea distribution that need further investigation :
  - Who will establish SCR distribution and dispensing?
  - Who will invest in this infrastructure?
  - Will the steady demand for urea, and the lack of interest in urea delivery by franchise oil company distributors, lead to parallel and independent SCR urea distribution systems?
  - Will existing retail fueling stations/truck stops show interest in dispensing urea?
  - How will the urea be dispensed into the vehicle? Vehicle dispensing mechanisms are still being considered

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