Urea Infrastructure Hurdles: Report on TIAX Selective Catalytic Reduction Urea Infrastructure Study

Motor Fuels: Effects on Energy Efficiency & Emissions in the Transportation Sector
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Reference: 72457 NREL SCR

- Introduction
- Supply and Demand
- Impurities
- TS&D Pathways
- Costs
- Environmental Issues
- Conclusions

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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.
- TIAX determined SCR-Urea infrastructure needs and issues relating to:
  - Pathways for manufacture and distribution of urea-water solutions
  - Urea demand
  - Capital requirements and retail costs
  - Environmental impact of spills
  - Life-cycle greenhouse gas emissions

SCR Catalyst

Integrated Urea/Diesel Tank

Key issues have been identified among the various aspects of SCR-Urea production and distribution

- SCR and other emissions reduction equipment may not tolerate impurity levels found in some grades of commercially-produced urea.
- Urea distribution costs can range from $0.70 to $35/gallon depending on:
  - urea distribution volume
  - number of retail stations
  - product segregation requirements
- Dispensing equipment represents the major part of the distribution costs.
- Standard urea handling precautions and spill cleanup procedures need to be adapted for retail urea dispensing locations.
- The life-cycle greenhouse gas impacts of the urea transportation, storage, and distribution (TS&D) pathways were estimated at up to 1 percent of the current diesel heavy-duty vehicle life-cycle greenhouse emissions.

A comprehensive methodology was used to examine the various aspects of an SCR-Urea Infrastructure

- Contacted various industry participants, including urea manufacturers and distributors, to determine current availability of SCR-compatible urea and existing urea distribution pathways
- Used projected fuel consumption to estimate the amount of urea required to implement SCR in all on-road diesel vehicles meeting federal model year 2007+ emission standards
- Developed a most likely pathways scenario and a range of estimated costs for the implementation of an SCR-urea distribution infrastructure along these pathways
- Used published health and safety standards to estimate the environmental and health impacts from the use of SCR-urea
- Used GREET modeling to determine pathway specific life-cycle greenhouse gas emissions associated with SCR-urea production and distribution infrastructure
- Further details available in NREL publication number: NREL/SR-540-32689 www.ott.doe.gov/pdfs/adl_urea.pdf

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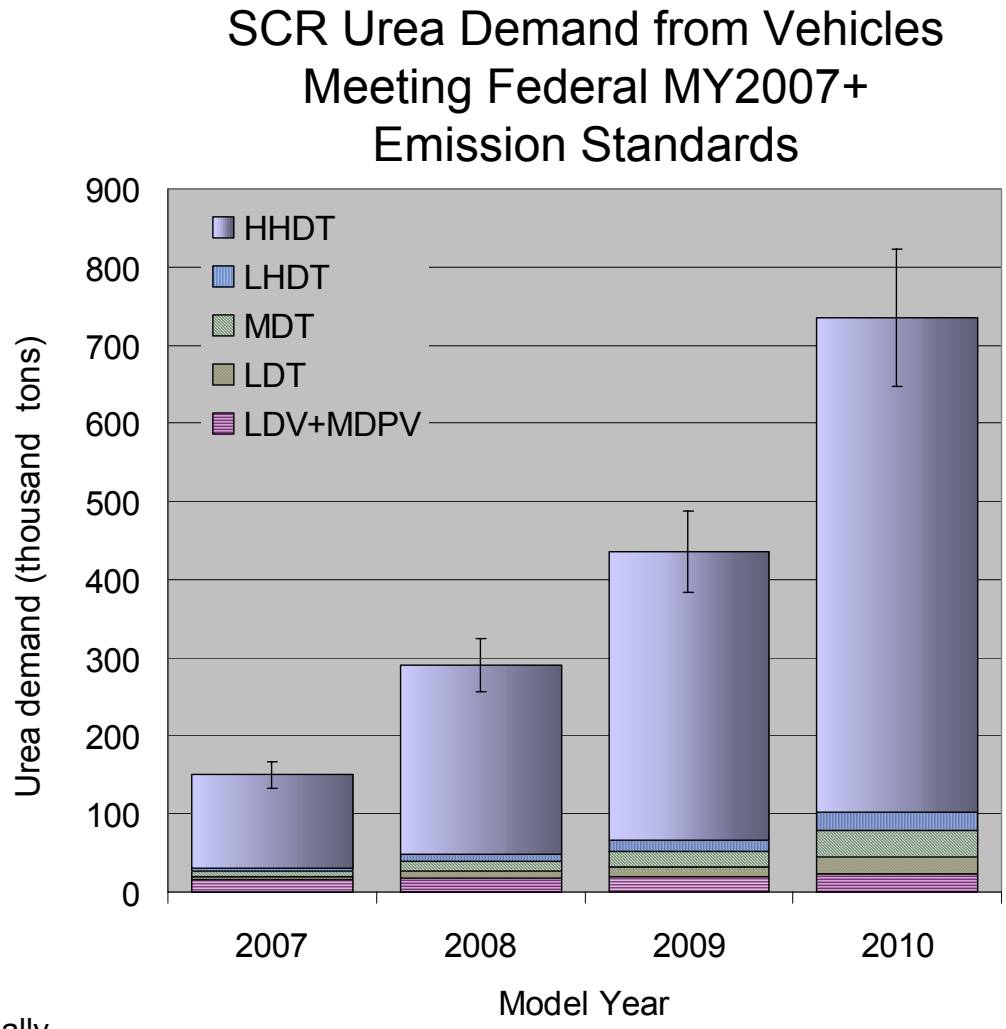
In the near-term, sufficient capacity exists to support the estimated SCR-urea demand

- Near-term domestic on-road SCR-urea consumption was estimated from projected on-road diesel consumption.
- Virtually all on-road SCR-urea demand will come from heavy-duty commercial diesel vehicles.
- On-road SCR-urea demand could be met with the current unused production capacity of U.S. manufacturers.
- If 50% of U.S. on-road diesel vehicles use SCR in 2010, the added demand* will be less than the currently unused U.S. production capacity.

*about 2 million tons annually



Domestic SCR-Urea demand may be supported with a combination of domestic and world urea supply

- Urea production and import levels are heavily influenced by natural gas prices, the main feedstock for urea production.
- The recent rise in domestic natural gas prices has lead to increased supply of urea from foreign markets.
- Roughly one-third of domestic consumption is foreign urea resold by domestic distributors.
- Based on existing and projected suppliers, sufficient urea production capacity exists worldwide to meet the on-road SCR urea demand.

Current Urea Production and Distribution

	All Urea Grades	Million Tons/Year
WORLD	Demand	100
	Production	110
	Capacity	133
DOMESTIC (U.S.)	Demand	9-10
	Production	6
	Capacity	10

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Common urea impurities in urea may drive need for a high-purity SCR-Urea grade

- Three main urea grades are available:
  - Agricultural (solid)
  - Industrial grade (solid or liquid)
  - High-quality/Reagent grade (solid or liquid)
- Any of these grades could be produced in sufficient quantity for SCR
- Agricultural and industrial grades of urea are widely distributed to high-volume consumers with significant quantities of additives
- Such additives would be incompatible with SCR emission control systems
- Higher-purity grade urea can be produced by avoiding additive introduction during manufacturing

Sample Compositions of Commercial Urea (Solid)

	Agricultural Grade	Industrial Grade
Form	Granular	Granular
Total Nitrogen (%)	46.0	46.0
Biruet 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 Grade	
Form	Crystals
Biruet Content (%)	0.0
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

An SCR-Urea specification still needs to be developed

- A strict urea purity specification may require refined production and TS&D processes that avoid cross-contamination from other urea grades via transport and storage tanks.
- The contaminant thresholds of the SCR and complement emission control systems will dictate quality of urea needed.
- Vehicle, engine exhaust equipment, and urea manufacturers need to determine compatible SCR urea specification.

Possible SCR Urea Specification*

Property	Maximum Value	Property	Maximum Value
Alkalinity (%)	0.1	**Zinc (ppm)**	1.0
Calcium (ppm)	1.0	**Chromium (ppm)**	1.0
Magnesium (ppm)	1.0	**Nickel (ppm)**	1.0
Sodium (ppm)	1.0	**Silicon (ppm)**	2.0
Potassium (ppm)	1.0	**Phosphate (ppm)**	2.0
Iron (ppm)	1.0	**Carbonate (%)**	0.1
Copper (ppm)	1.0	**Biuret (%)**	0.3

*Communication with M. Knenlein, FuelTech, April 2002

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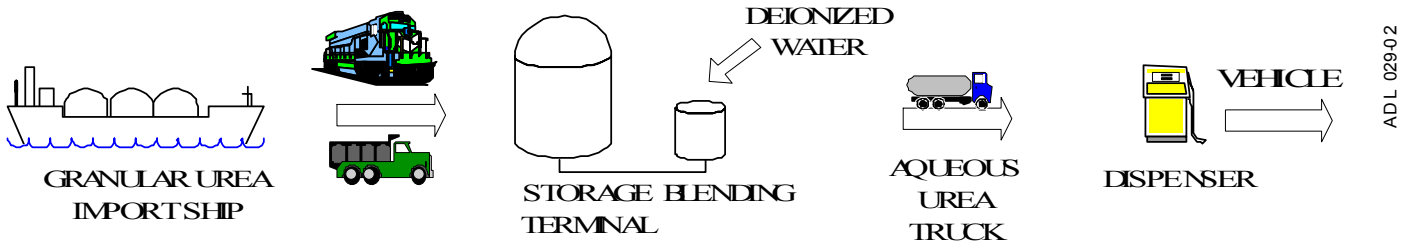
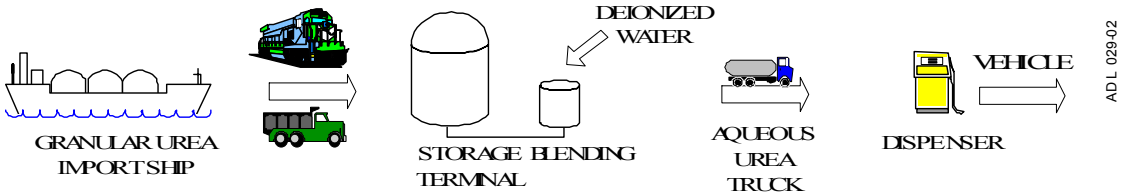
Several aspects of the existing urea distribution pathways may be used for SCR-Urea



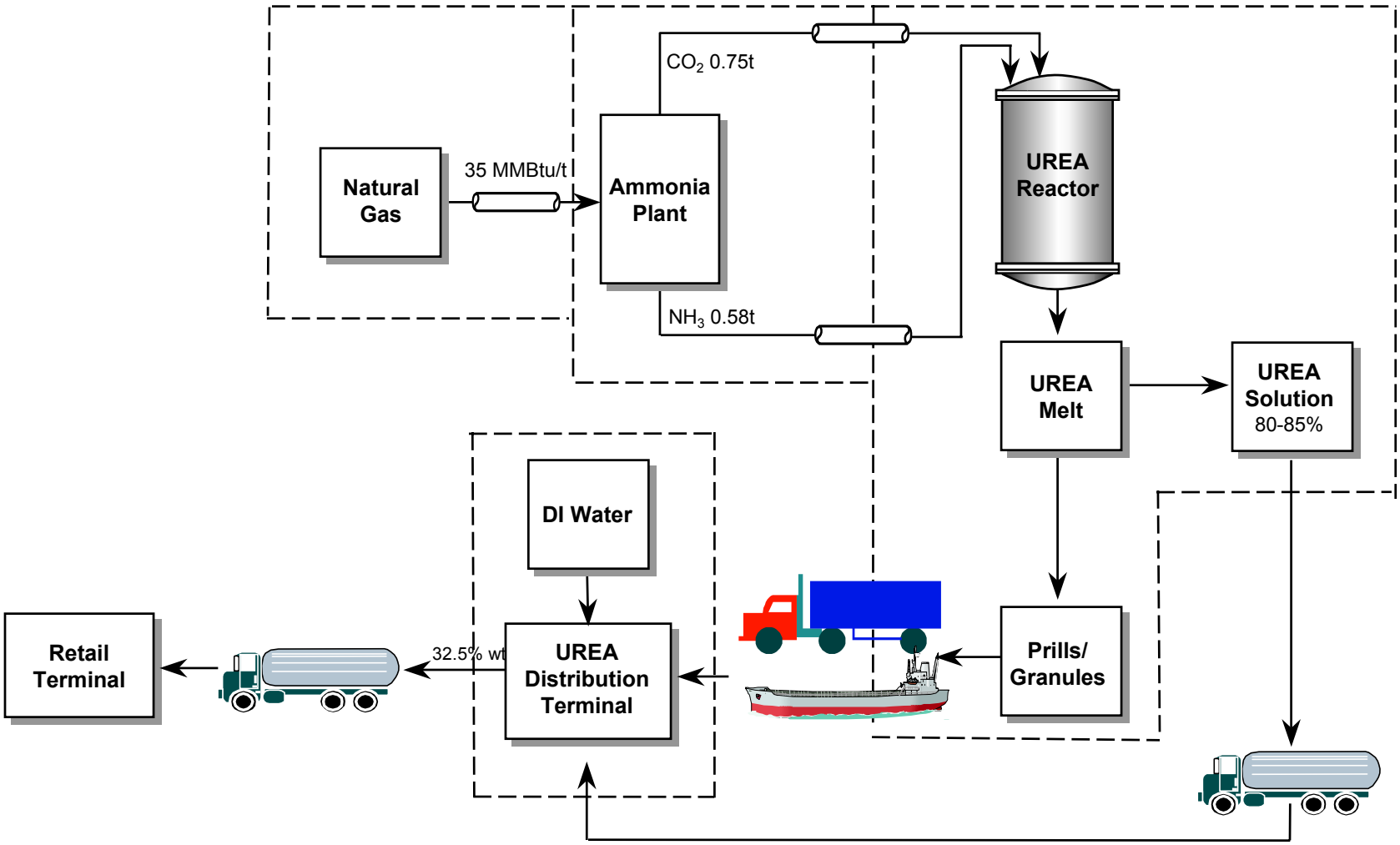
- The current urea and petroleum distribution infrastructure are potential models for SCR-urea distribution.
- The most likely short-term pathways include:
  - urea movement from the plants to intermediate terminals by independent contractors and terminal operators
  - distribution from the terminals to the retail points
- If current urea grades can be used to produce SCR-urea, the short- to mid-term implementation of an SCR-urea infrastructure will not be limited by the availability of urea or the need for a new distribution network.
- If a higher purity grade than currently available is required, new pathways will need to be developed to ensure minimal contamination.

Several issues pertaining to blending, storage, and dispensing SCR-Urea still need to be resolved



- Solid urea and urea-liquor needs blending with de-ionized water to 32.5%wt solution before dispensing to vehicle.
- Blending facilities' location in the supply chain will be determined by the cost structure.
- Additional storage and dispensing equipment will be required by the dispensing station, and may require development of specialized dispensing technology, such as co-fueling systems.

An example urea production and distribution pathway



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The cost envelope for offering retail SCR-grade urea encompasses a wide range of implementation scenarios

- Production costs are expected to range between $0.12 to $0.30/gallon of SCR-urea solution.
- Distribution costs of urea can range from $0.70 to about $35 per gallon of 32.5%wt urea depending upon:
  - –the degree of TS&D infrastructure development
  - –the cost of urea production
  - –the impact of the SCR-grade urea specification
- Dealer profit mark-up is estimated to range between $0.05 to $0.10/gal based on typical diesel supply chain mock-ups.

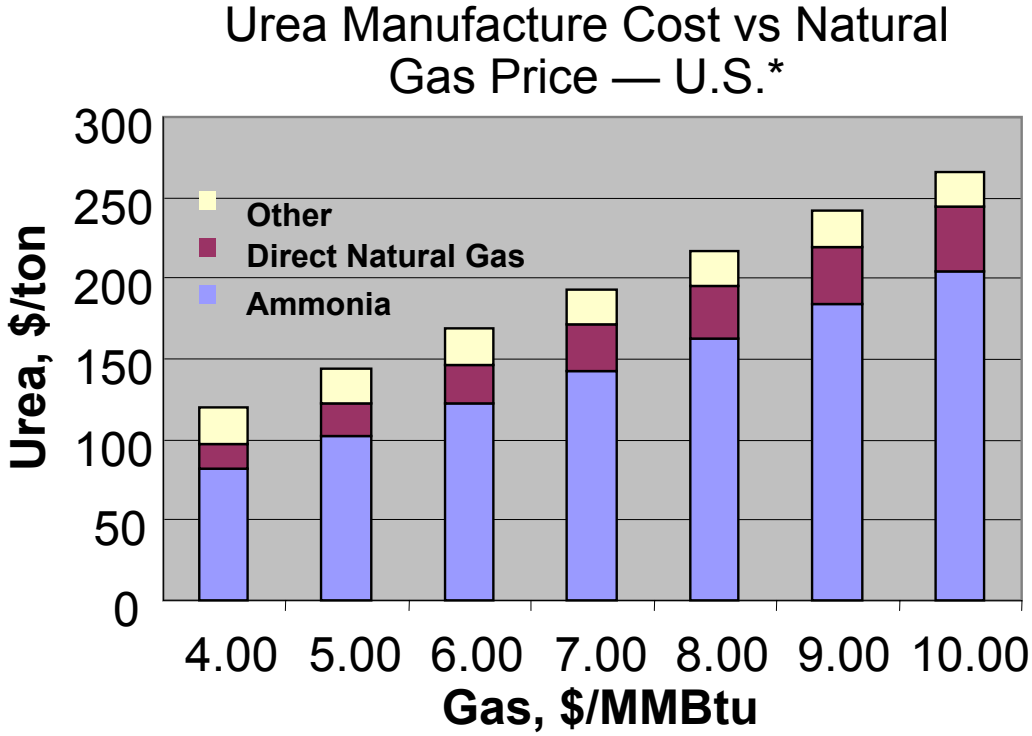
Envelope of Urea Costs*

SCR-Urea Costs	$/ton	$/gal
Production	80 to 200	0.12 to 0.30
Distribution	500 to 24,000	0.70 to 35
Dealer mark-up along the supply chain	—	0.05 to 0.10

*Ranges above reflect range of cost between establishing SCR-grade urea dispensing at about 5,000 retail locations serving a large population of SCR-equipped vehicles and about 50,000 LD vehicle retail stations serving a small population of SCR-equipped vehicles.

The cost to purchase and manufacture SCR-Urea influenced strongly by natural gas prices

- Retail urea price will vary with the price of natural gas and the supply-chain pathway.
- In the U.S., urea market price closely follows the natural gas price.
- Currently, urea is traded as a commodity.
- Due to the seasonal demand characteristics, urea supply-demand is not always in equilibrium.
- Although a steady SCR-urea demand may help stabilize domestic production, its stabilizing effect on urea basket price is uncertain.



*The 2000 and 2001 average natural gas price for the U.S. was $4/million Btu. The 2002 average to-date is $3/million Btu.

Costs of transportation, storage, and distribution of SCR-Urea vary depending upon distribution of the retail market

- The cost of distributing urea can range from $0.70 to $35/gallon depending on:
  - volume of urea distributed throughout the system
  - number of retail points
  - level of product segregation required.
- The lower end of the price range represents urea distribution focused at truck stops serving a large population of SCR-equipped vehicles
- The upper part of the price range represents urea distribution at light-duty retail outlets with low urea throughput.
- Distribution and retail costs are reduced if SCR-urea dispensing infrastructure is installed in fewer retail stations with relatively higher urea throughput.
- Dispensing equipment costs represent the major part of the distribution costs.

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Environmental issues: spills along pathways

- Given existing urea production facilities and extensive distribution pathways, SCR-urea should not have significant incremental spill incidents or well-to-tank greenhouse gas emissions.
- Urea is considered a stable and safely transportable product and degrades quickly in soil, water, and air.
- However, ingested or absorbed in large quantities, it can be hazardous to plant and animal life.
- Spill clean-up procedures are well-established and will have to be modified and/or updated to accommodate new locations where urea will be used.

Listing of Urea as Hazardous and/or Carcinogenic by Federal Agency

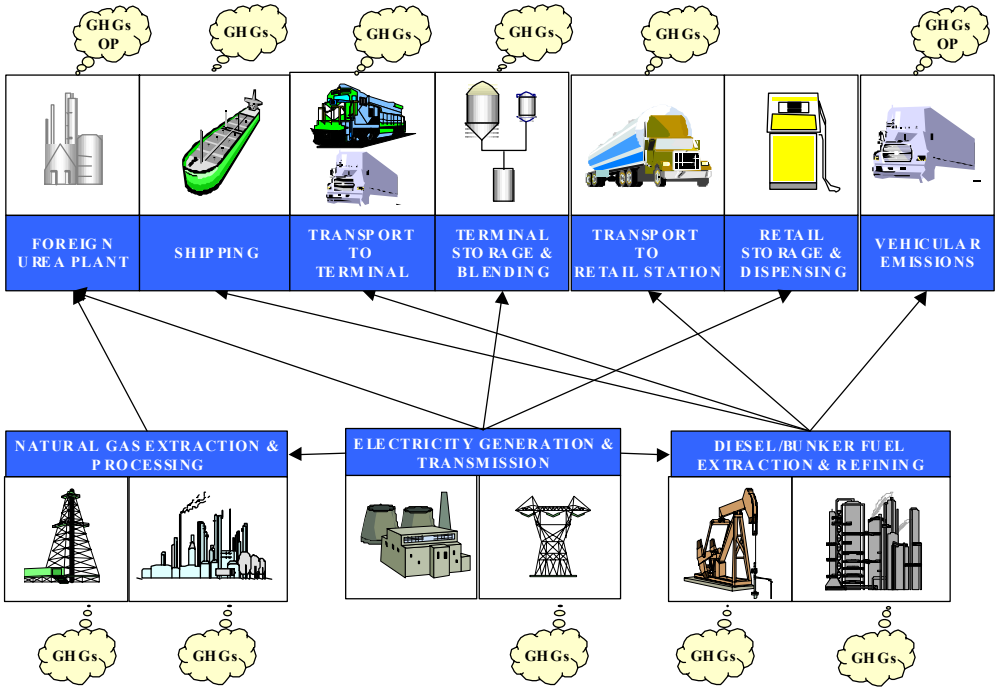
Agency Listing	Hazardous	Not Hazardous	Carcinogenic	Not Carcinogenic
EPA		X		X
OSHA	X[a]			X
DOT		X		
Federal Hazardous Waste Regulations (40 CFR 261)		X		

[a]Some of the manufacturers' MSDS surveyed indicate that urea is not hazardous under OSHA Hazard Communication Standard (22 CFR 1910.1000).

Environmental issues: greenhouse gas (GHG) emissions

- The life-cycle GHG impacts of SCR-Urea TS&D pathways were estimated at up to 1 percent of the current heavy-duty diesel vehicle life-cycle GHG emissions.
- This impact represents much less than 0.1% of the current US GHG emissions inventory.
- Issues to be addressed:
  - N_2O emissions
  - life-cycle cost of non-GHG emissions generated

GHG Emissions Along the Production and Distribution Pathways



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Areas that Require Further Study

- Development of an SCR-urea specification
- Need for refined production and TS&D processes that avoid cross-contamination from other urea grades and contamination from transport and storage tanks
- Availability of appropriate dispensing and storage equipment at the retail level
- Level of penetration of SCR-urea at the retail stations
- Life-cycle cost implications to the diesel vehicles or fleets using SCR
- Life-cycle criteria pollutant cost evaluations

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 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, such as co-fueling of diesel and urea.