Costs/Impacts of Distributing Ultra Low Sulfur Diesel

Robert E. Cunningham
Senior Vice President
Turner, Mason & Company

Clean Fuels 2001
INTERTECH: 8th International Clean Transport Conference
San Antonio, Texas
January 31, 2001

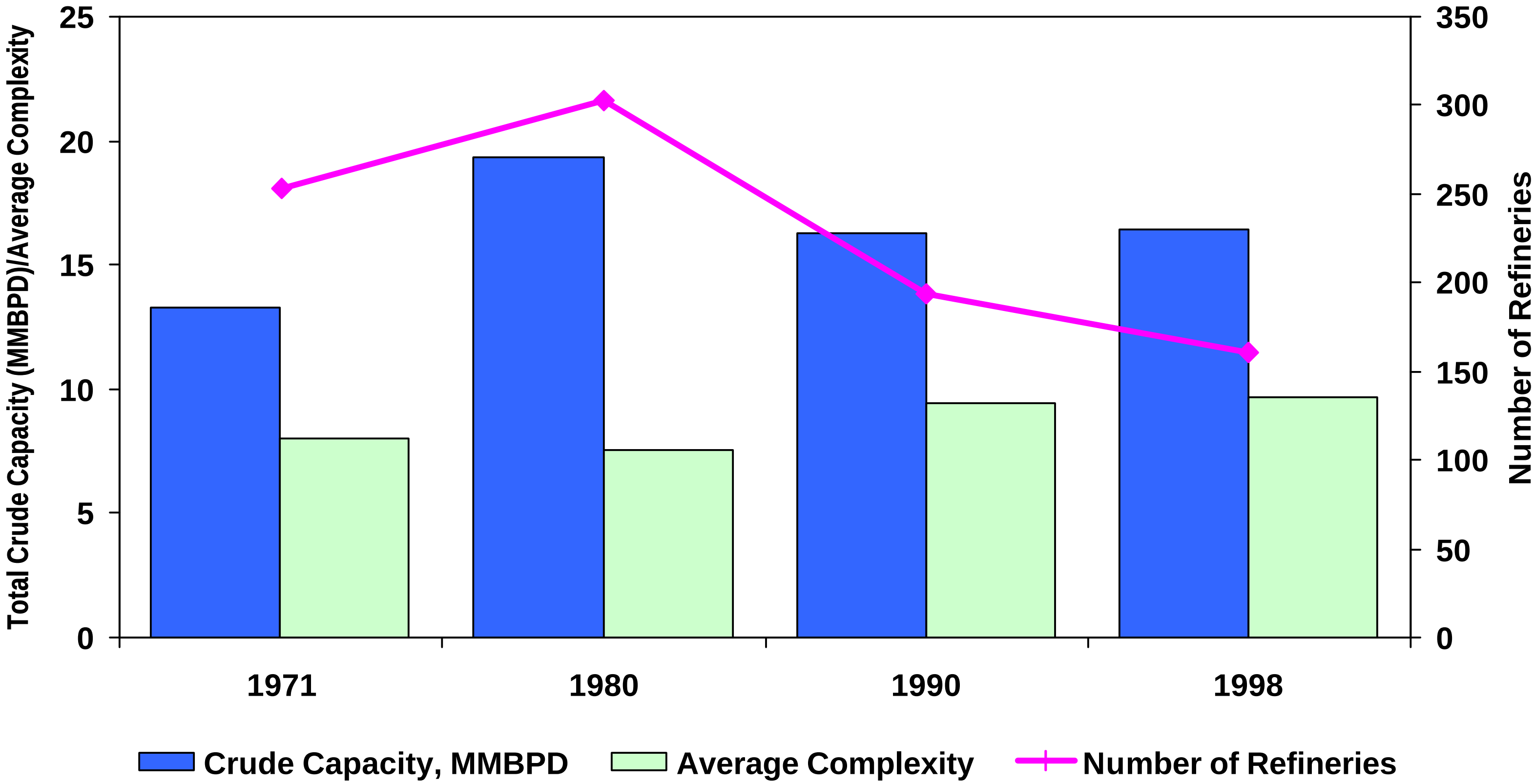
Costs/Impacts of Distributing Ultra Low Sulfur Diesel

- Distillate Refining and Distribution System in U.S.
- Specs and Properties; Transition from LSD to ULSD
- Problems Maintaining/Delivering Ultrapure ULSD
- Conclusions – Costs/Impacts of Distributing ULSD

Costs/Impacts of Distributing Ultra Low Sulfur Diesel

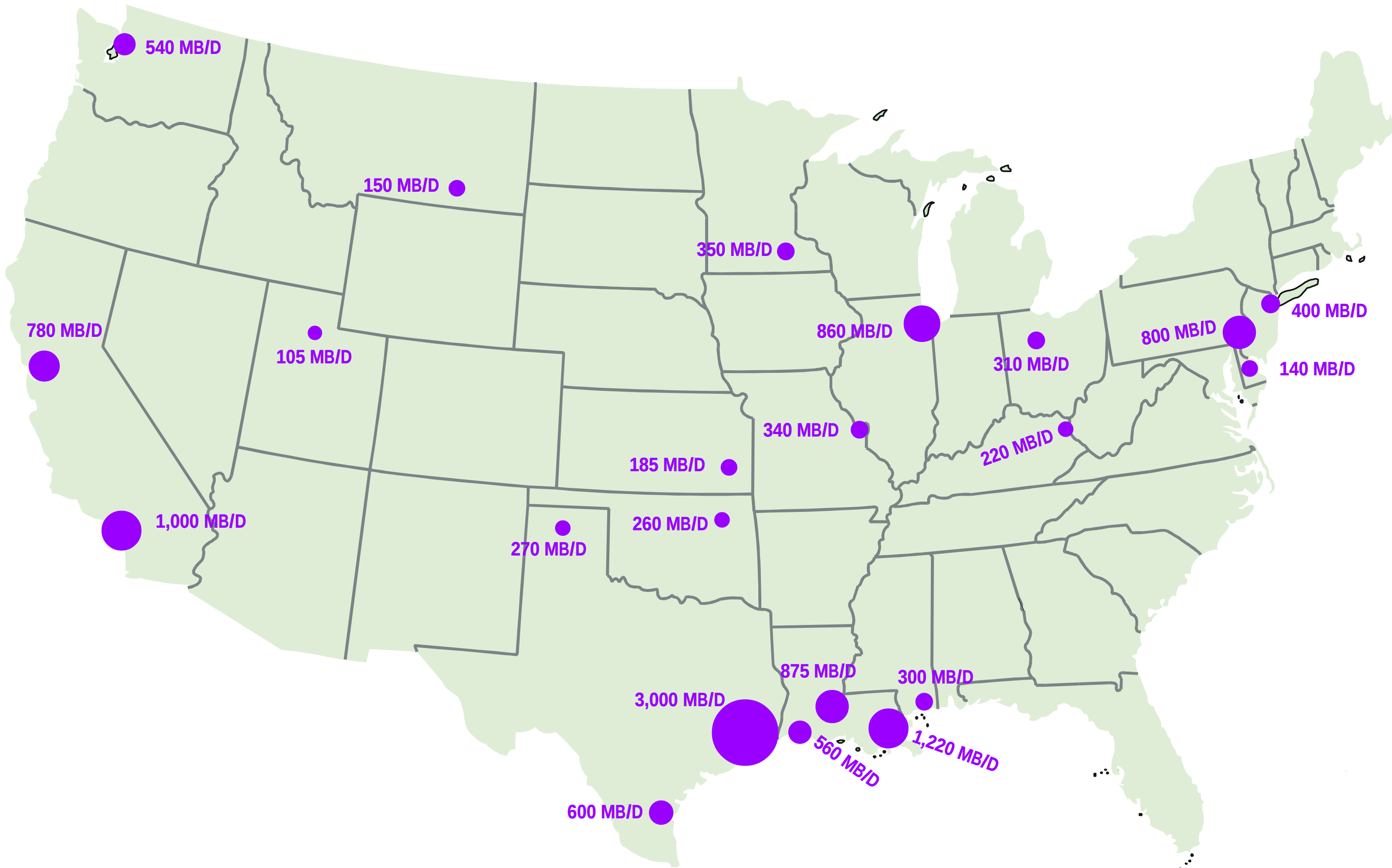
- Distillate Refining and Distribution System in U.S.
- Specs and Properties; Transition from LSD to ULSD
- Problems Maintaining/Delivering Ultrapure ULSD
- Conclusions – Costs/Impacts of Distributing ULSD

U.S. Refining Industry Capacity, Complexity and Number



TURNER, MASON & COMPANY
Consulting Engineers

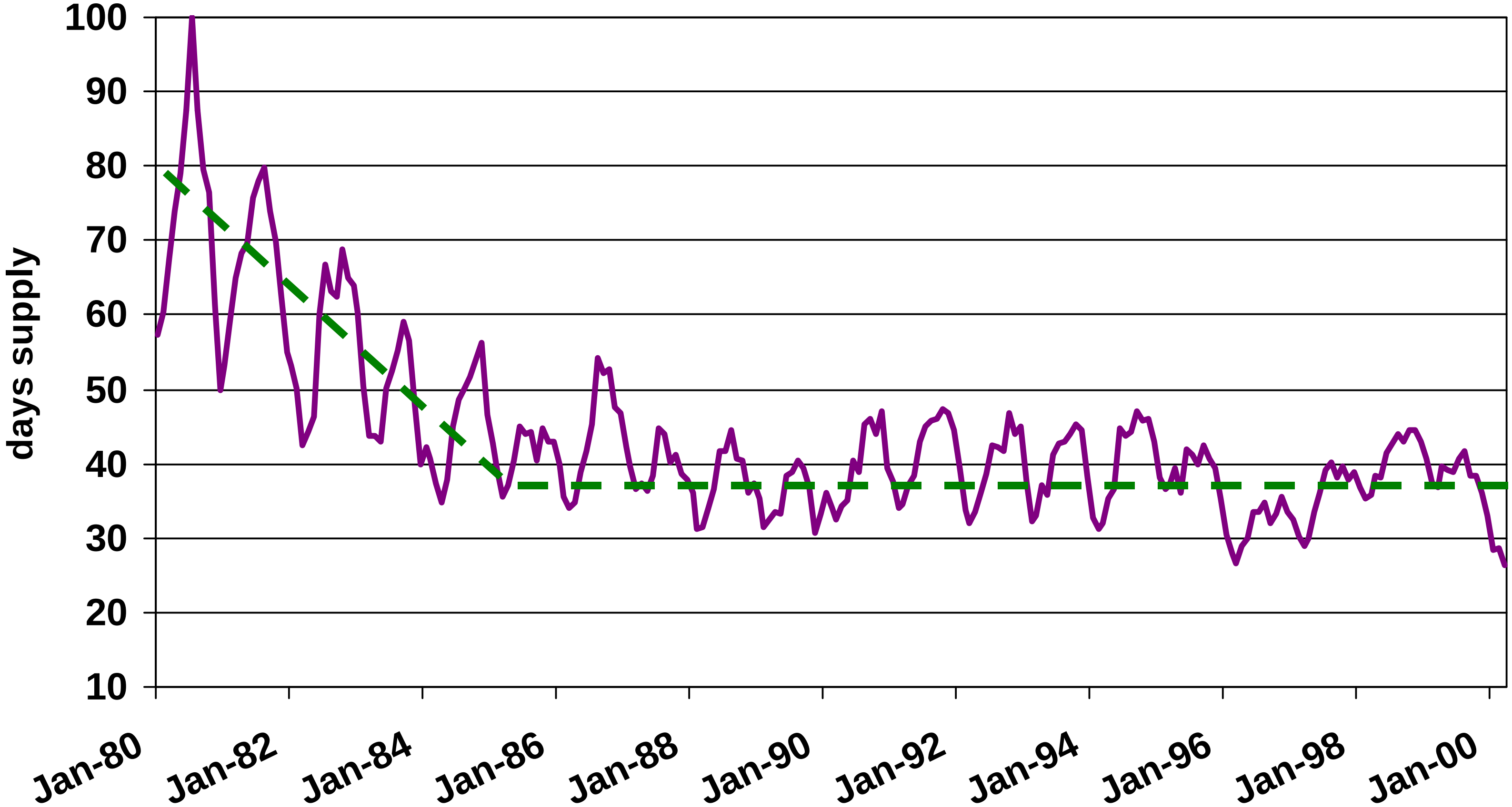
U.S. Refining Centers[1]



(1) Based on Crude Capacity from 12/21/98 *Oil & Gas Journal*.

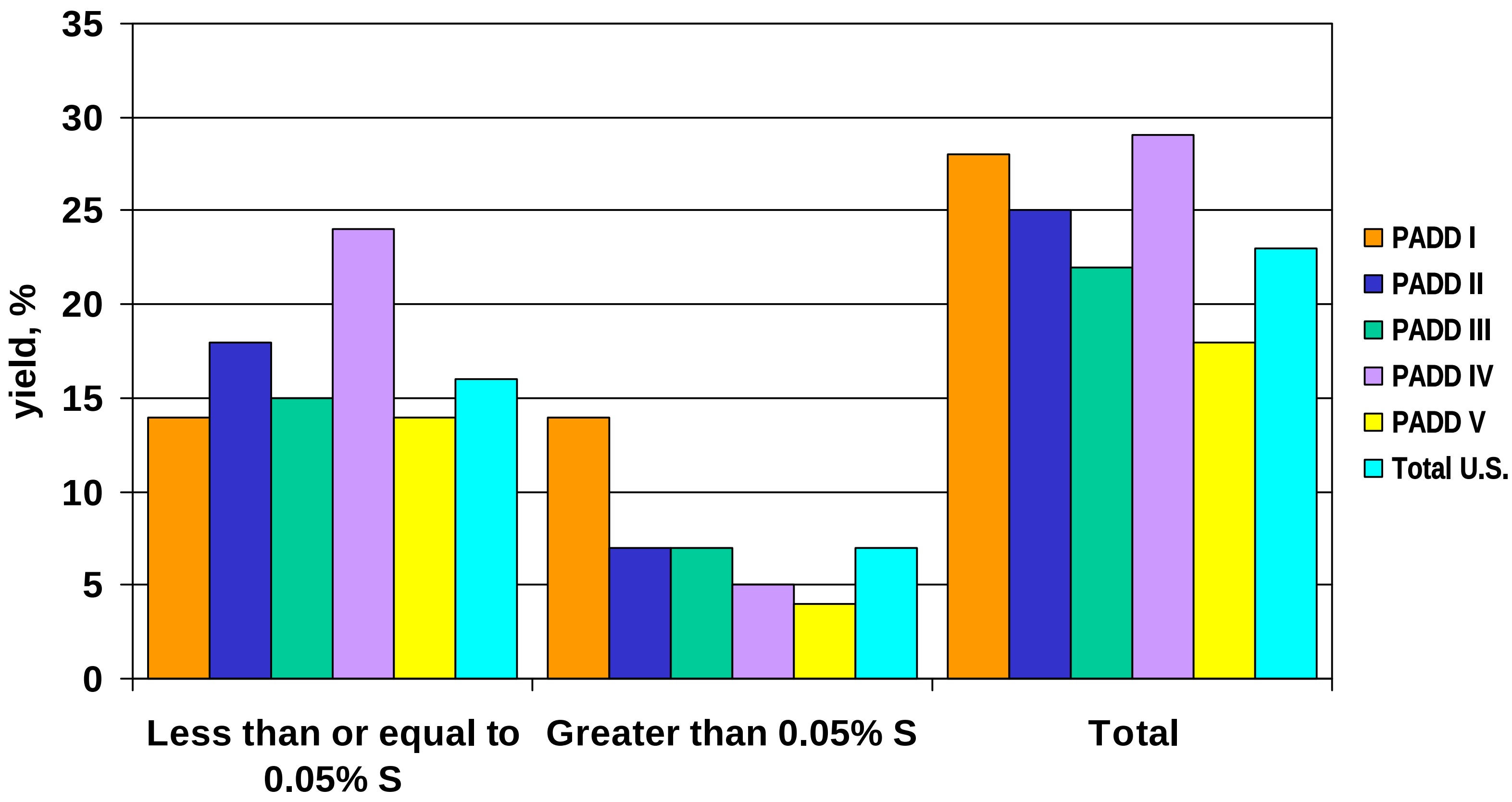
TURNER, MASON & COMPANY
Consulting Engineers

U.S. Distillate Stocks

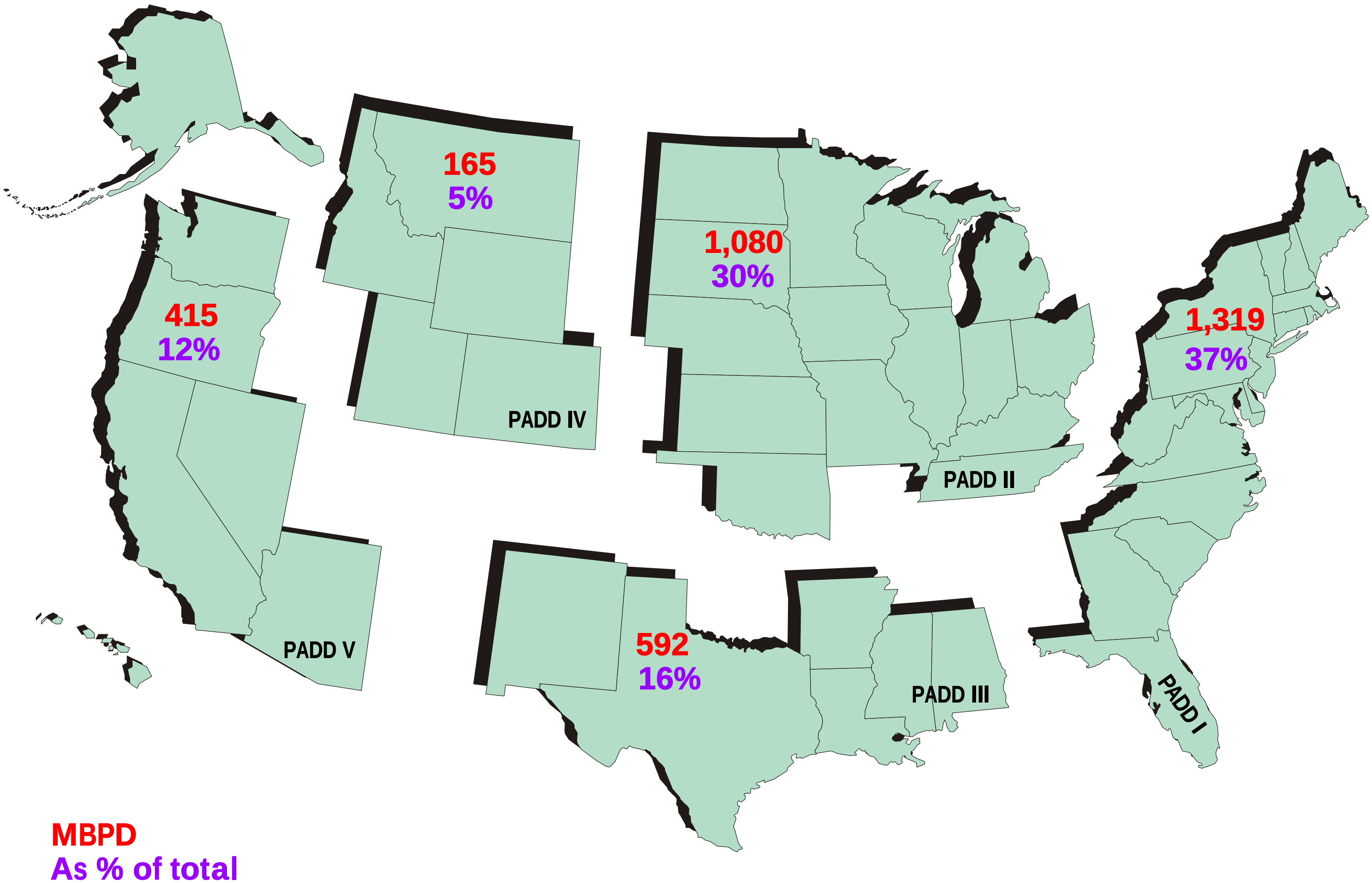


TURNER, MASON & COMPANY
Consulting Engineers

U.S. Distillate Production As % of Crude

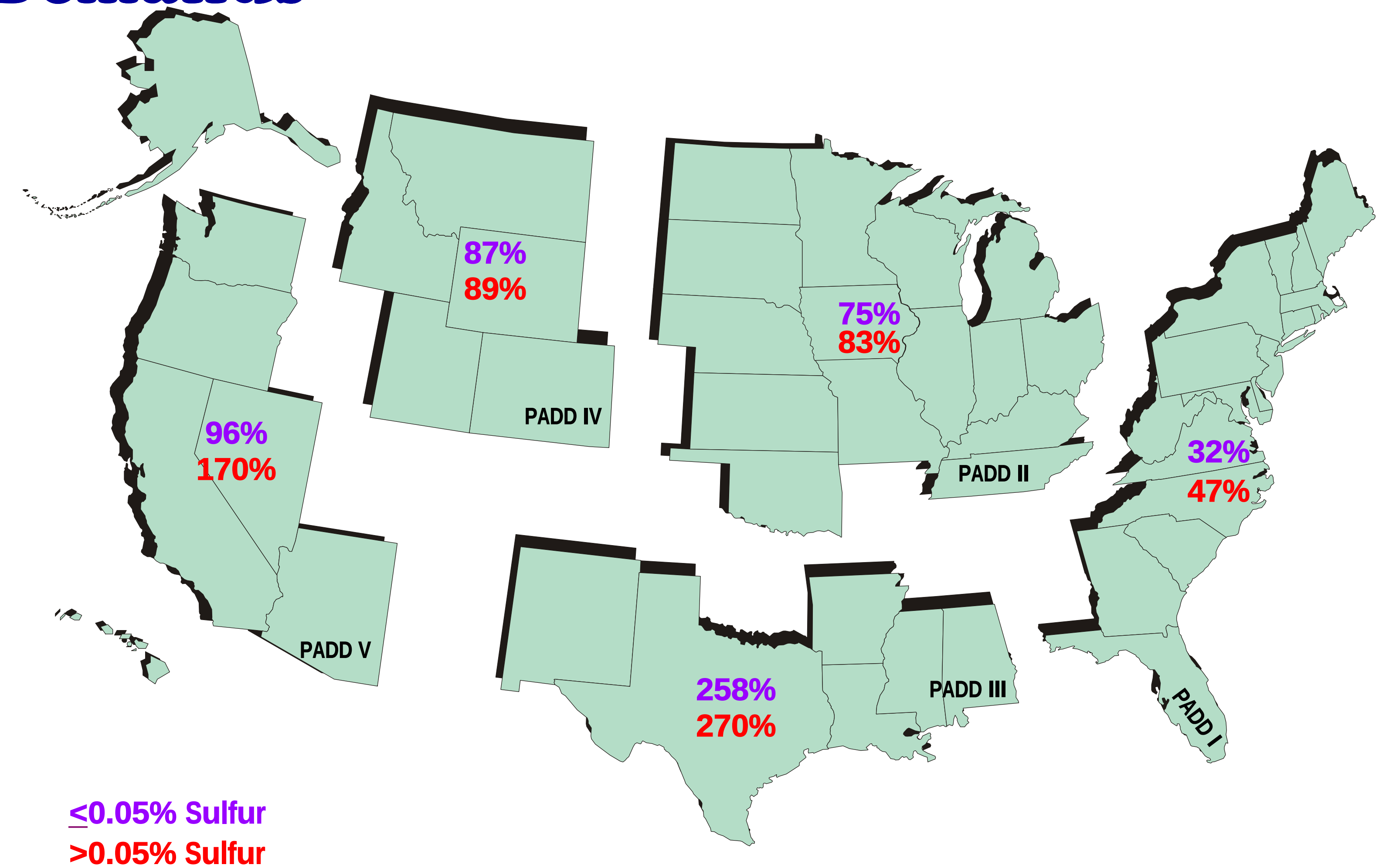


U.S. Distillate Demands by PADDs



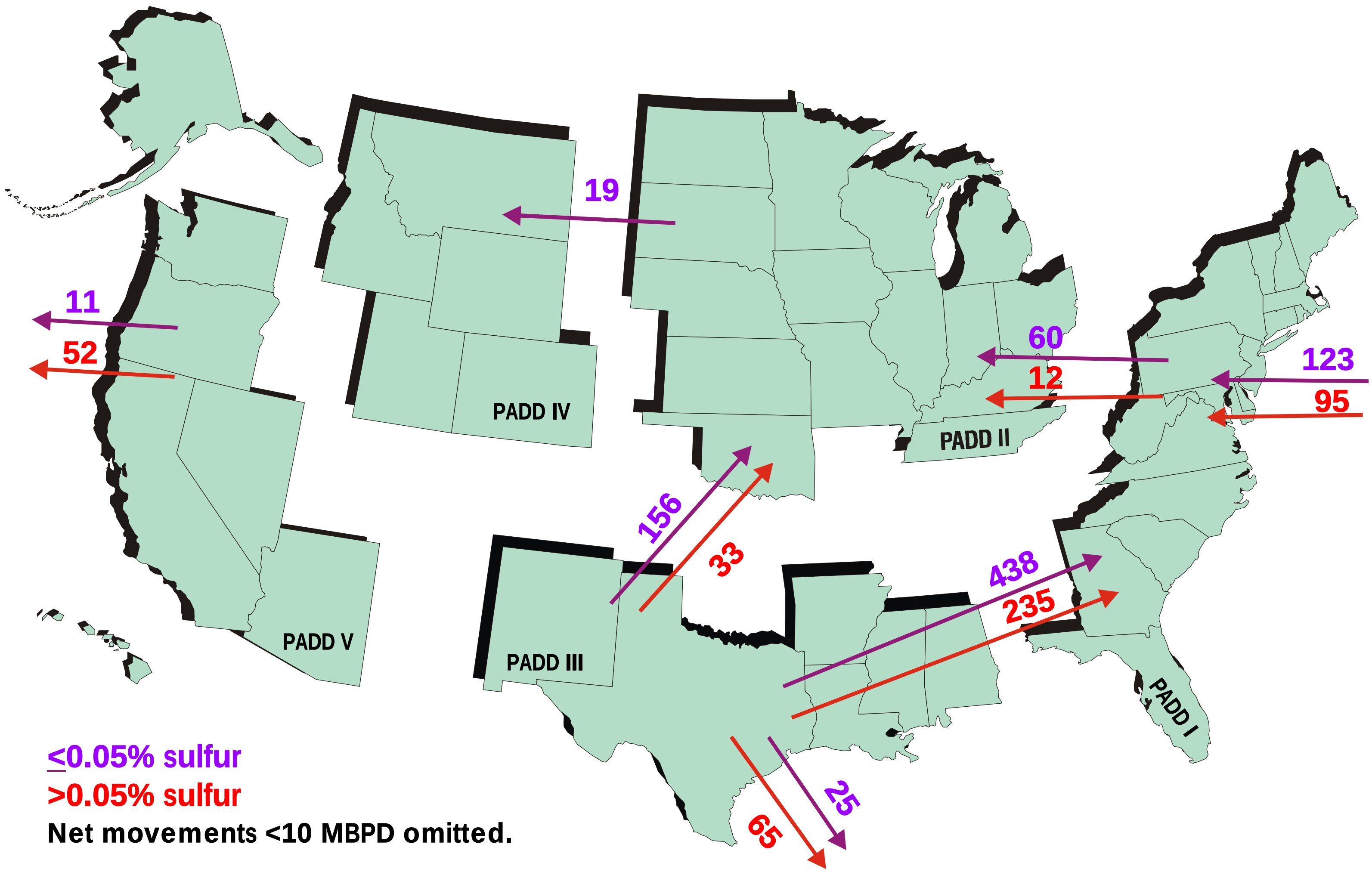
TURNER, MASON & COMPANY
Consulting Engineers

Distillates – Capability of PADD Refining Supply to Meet PADD Demands



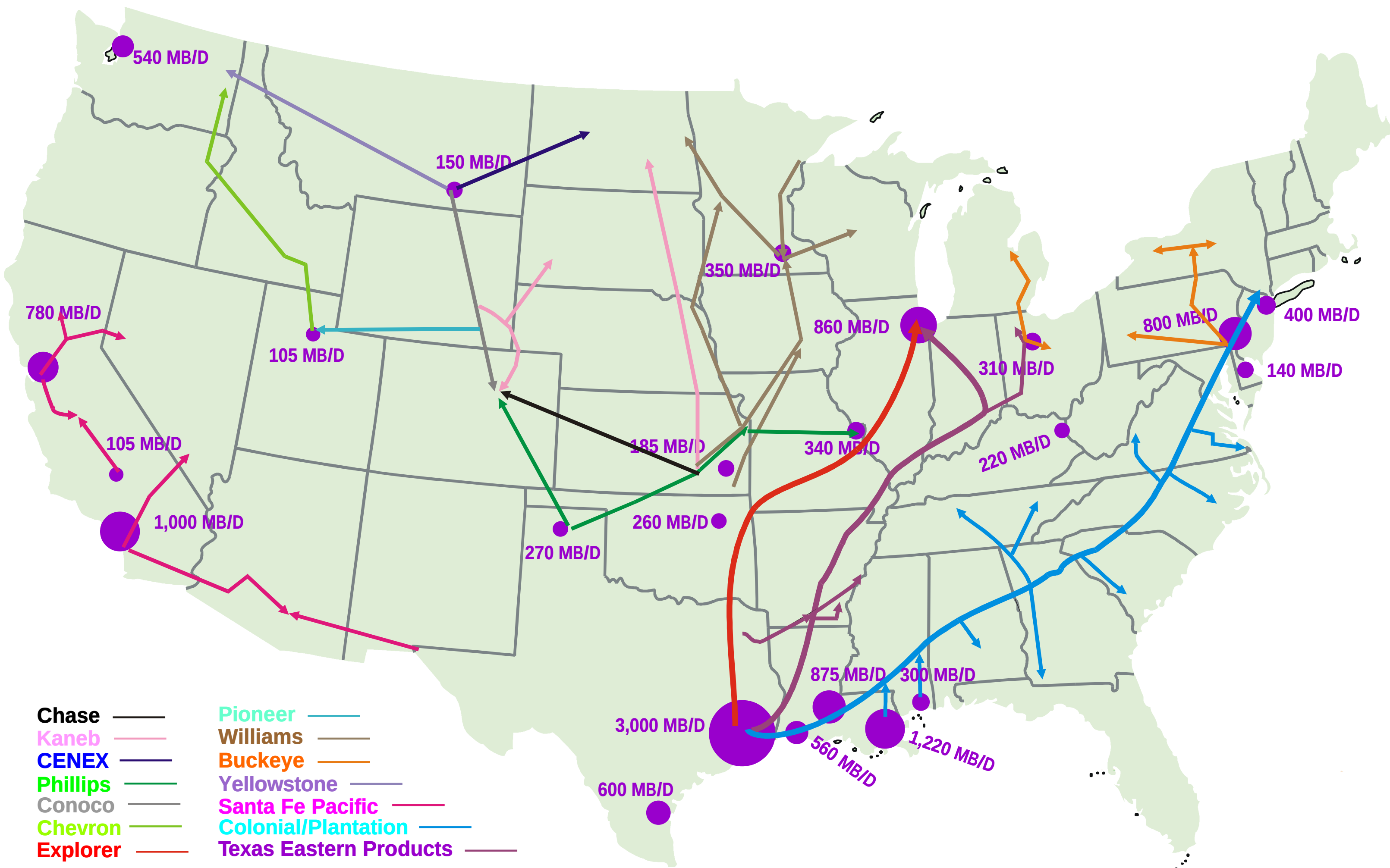
TURNER, MASON & COMPANY
Consulting Engineers

U.S. Distillate Inter-PADD Net Movements (MBPD)



TURNER, MASON & COMPANY
Consulting Engineers

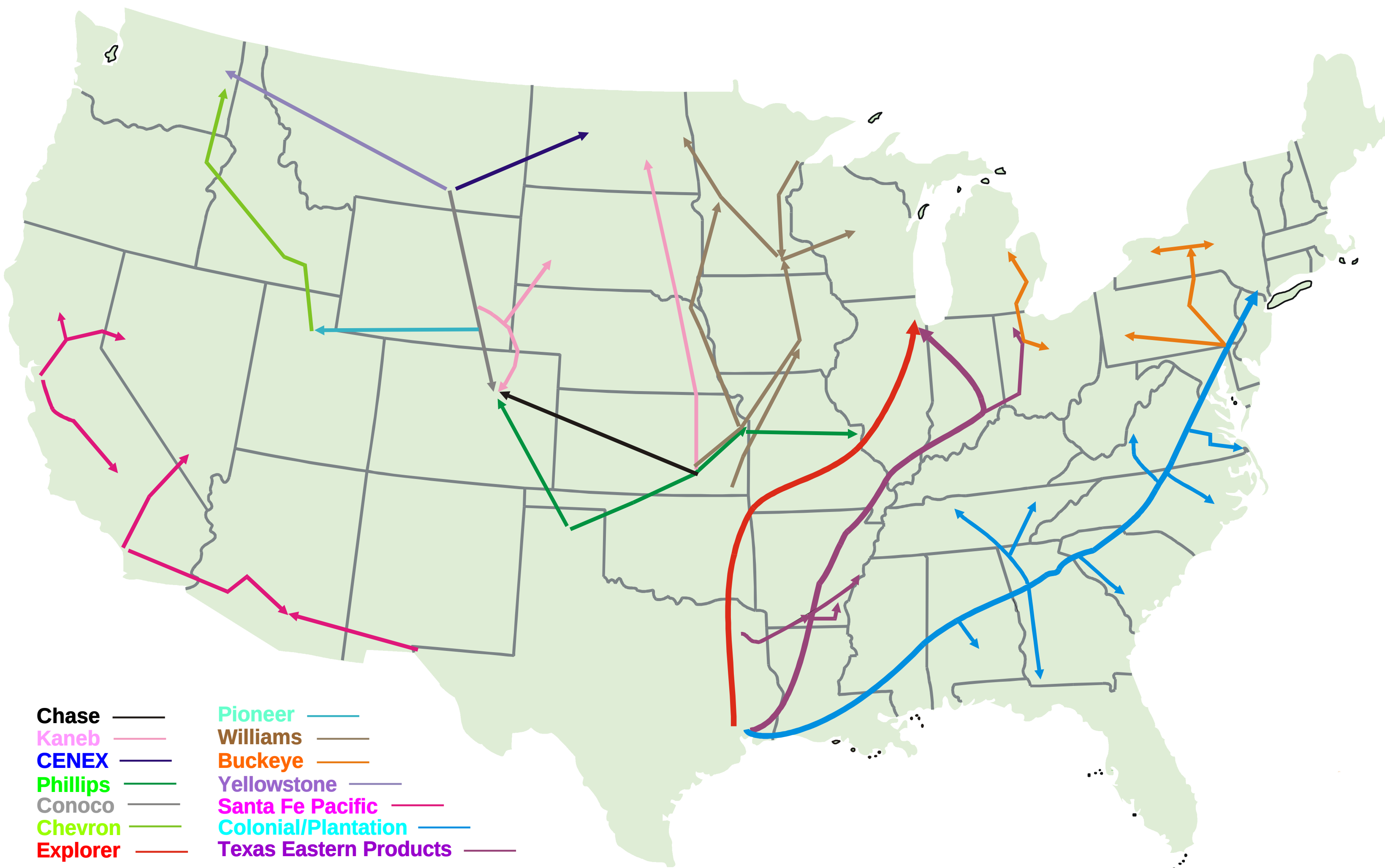
Refining Centers(1) Plus Product Pipelines



(1) Based on Crude Capacity from 12/21/98 *Oil & Gas Journal*.

TURNER, MASON & COMPANY
Consulting Engineers

Clean Products Pipelines



TURNER, MASON & COMPANY
Consulting Engineers

U.S. Petroleum Product Distribution System

	Number	Average Throughput MBPD	Average Storage Capacity MB
Refineries	160	100	1,600
Pipelines	60	200	*
Product Terminals	1,300	10	500
Gasoline Retail Outlets	120,000	0.07	0.3
Diesel Retail Outlets	8,000	0.3	0.6
Diesel at Gasoline Outlets	14,000	0.01	0.04

* Included in terminals.

U.S. Petroleum Product Terminals

	Storage Capacity MB	% of Terminals	% of Terminals Storage Capacity	Average Throughput (MB/D)
Small	<200	44	10	2
Midsize	200-1,000	46	39	8
Large	>1,000	10	51	50
Total/Average		100	100	10

Source: *Petroleum Terminal Encyclopedia*, 2000

Costs/Impacts of Distributing Ultra Low Sulfur Diesel

- Distillate Refining and Distribution System in U.S.
- Specs and Properties; Transition from LSD to ULSD
- Problems Maintaining/Delivering Ultrapure ULSD
- Conclusions – Costs/Impacts of Distributing ULSD

Distillate Product Specifications

Abbreviation	Name	Usage	Sulfur Maximum wppm	Aromatics Maximum V%	Cetane Number Minimum
Current					
LSD	EPA diesel	On-road	500	35	40
LA-LSD	CARB diesel	On-road	500	10(1)	48
No. 2/HSD	Distillate	Heating/ off-road*	5,000		
2007 Forecast					
ULSD	EPA diesel	On-road	15	35	40
LA-ULSD	CARB diesel	On-road	15	10(1)	48
No. 2/HSD	Distillate	Heating/ off-road*	5,000		

* Includes marine and railroad.
(1) Or equivalent emissions.

Distillate Product Average Properties

Abbreviation	Name	Usage	Sulfur wppm	Aromatics V%	Cetane Number
Current					
LSD	EPA diesel	On-road	350	32	45
LA-LSD	CARB diesel	On-road	140	18	54
No. 2/HSD	Distillate	Heating/ off-road*	2,600	34	42
2007 Forecast					
ULSD	EPA diesel	On-road	8	32	46
LA-ULSD	CARB diesel	On-road	8	22	51
No. 2/HSD	Distillate	Heating/ off-road*	2,600	34	42

* Includes marine and railroad.

Pipeline Compliance Margins

- Pipelines require more restrictive product specs than retail specs to allow for some interface inclusion
- Current LSD with regulatory maximum of 500 ppm sulfur must be delivered to most pipelines at below 470 ppm sulfur to allow margin for contamination
- Survey of pipelines indicates they would require 5 ppm spec ULSD to be delivered at 1.5 ppm sulfur
- For proposed 15 ppm sulfur ULSD, pipelines will require about 8 ppm sulfur

Planned Quick Transition: ULSD Totally Replaces On-Road LSD

- Pros
  - Pipelines ship ULSD
  - Refineries, terminals and retail use existing LSD tanks for ULSD
  - Truck stops still handle only one diesel
  - Quicker tailpipe emissions reductions if retrofit older engines
- Cons
  - Increased chance of shortages
  - Requires refining HDS investments much sooner

Planned Quick Transition: ULSD Totally Replaces On-Road LSD (continued)

- **Cons**
  - **Eliminates LSD as pipeline batch buffer; use No. 2 as buffer; *hence, greater ULSD downgrading***
  - **Most terminals have only one tank for diesel; makes blending down off-specification ULSD infeasible; *hence, more shortages***
  - **Less foreign supply capability and imports; *hence, more shortages***
  - **More downgrading increases supply needs; *hence, more shortages***

Optional Gradual Transition: ULSD as Third Distillate

- Pros
  - Delays most refining investments
  - Avoids costs of desulfurization of most on-road diesel with no resulting environmental benefit
  - Matches supply and new engine demand for ULSD
  - Slow new ULSD engine penetration – over 20 years without retrofit
- Cons
  - Major pipelines batches large; hence, no ULSD pipeline shipments initially

Optional Gradual Transition: ULSD as Third Distillate (continued)

- Cons
  - Some terminals must add tank dedicated to ULSD
  - Truck stops must add facilities to handle two diesels; not needed after transition period
  - Fewer terminals; hence, greater trucking distances
  - Larger supply and distribution investment to handle ULSD as third distillate; not needed in future
  - Distribution costs for ULSD would be much higher initially

Costs/Impacts of Distributing Ultra Low Sulfur Diesel

- Distillate Refining and Distribution System in U.S.
- Specs and Properties; Transition from LSD to ULSD
- Problems Maintaining/Delivering Ultrapure ULSD
- Conclusions – Costs/Impacts of Distributing ULSD

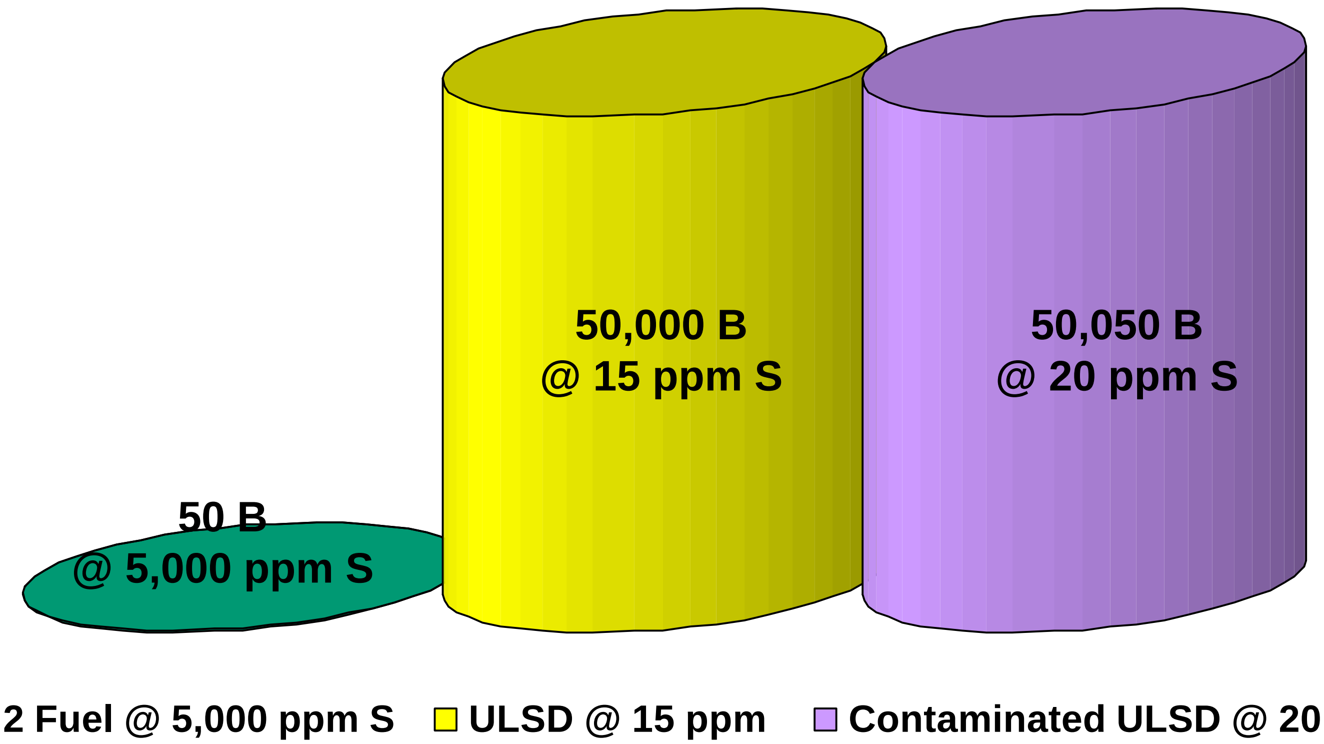
ULSD Creates Need for More Dedicated Handling Facilities

- Ultra high purity product requires dedicated facilities to minimize contamination and keep on-spec
- Refineries, pipelines and terminals would require dedicated tankage
- Separate, dedicated piping, loading racks, trucks or truck compartments
- Switching or multiple service of handling facilities not feasible due to contamination risk

Contamination/Off-Spec Risk Skyrockets

- Current
  - Average LSD (350 ppm S) can tolerate about 7% contamination with average HSD/No. 2 fuel (2,600 ppm S)
- Future
  - Average ULSD (10 ppm S) can tolerate less than 0.2% contamination with average HSD/No. 2 fuel (2,600 ppm S)

ULSD Prone to Go Off-Spec with 33% Increase in Sulfur from 0.1% Contamination with No. 2 Fuel



Disparity of Sulfur in Adjacent Batches

- Wide disparity of sulfur specs in adjacent pipeline batches will make ULSD prone to contamination
  - 5,000 ppm S: Heating oil/off-road diesel (HSD)
  - 3,000 ppm S: Kero jet
  - 500 ppm S: Current LSD
  - 15 ppm S: EPA required ULSD

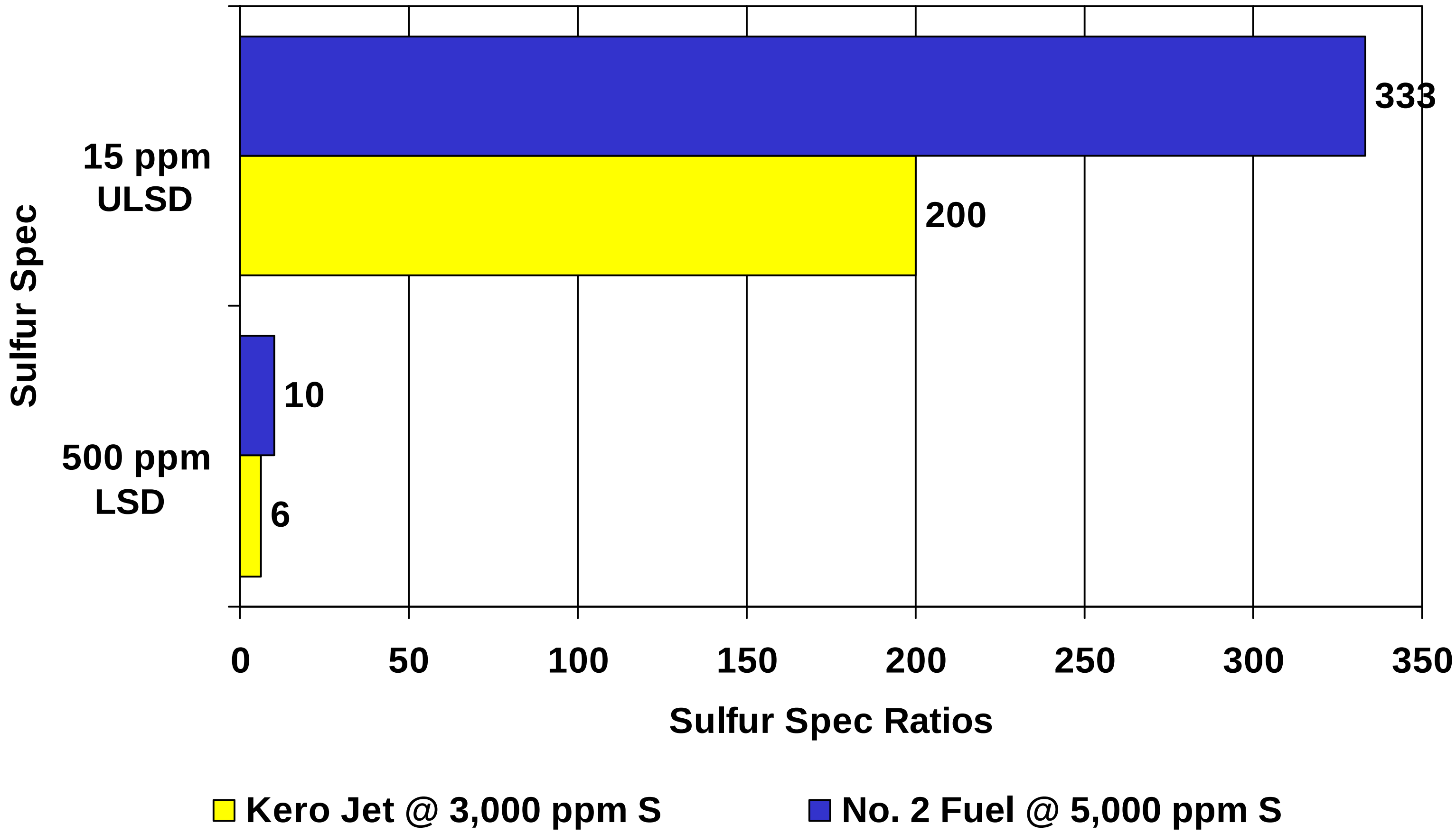
Adjacent Batch Sulfur Spec Ratios Will Soar and Increase Quantity Downgraded

- **Currently, sulfur spec ratio of No. 2 fuel versus LSD is 5,000:500, or 10:1, for adjacent pipeline batches**

- **In 2006, sulfur spec ratio of No. 2 fuel versus ULSD will jump to 5,000:15, or 333:1, for adjacent pipeline batches**

- **This shift will increase on-road diesel contamination and downgrading from small to substantial level**

Sulfur Spec Ratios of Abutting Products to ULSD and LSD in Pipeline Shipments



No Experience with Extremely High Spec Ratios for Adjacent Batches

- Closest historical comparison would be introduction of unleaded gasoline
- Maximum lead in unleaded gasoline was 0.05 gms/gallon
- Due to voluntary spec reductions, leaded gasoline had maximum lead spec of 2.5 gms/gallon
- Hence, ratio of lead specs in leaded versus unleaded gasoline was 50:1

Pipeline Interfaces Will Increase

Current

Total interfaces up to 2.0% – split 25/75% based on delta gravity
Minor product quality changes within specs
1.0% LSD downgraded to HSD/No. 2

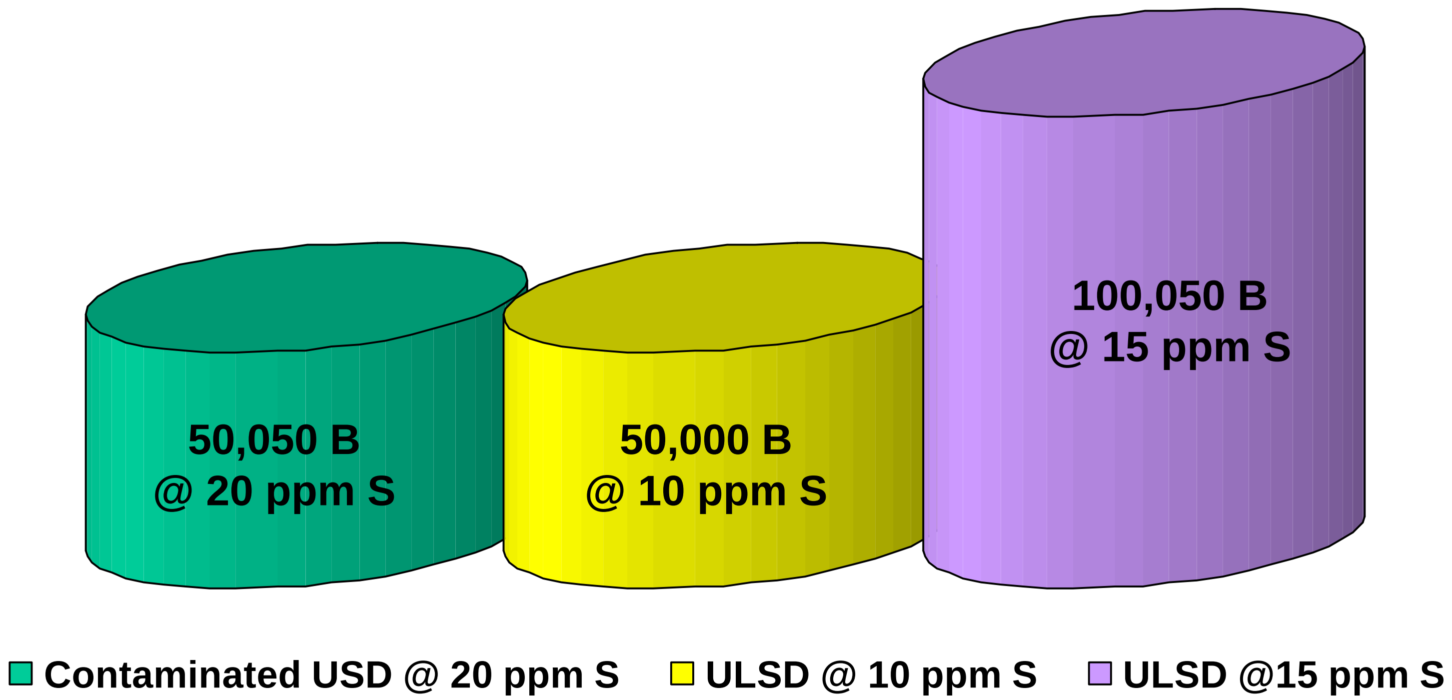
Future

Total interfaces up to 5.0% – split 0/100% based on delta sulfur
Minimize delta sulfur in ULSD within spec
5.0% ULSD downgraded to HSD/No. 2

No Extra Distribution Facilities

- Single tank in each service at most terminals, retail
- Tanks normally well utilized
- Tanker trucks usually have several compartments
- Adding second diesel would require separate dedicated compartment(s) or tanker(s)
- For second diesel, added dedicated tank, pumps and nozzles needed at most truck stops

Blend-Down of Off-Spec Batch of ULSD Requires Availability of Unused Dedicated ULSD Tank



Extra unused ULSD tankage probably will not be available to blend down off-spec batches to avoid downgrading them.

Costs/Impacts of Distributing Ultra Low Sulfur Diesel

- Distillate Refining and Distribution System in U.S.
- Specs and Properties; Transition from LSD to ULSD
- Problems Maintaining/Delivering Ultrapure ULSD
- Conclusions – Costs/Impacts of Distributing ULSD

More Downgrading

- Downgraded on-road diesel will increase from about 2.5% for LSD up to about 17% for ULSD
- Based on two pipeline and one terminal breakout from adjacent HSD/No. 2 fuel

Off-Spec ULSD Routing/Blockage

- Single ULSD tank at most terminals
- Off-spec ULSD must be removed and then replaced
- When off-spec, ULSD supply temporarily blocked, causing retail shortages

Spot Shortages

- Supply outages due to off-spec diesel will occur more frequently
- Distribution will sometimes be restricted by off-spec product and inability to dilute to bring back on-spec

Price Spikes

- Spot outages/shortages will create unsatisfied demand
- In uncontrolled or free market, demand will be restricted to match supply by higher prices
- Prices will remain higher until normal supply is restored
- Consumers, media and politicians will accuse industry of price gouging during price spikes

Higher Distribution Costs

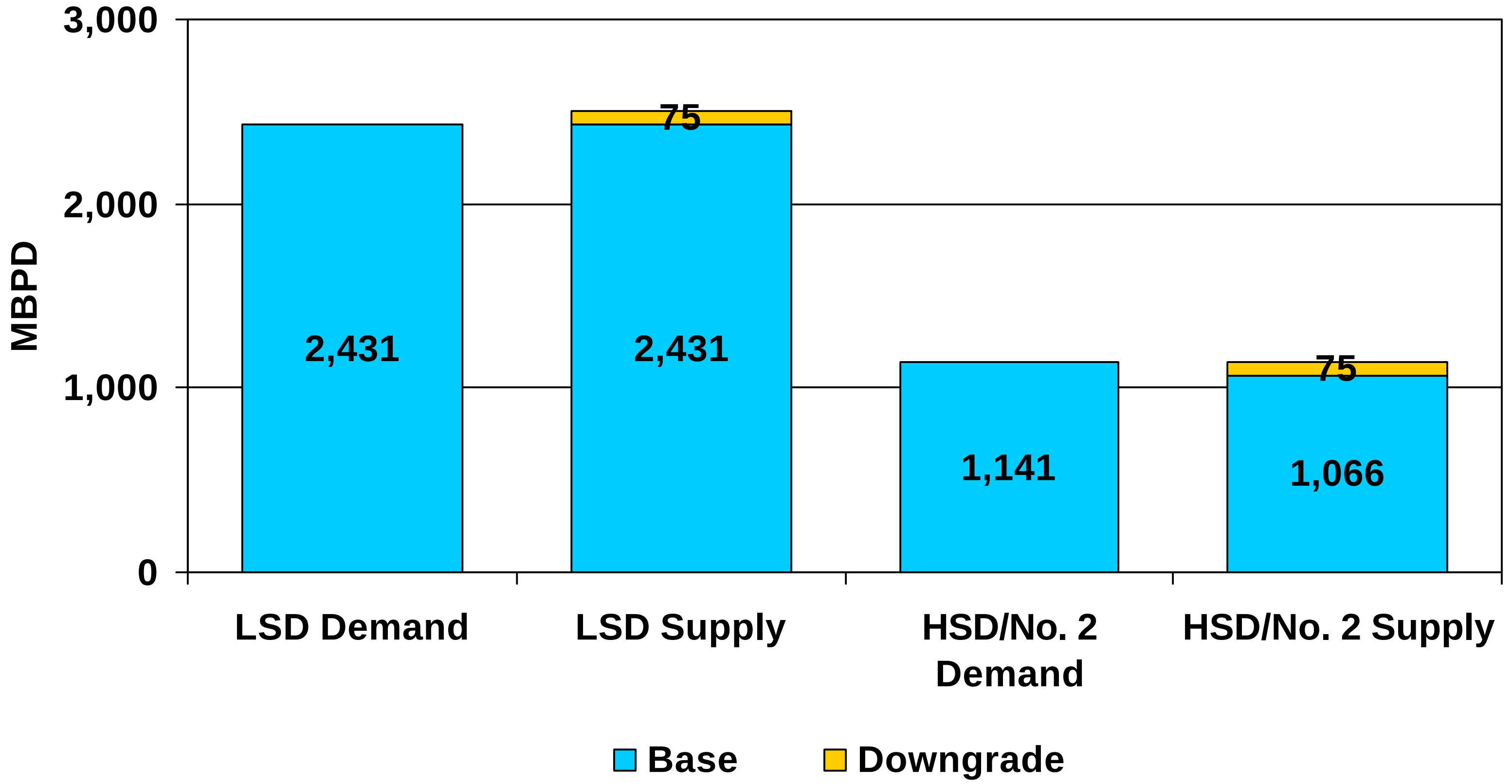
- Estimated added distribution costs over LSD for 100% penetration (¢/gallon of ULSD)
  - Average: 0.9
  - Range: 0.5-1.4

- Based on up to 17% downgraded at about 5¢/gallon higher cost for ULSD over HSD/No. 2 fuel and capital charge for added distribution investments

Increased Supply Required for Downgrading Losses

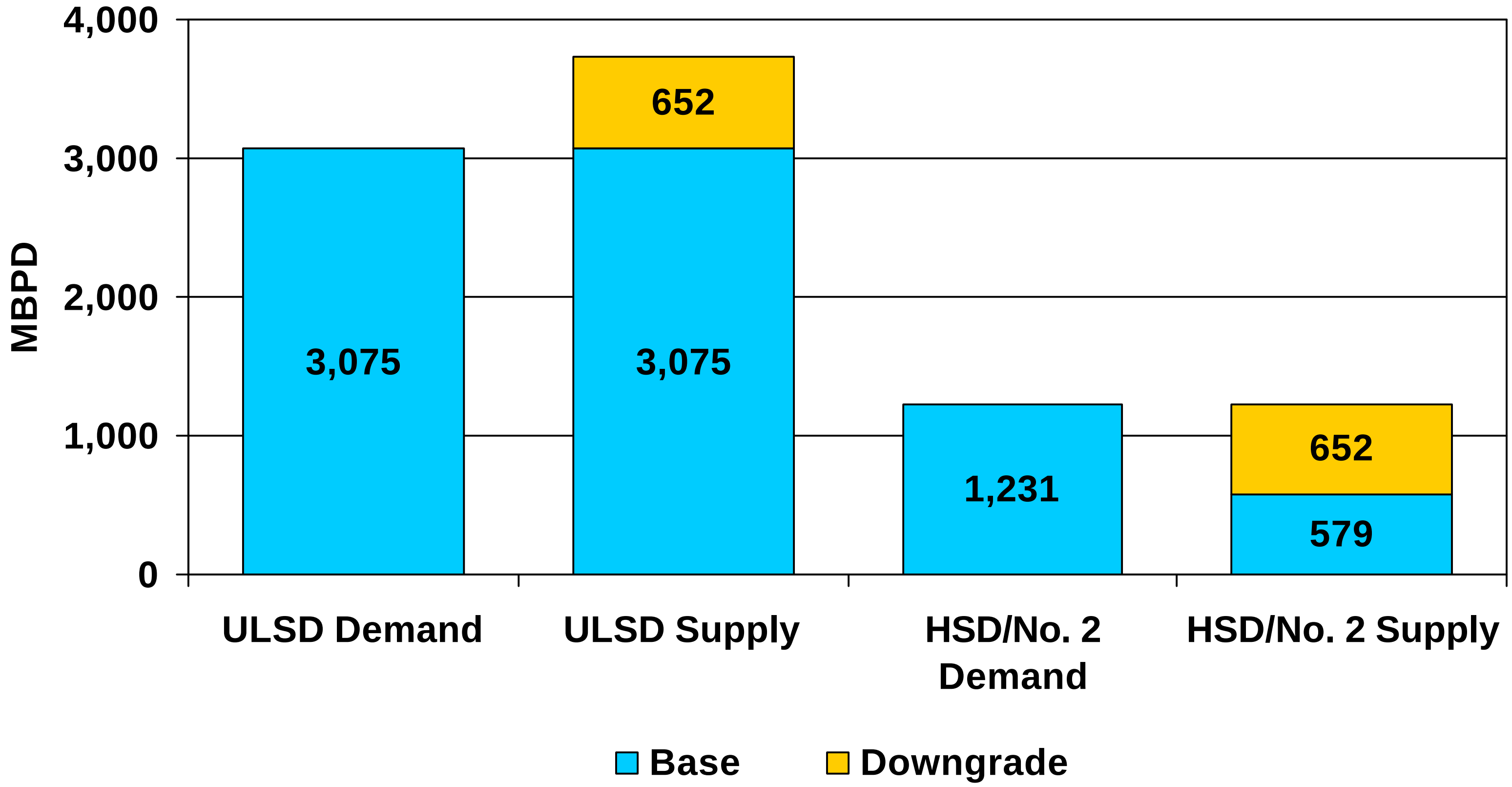
- **Refineries must make more on-road diesel for ULSD downgrading to HSD**
- **Problem in parts of PADDs IV and V with low demand for HSD/No. 2 fuel versus ULSD**
- **If insufficient HSD/No. 2 fuel demand, some off-spec ULSD must be returned to refineries or exported**
- **Contaminated ULSD cannot be blended down to spec unless extra dedicated ULSD tanks are added**

U.S. Distillate Supply and Demand – 1999
Impacts of Downgrading



TURNER, MASON & COMPANY
Consulting Engineers

U.S. Distillate Supply and Demand – 2008
Impacts of Downgrading



ULSD in Light Duty Vehicles Will Require More Outlets

- Urban market
  - Switch from LSD to ULSD at service stations with existing diesel facilities (about 12% of retailers)
- Rural market
  - More costly to supply ULSD in rural areas and small towns at service stations with no diesel; requires new facilities
- Truck stops
  - Inconvenient location for refueling most new diesels in light duty vehicles (SUVs)

ULSD Production Not Viable for Small Refineries

- Most small refineries (<50 MB/D) will not invest to make ULSD (diseconomies of scale)
- Small refineries may
  - Continue to make LSD for four years (if small refiner)
  - Join with nearby small refineries in combined facility to make ULSD
  - Shut down
- Result in probable ULSD shortages in PADD IV

Refining Impacts of ULSD

- LCO problems
  - High aromatics, low cetane, low API gravity and high benzothiophenes
  - Gravity and cetane limit use in HSD/No. 2 fuel
  - Cannot include in CARB LA-ULSD
  - Difficult to desulfurize with existing moderate pressure HDS units
  - Could become lower value limited use component

Refining Impacts of ULSD (continued)

- Possible solutions to LCO problems
  - Route to hydrocracker feed
  - Sell as hydrocracker feed
  - Build higher pressure diesel HDS unit
  - Build Phillips S-Zorb unit (desulfurizes easily)

Estimated Yields of On-Road Diesel in Distillate from U.S. Conversion Refineries*

	On-Road Diesel in Distillate, %				
	0-20	21-50	51-80	81-100	Total
Current LSD (68%)					
% of 111 Refineries	15	18	29	38	100
% of Crude Capacity	13	14	32	41	100
Forecast ULSD (61%)					
% of 100 Refineries	31	7	39	23	100
% of Crude Capacity	19	8	45	28	100

* Non-conversion refineries have 6% of crude capacity but only 1% of LSD output.

Estimated ULSD Supply and Shortage

	MBPD		
	Distillate	ULSD or LSD	% ULSD or LSD
1999 – Current – LSD			
Actual Refining	**3,399**	**2,307**	**68**
Net Imports/Other	**173**	**124**	**72**
Shortage	**0**	**0**	
2008 – Forecast – ULSD			
Refining	**3,900**	**2,379**	**61**
Net Imports/Other	**406**	**284**	**70**
Shortage	**0**	**1,064**	**100**

If you want a copy of this presentation, please give your business card to Bob Cunningham.

You may also send your request via email to rec@turnermason.com

or visit the Turner, Mason & Company website at turnermason.com