

FCC Benchmarking – Exploring Industry Trends and Creating Paths Forward

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MORE PRODUCTION - LESS RISK!

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May 2013
Galveston, TX

BASF Benchmarking

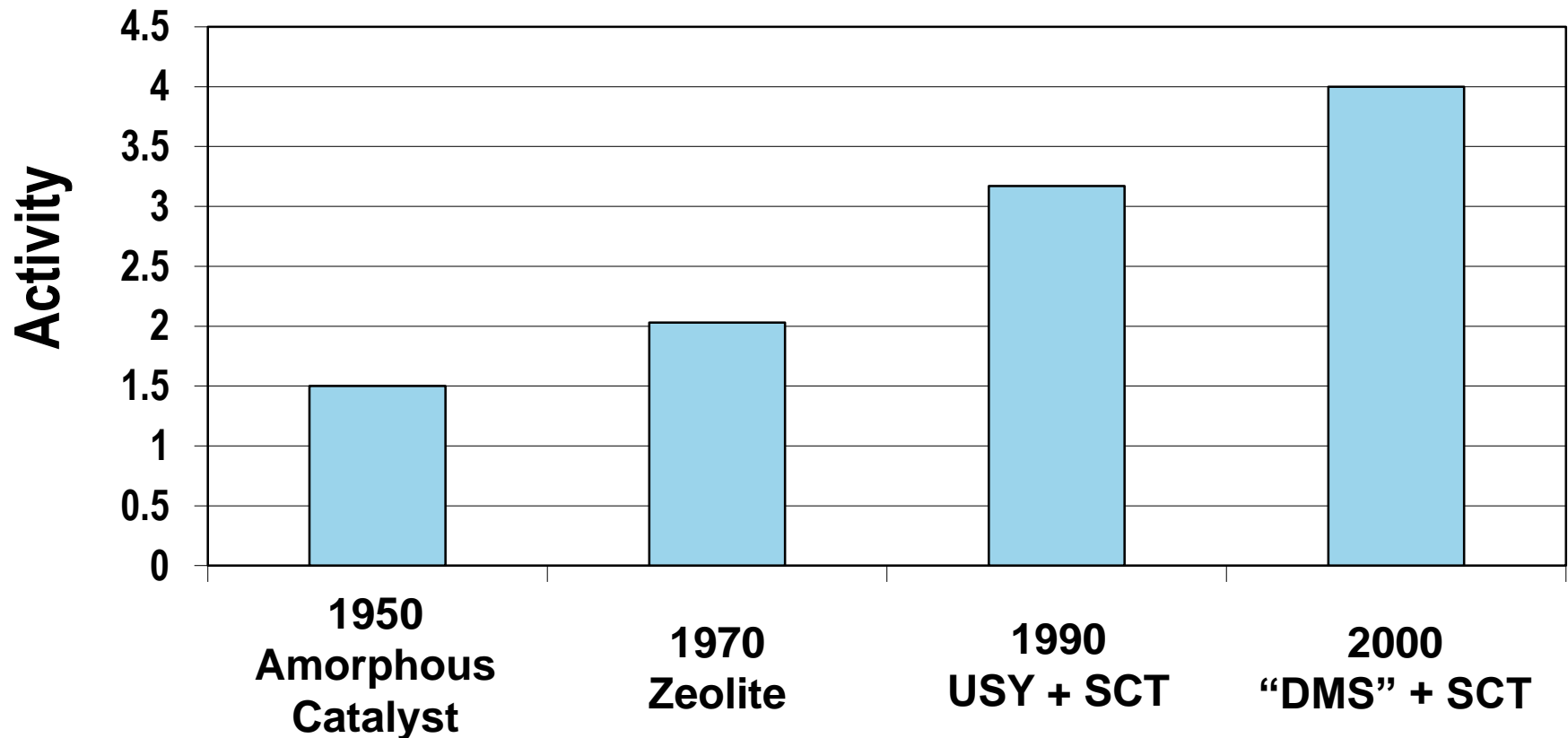
- BASF maintains a database of unit operation, ECat (equilibrium catalyst) and feed properties for FCC unit across the world
- The database contains a diverse range of catalyst suppliers, unit designs, operating conditions and yields
 - Our ECat database contains information for over 200 units
 - Our unit operation database contains over 1,000 operating snapshots of over 250 units in the past 20 years
- From this, we can evaluate global and regional trends, and design catalyst solutions that will meet the coming demands

In Today's Refining World ... FCC is a Key Player due to its Inherent Flexibility

- Over the years technology advances, crude slates, and economics have changed how refineries operate the FCC
 - Hardware examples – advanced feed nozzles, riser termination devices, stripper efficiency improvements
 - Catalyst examples – zeolite catalysts, coke selective matrices, higher activity with attrition resistance

- Gasoline demand declining in North America and Western Europe
- Diesel growth is higher than gasoline in all regions
- Tight Oil is changing the crude slates to refineries in North America
- Heavier crudes to refineries globally
- Increasing demand for petrochemical feedstocks from heavy oil sources

FCC Process and Catalyst Technology Advancements Work Together



BASF Investment in Innovation and Technology

- Continued commitment to innovation through investment in R&D
- BASF operating six FCC technology development platforms:
 1. Rare earth replacement technology
 2. Next generation high conversion and impact of tight oil
 3. Heavier crudes to refineries
 4. Growing petrochemicals demand – particularly propylene
 5. Incremental demand for diesel over gasoline
 6. FCC emissions reductions – NO_x/SO_x/Particulates
- Our focus remains value creation for the oil refining industry

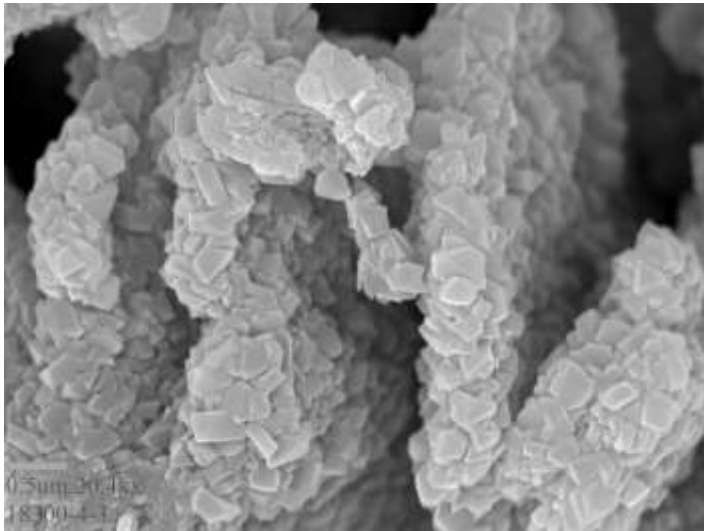
BASF FCC Catalyst Platforms

Distributed Matrix Structures (DMS)

Proximal Stable Matrix & Zeolite (Prox-SMZ)

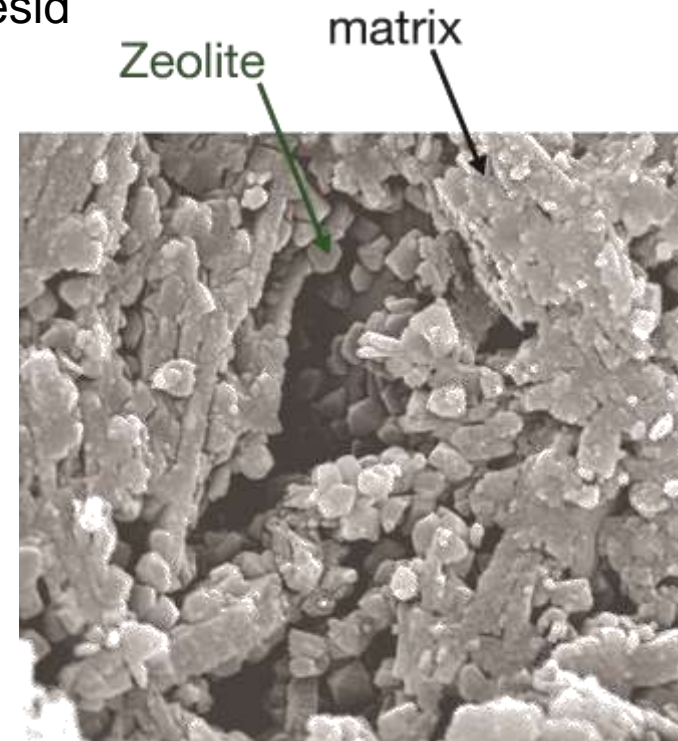
DMS

- High activity zeolite
- Coke selective cracking
- High conversion, Gasoline, $C_3=$



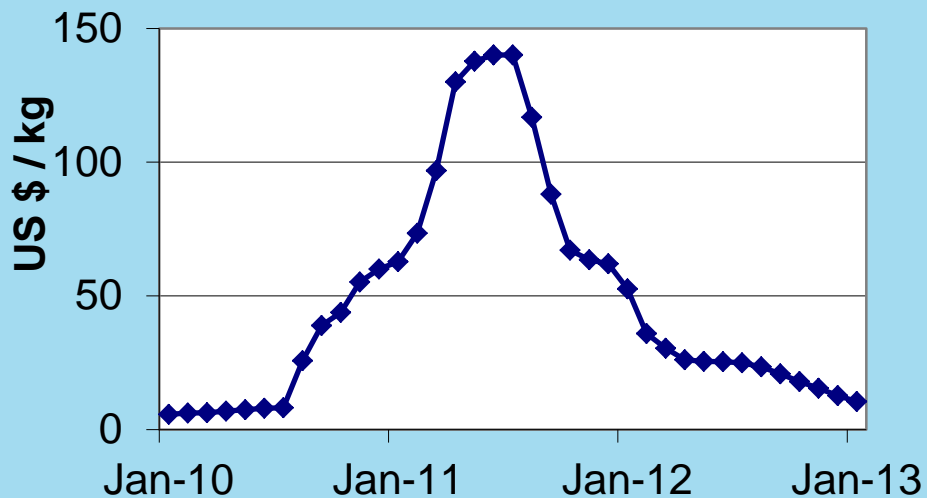
Prox-SMZ

- Stable Matrix and Zeolite Cracking
- Optimized for middle distillates and resid

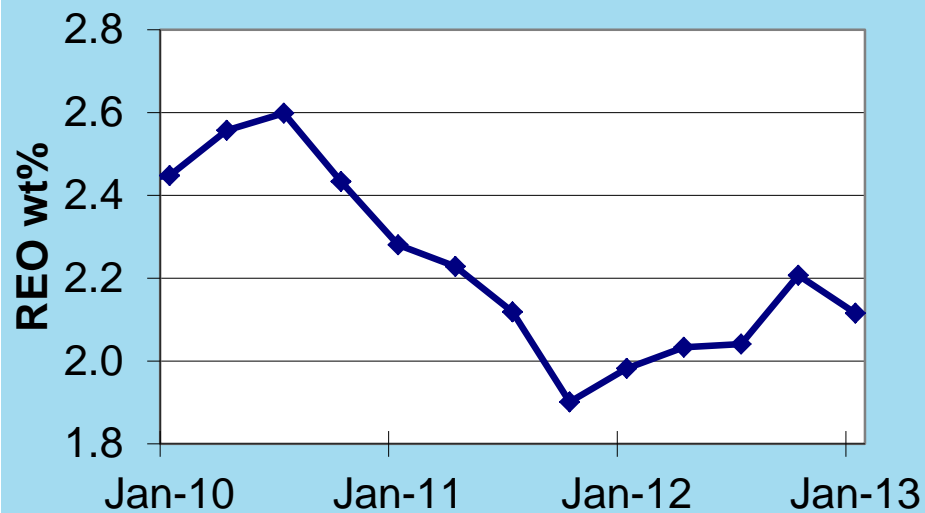


1. Volatile REO Pricing

Lanthanum Oxide Price
Asia Metals Index



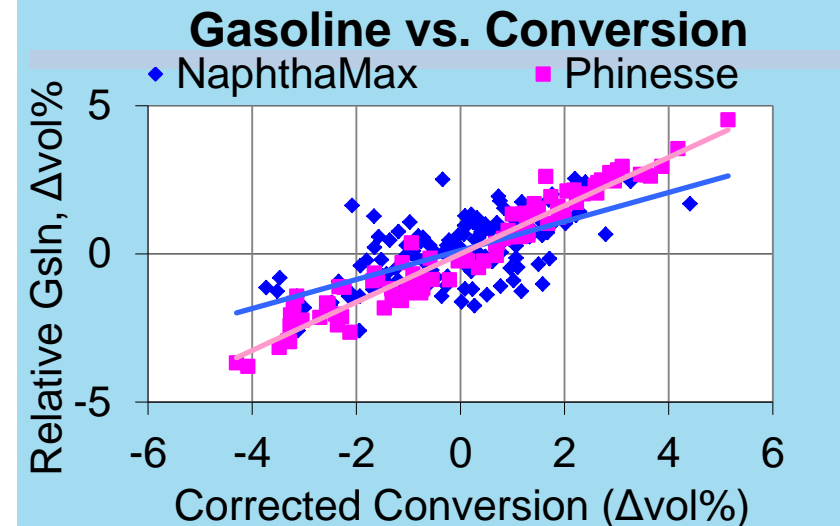
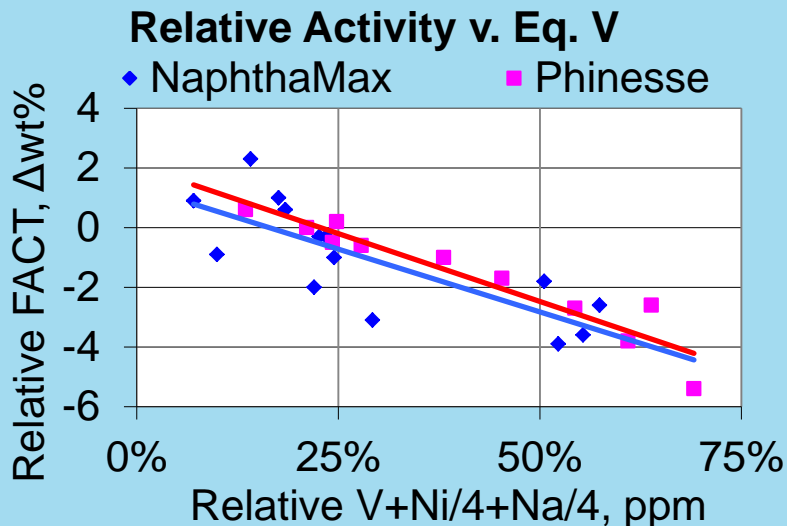
Average REO Shipped



- Due to export restrictions, Lanthanum oxide price increased from <\$10/kg to over \$140/kg
- The price increase, which has since come down to historic levels, prompted refineries to lower their catalyst REO (where it made sense) and BASF to research alternatives to REO

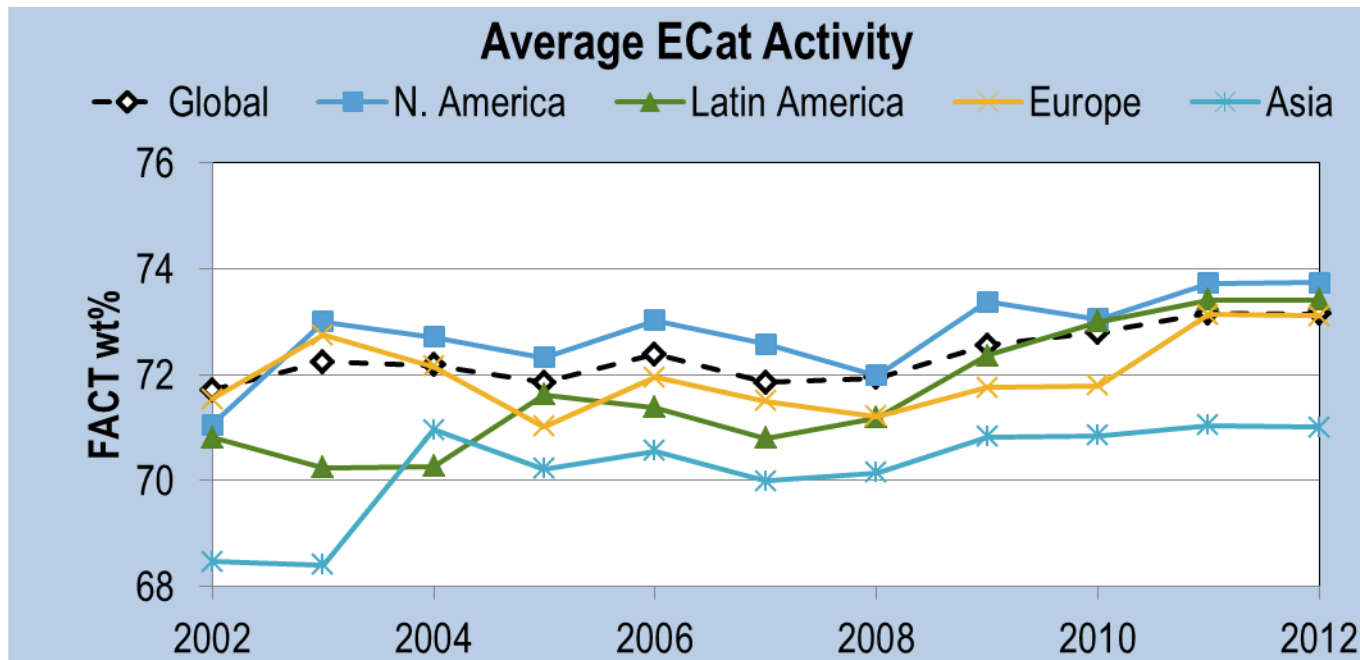
Alternative REO Replacement Technology- Phinesse™

- **Phinesse™** is BASF's first alternative REO FCC catalyst using phosphorus stabilization
- Phinesse is designed for high conversion gasoil units
- The first refinery trial in late 2012 conducted at Shell Sarnia
 - With 50% lower REO, Phinesse achieves the same activity and yield selectivities as BASF's market leading NaphthaMax® catalyst



2. Next Generation High Conversion Catalyst and the Impact of Tight Oil

- With increased hydrotreating and the introduction of Tight Oil to the North American Market, high activity catalysts are required
- North America was flat from 2002-2008, and increased ~2 numbers from 2008-2012
- Average global activity was also flat from 2002-2008 and has increase by ~1.5 numbers over the past 4 years



Tight Oil: BASF Leads the North American Market

- With the introduction of Tight Oil to the North American Market, high activity catalysts are required along with optimal delta coke to keep the unit in heat balance
- Between 2011 and 2020, gravity of processed crude oil will increase by 1.1 °API – Source: Hart Energy
- Typical tight oil quality: lighter, lower boiling range, lower heavy metals (Ni & V), higher alkali metals, and higher paraffin content
 - The quality of crude from a single production field can vary greatly
 - FCC catalyst technology and service must be flexible to meet the changing feed quality and operating conditions associated with the crude
- BASF is the market leader for tight oil FCC applications providing catalyst solutions to meet the unique challenges of processing tight oil

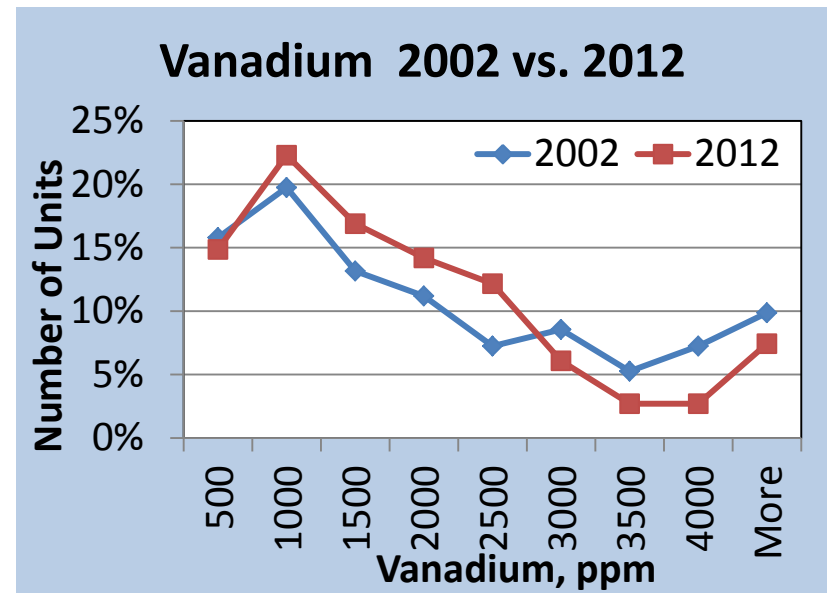
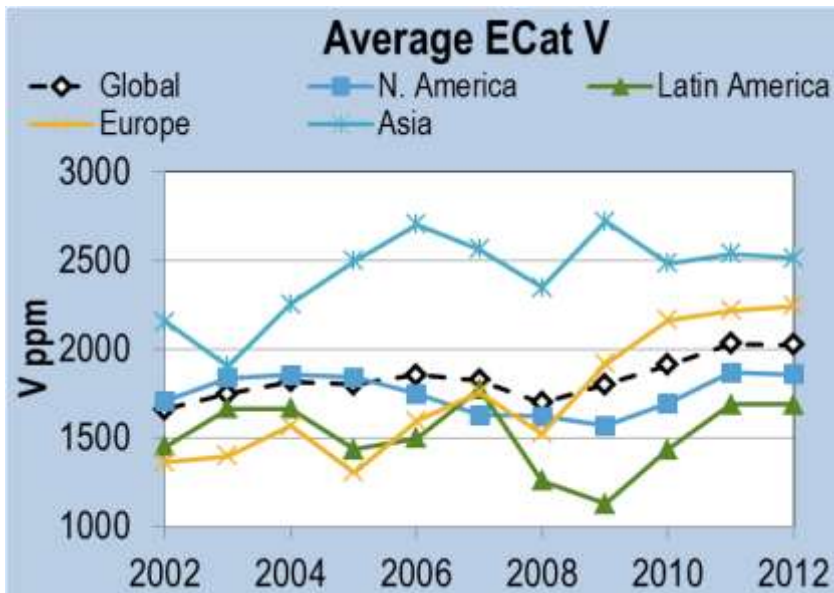


Tight Oil Quality Variability from one Field

Source Baker Hughes

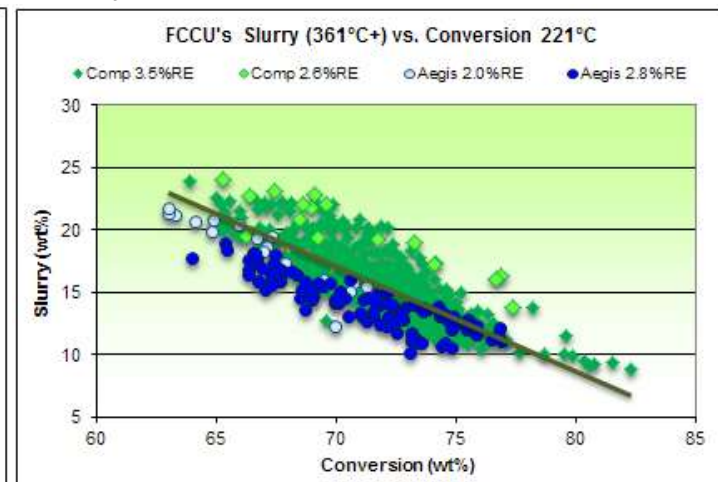
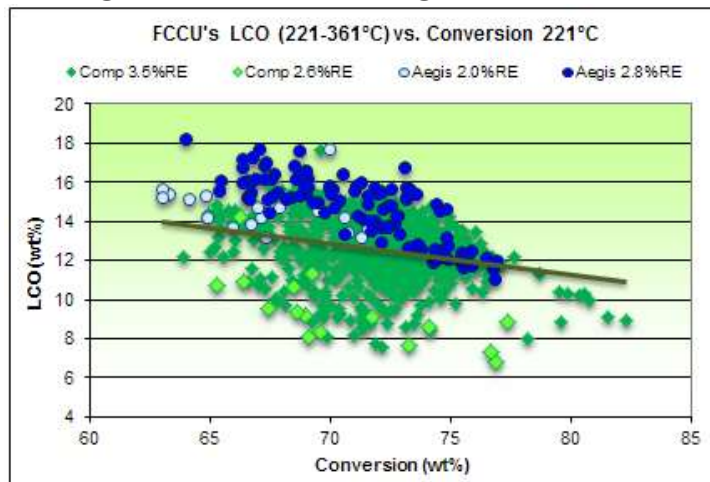
3. Heavier Crudes to Refineries

- Outside N. America, crude to refineries is expected to continue to get heavier
- Over the past 10 years Vanadium in all regions have increases. Global average increased 500 ppm.
- The number of FCC units processing very high vanadium numbers (>3000ppm on Ecat) hasn't changed much over 10 years, but more units are processing moderate levels (1000-3000 ppm)



Upgrading Resid Feedstock with BASF Catalyst at Tamoil Collombey

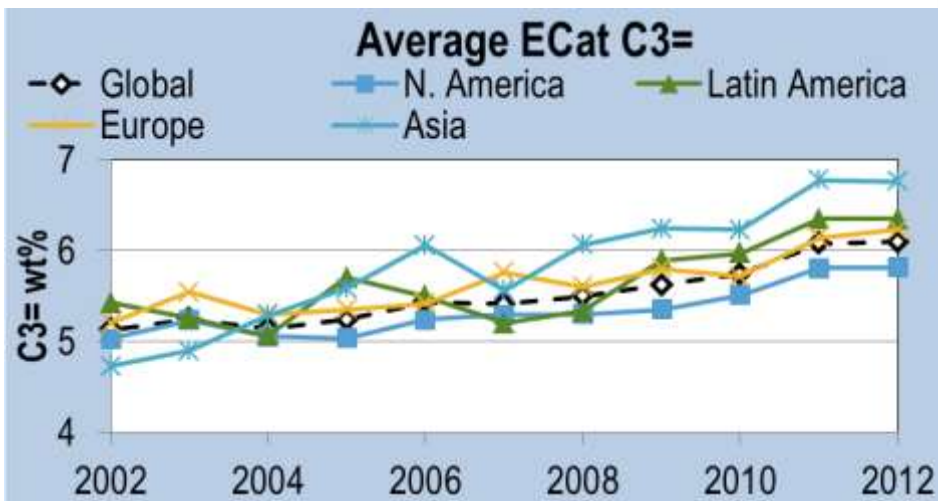
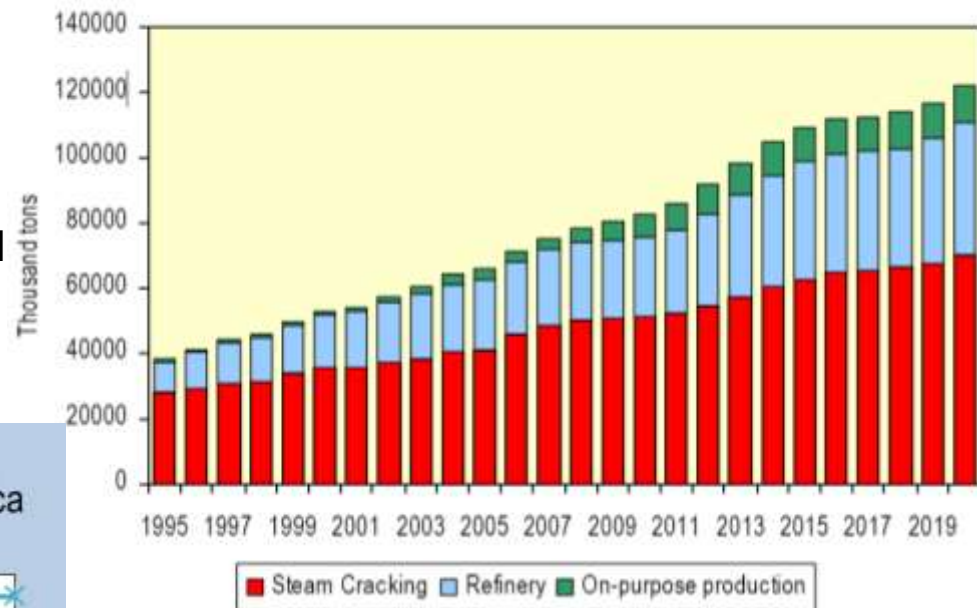
- Tamoil S.A. Collombey Refinery is an IFP R2R unit
- BASF Aegis™ catalyst replaced a competitors technology
- The Tamoil Collombey Aegis catalyst is designed for improved bottoms upgrading, maximum gasoline + LCO, minimized LPG, and high metals tolerance
- The unit response showed a lower LPG to Gasoline ratio, improved bottoms upgrading, and no change in coke selectivity



4. Growing Petrochemicals Demand

- Refinery (FCC) based portion doubles 2005-2020
- Incremental growth 2005-2020 is sourced 50% from refineries
- On-purpose market develops but still small
- Steam cracking remains largest source but share declines

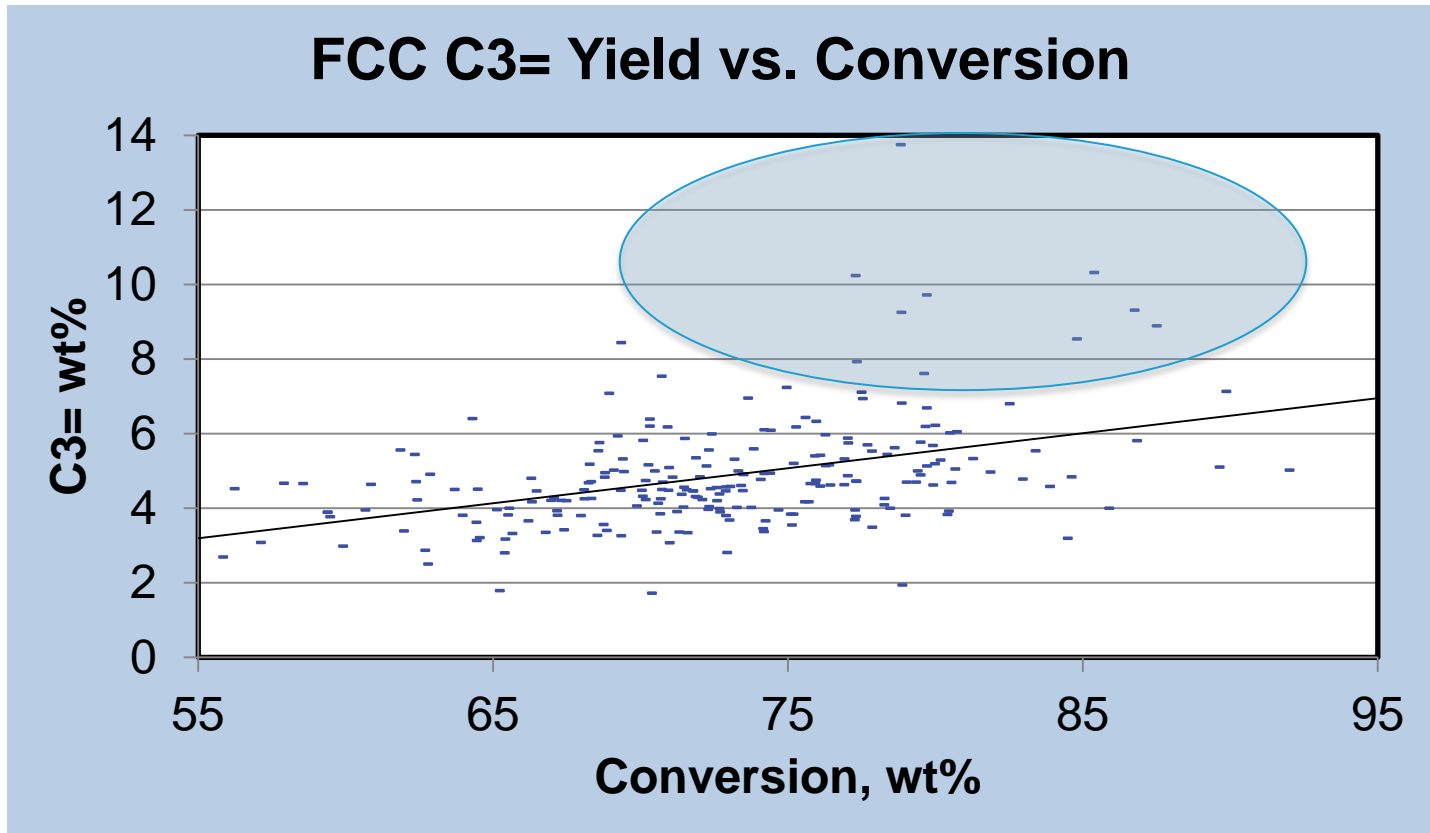
Figure 1.1 Global Propylene Production by Process Technology



- BASF ECat trends show significant propylene make increase from all regions

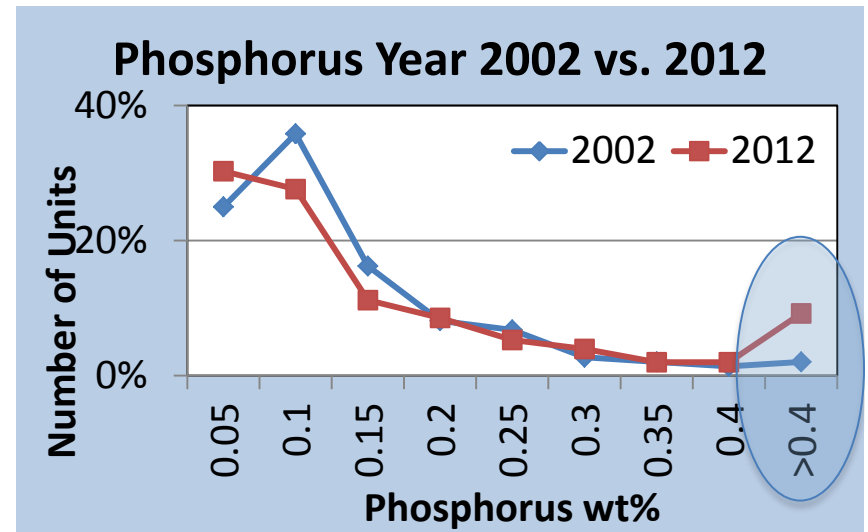
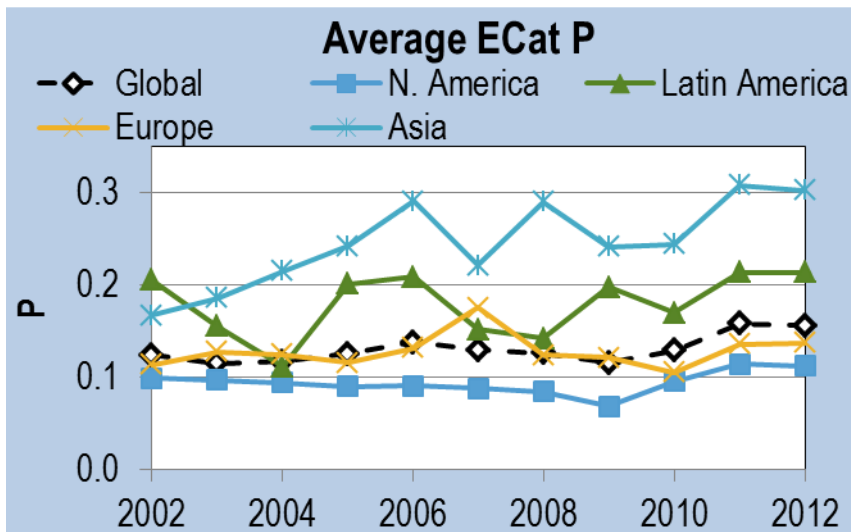
Growing Petrochemicals Demand

- Global average of FCC unit C3= yield is 5 wt%
- Max propylene units show C3= yields of 8-14 wt%



Growing Petrochemicals Demand

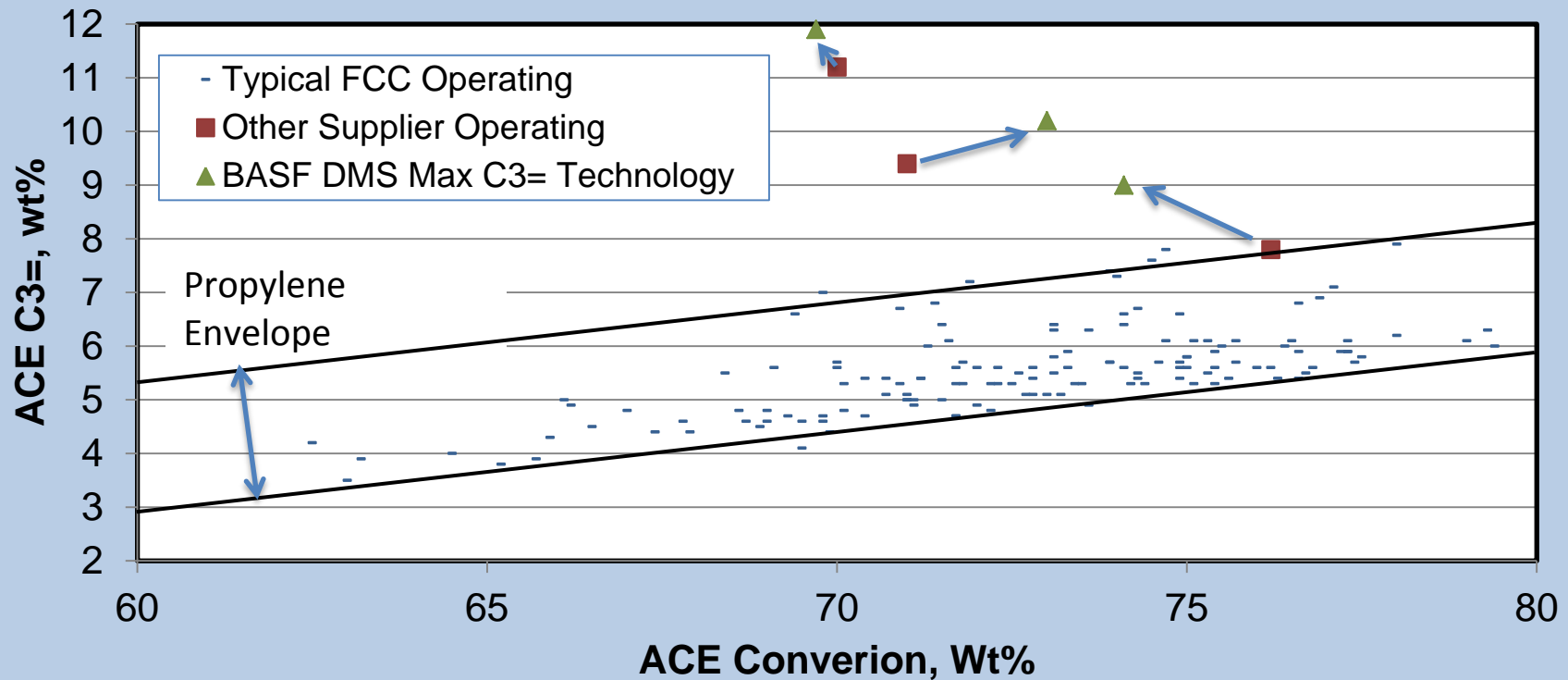
- Catalyst options to increase propylene production includes high activity, reducing REO, and using ZSM-5 (indicated by phosphorus on Ecat analysis)
- Global average of Phosphorus has increased 40% over the past 10 years (0.11 to 0.16wt%)
- Comparing 2002 to 2012 , there is an increase from 2 % to 9% of units who operate with high ZSM-5 above ~7wt% of catalyst inventory



Petrochemical FCC Operations

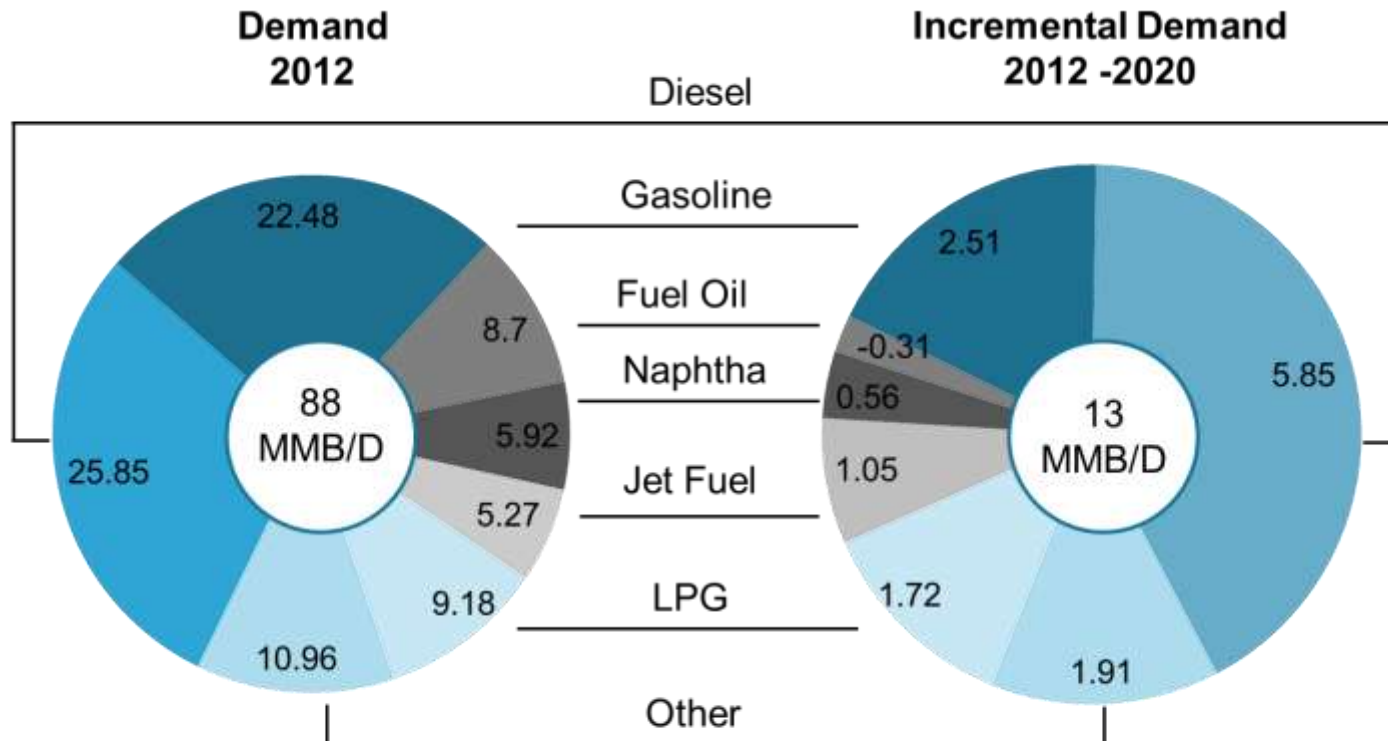
BASF DMS Technology Improves C3= Selectivity

Maximum Propylene Production Operations



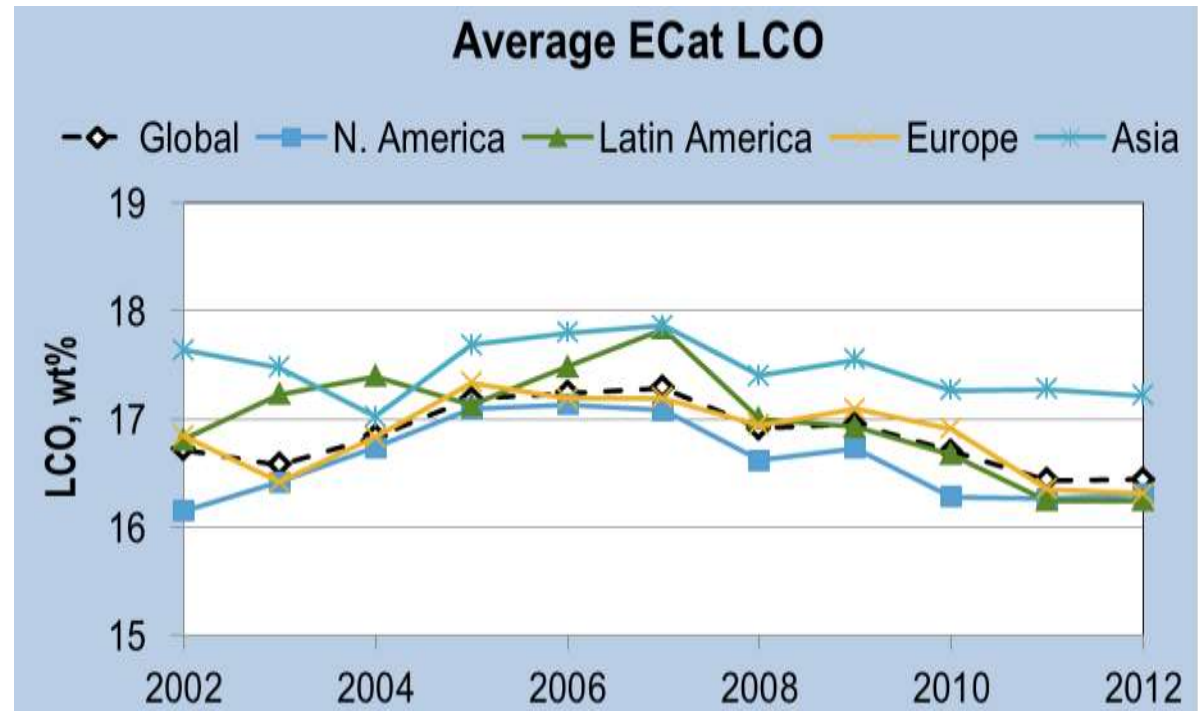
5. Increase Diesel Demand

- The Global growth rate for Diesel is higher than Gasoline
- World wide fuel demand and incremental change until 2020**



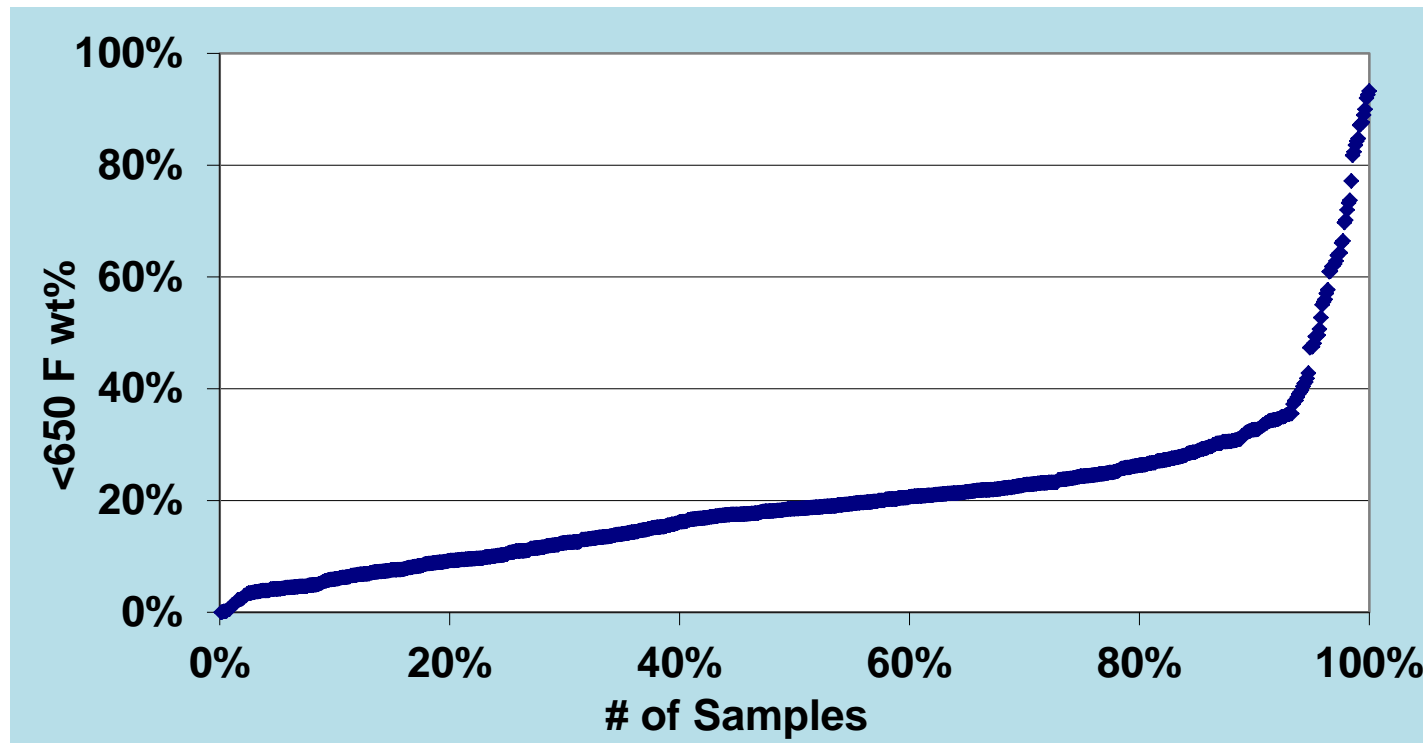
Benchmarking FCC LCO Production

- While we clearly see a decrease in LCO make going into 2008 with the economic crisis, long term global trends will drive to less gasoline and higher LCO make from FCC units



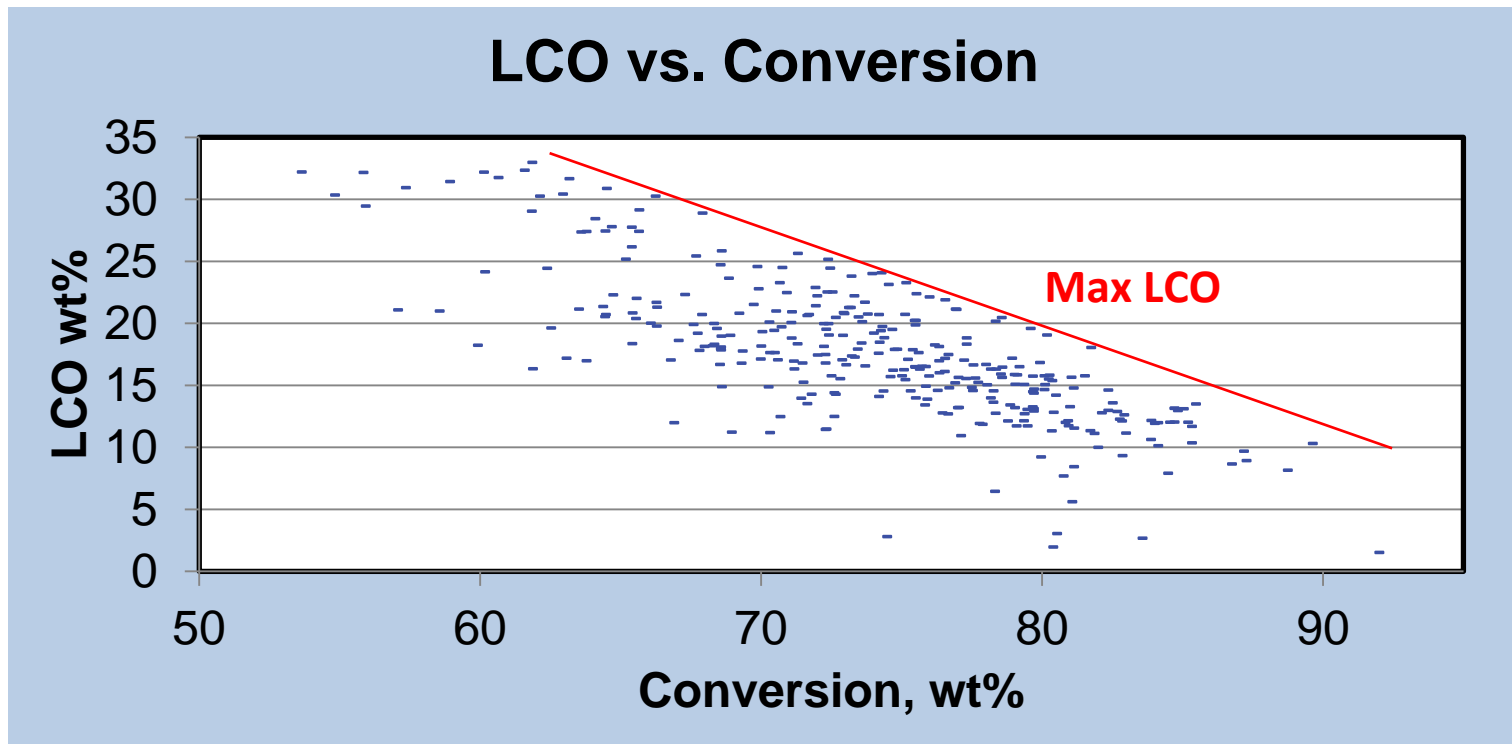
Feedstock Benchmarking for 650- degF

- The average units has 20 wt% diesel range material in the feed



LCO Yield Benchmarking

- The average units LCO yield is 17.5 wt%
- This means most units are net destroying diesel range material!



Prox-SMZ Technology Platform

Innovatively Addressing New Challenges

■ Prox-SMZ

- Novel platform for maximum distillate yield featuring:
 - Highly stable bottoms cracking matrix
 - Proximal interaction of zeolite and matrix
 - Ultra-low sodium for maximum hydrothermal zeolite stability

■ HDXtra™ for gasoil applications introduced 2008

■ Stamina™

- Prox-SMZ catalyst for resid feeds introduced 2009

■ Aegis™

- Combines DMS and Prox-SMZ for maximum flexibility with resid feeds

HDXtra Catalyst Trial at Frontier El Dorado

Corrected LCO Increased by 4 Vol %

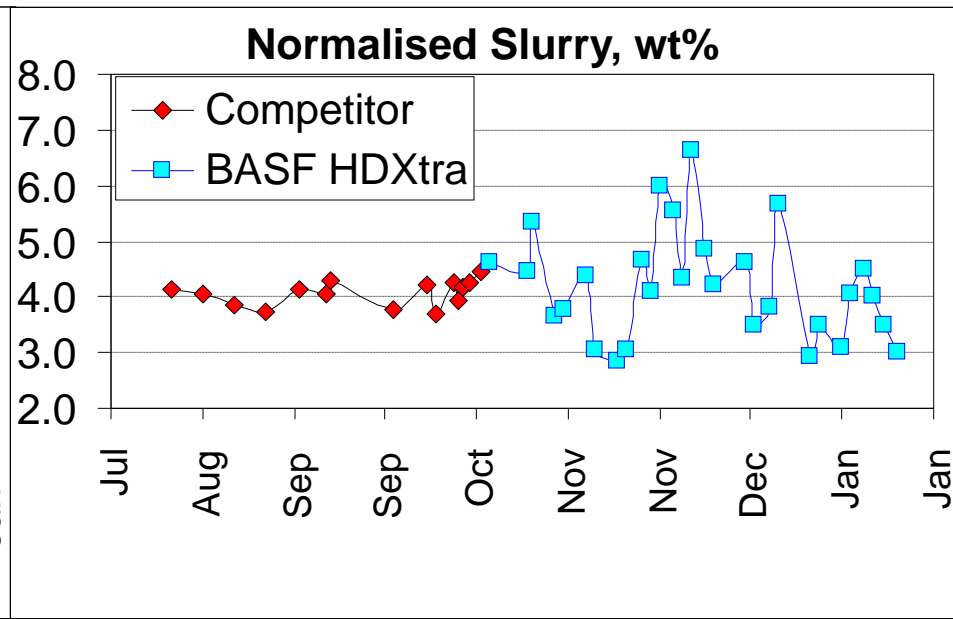
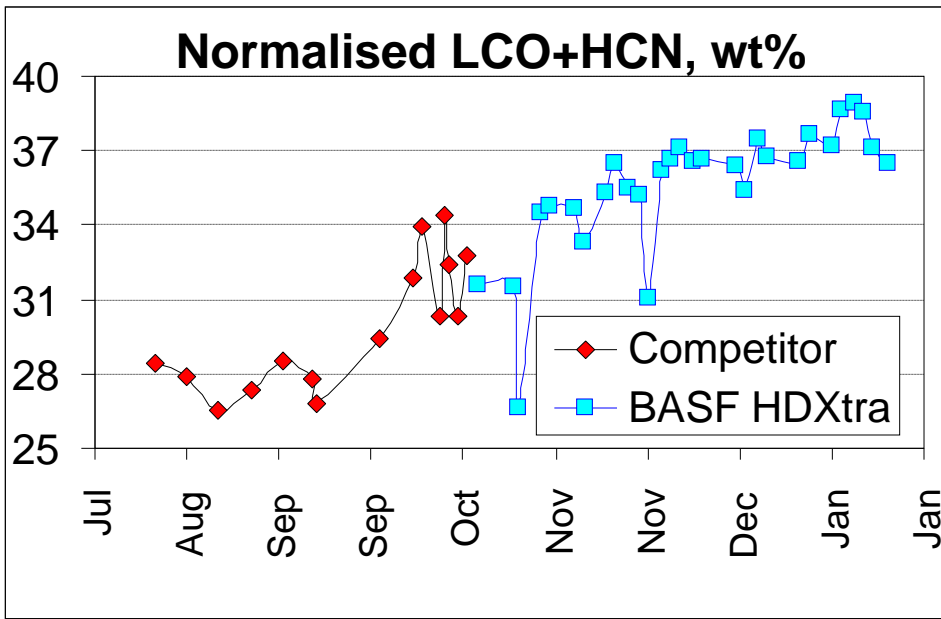
	<u>Base</u>	<u>HDXtra</u>	
As Produced Yields Vol %			
Gasoline	56.9	51.5	
LCO	20.7	30.9	+ 10.2%
CSO	5.7	5.1	
Corrected LCO (430-650F) Vol %	16.8	20.8	+ 4 %
Catalyst Z/M Ratio	2.1	0.8	

Note: ~50% catalyst changeout

European Trial of BASF Max LCO Catalyst HDXtra

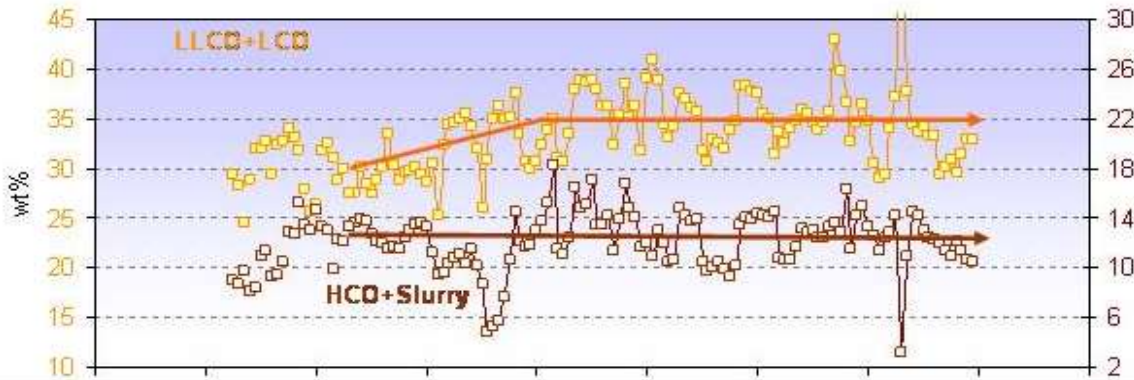
- Normalized production of Diesel from FCC reached unprecedented maximum levels

- Normalized production of Slurry from FCC remained in the same range

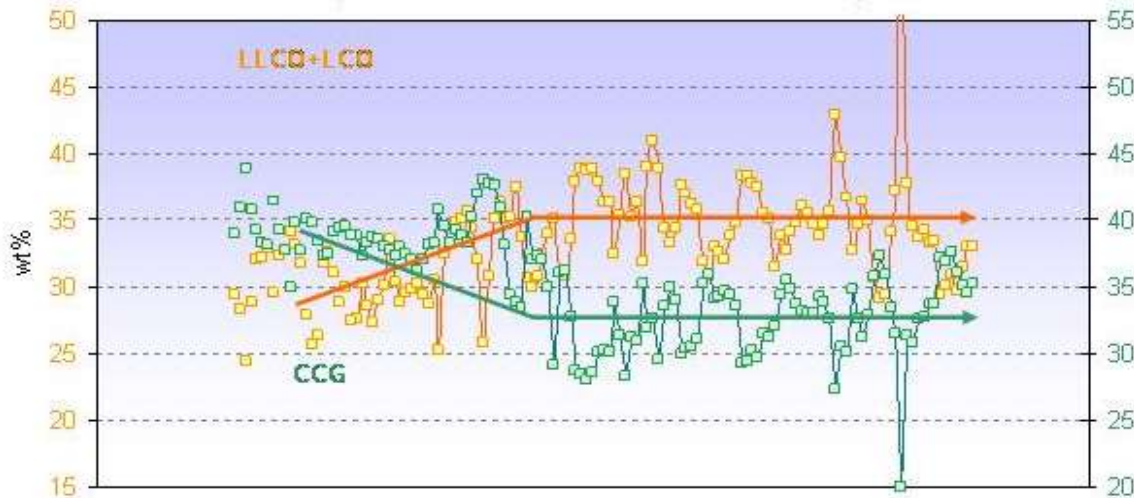


Stamina™ Europe

Total (LLCO+LCO) & Total (HCO+Slurry) Trends



Total (LLCO+LCO) & Total CCG Trends

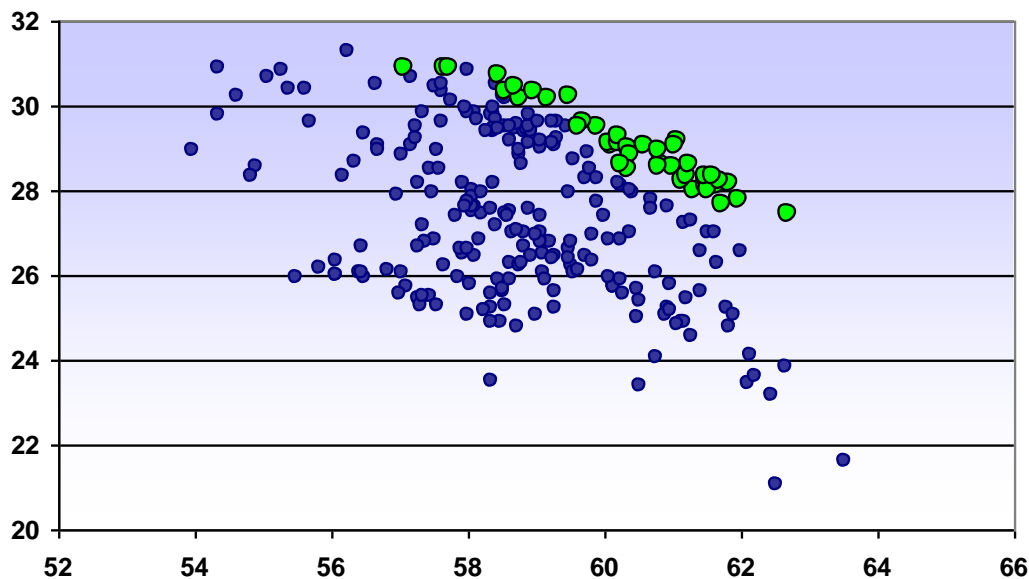


Maintained low slurry while increasing Distillate yields.

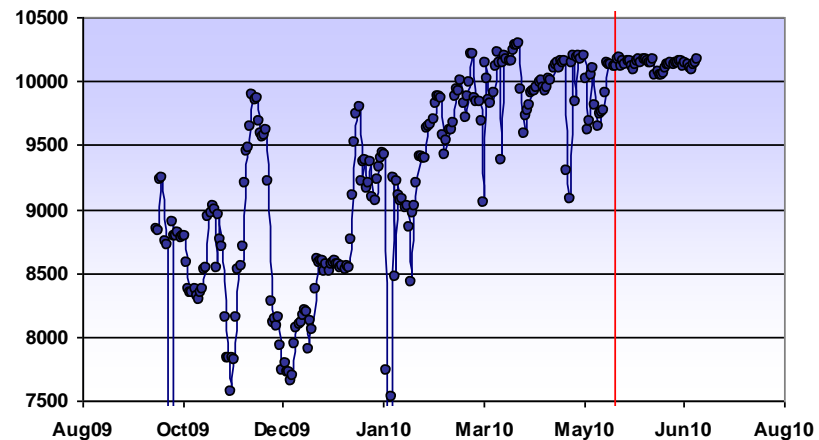
Asia Stamina Trial R2R Unit

- Good coke selectivity of Stamina allows the unit to run at max rates
- Stamina shows the best LCO selectivity

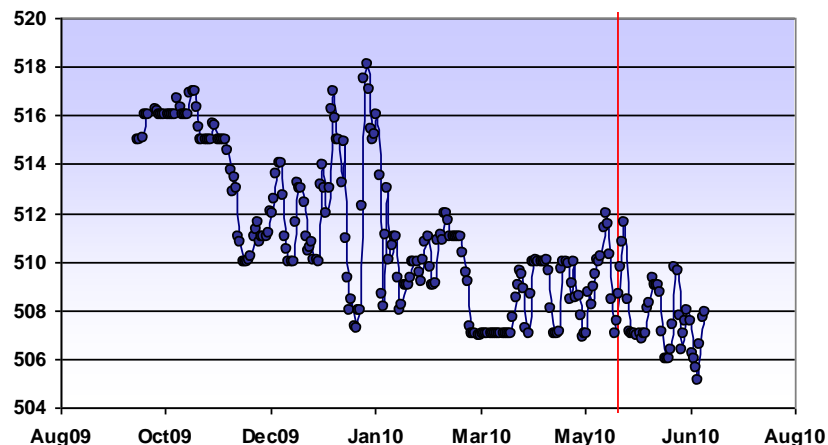
LCO vs Conversion



Feed Rate, MT/day



Reactor Temperature



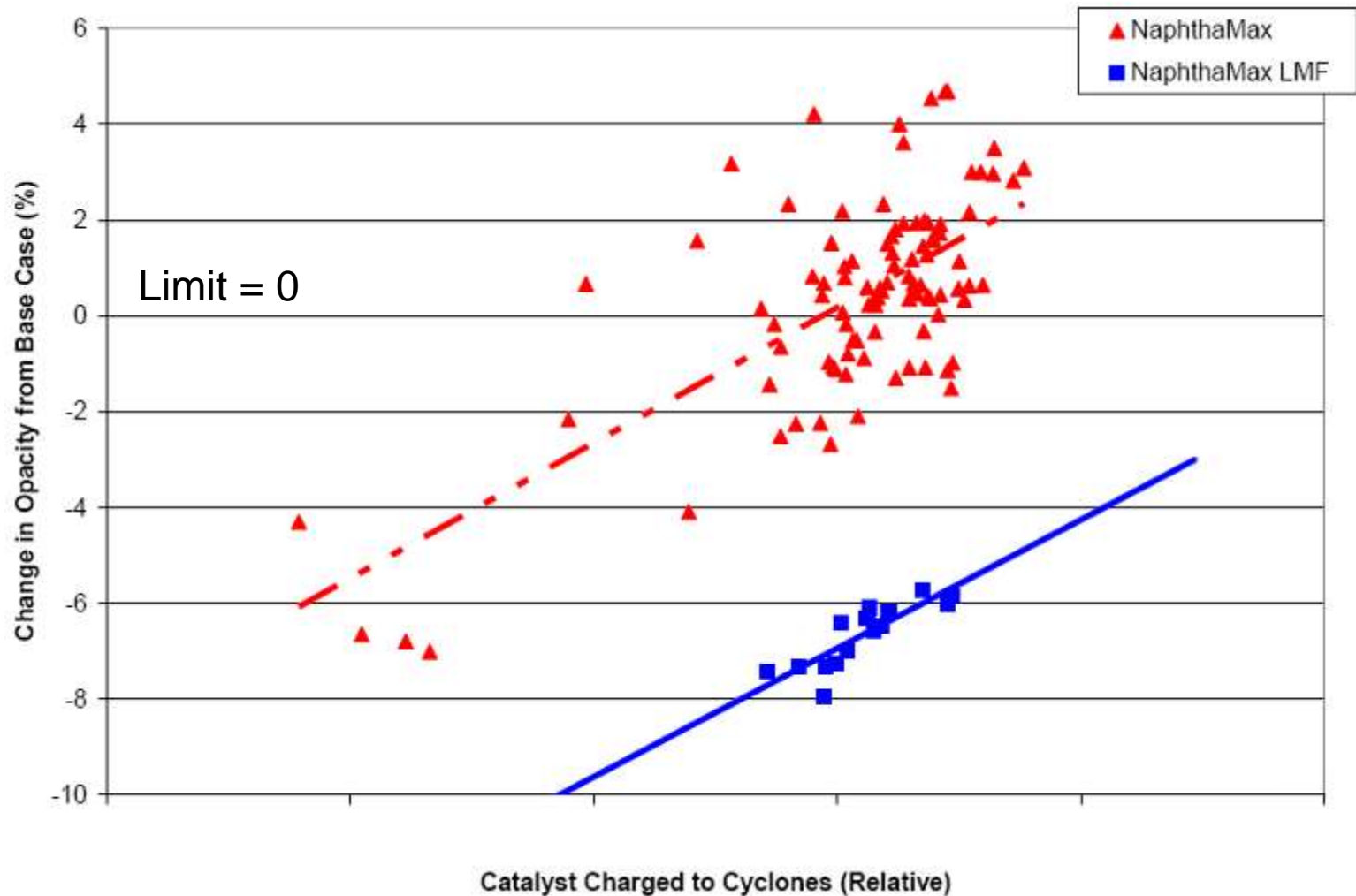
6. Emissions Reduction SO_x/NO_x and Particulates

- BASF has catalyst and additive solutions for the reduction of SO_x/NO_x and Particulates

Example reduced Opacity

- Commercial unit wanted to reduce opacity
 - Compared NaphthaMax[®] to NaphthaMax[®] LMF
- FCC was of standard geometry with typical hardware
 - UOP SBS, advanced feed injection and riser termination with a TSS
- Unit experience was positive
 - No yield degradation
 - Lowered opacity at similar operation

Opacity Reduction with NaphthaMax® LMF



Summary

- BASF has a strong commitment to FCC catalyst development that targets value creations for our customers

- We will continue to work our six market drivers
 1. Rare earth replacement technology
 2. Next generation high conversion and impact of tight oil
 3. Heavier crudes to refineries
 4. Growing petrochemicals demand – particularly propylene
 5. Incremental demand for diesel over gasoline
 6. FCC emissions reductions – NO_x/SO_x/Particulates



The Chemical Company