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Catalytic Solutions to Overcome IMO Challenges

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AGENDA

1 | IMO Regulations: Background

2 | Process Technology Approaches

3 | Focus on FCC

4 | FCC Case Studies

5 | Conclusions and Takeaways

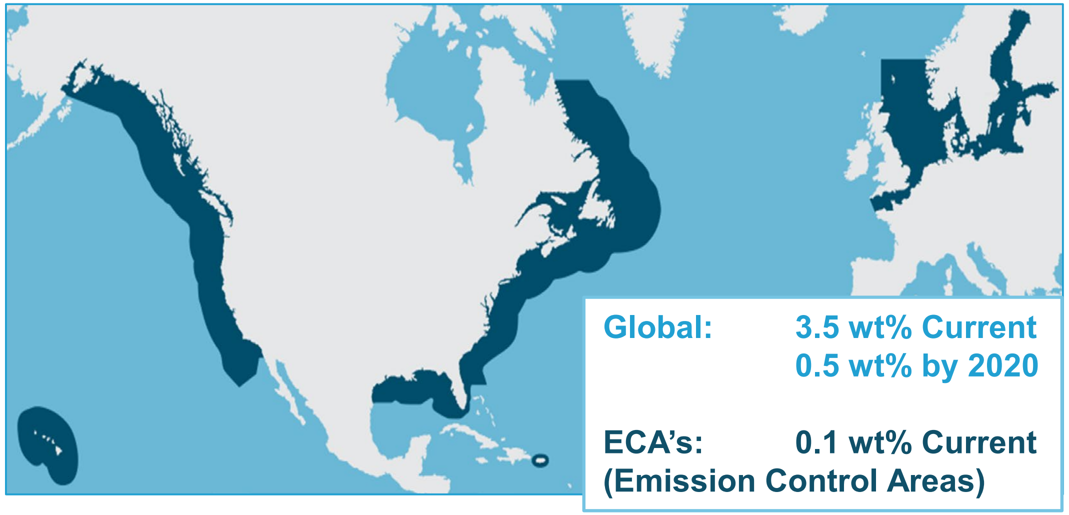
Background: IMO

International Maritime Organization

- UN Agency headquartered in London and formed in 1947.
- Regulation of shipment activities, including environmental control.
  - *MARPOL 73/78*
  - *Annex VI (Air pollution emitted by ships, 2005/2008)*
  - *SOx Emissions by limiting sulfur content in marine fuels or installing exhausting gas cleaning systems.*

Sulfur limits in marine fuels

- Low Sulfur Fuels already used in ECA’s:



- IMO states that “There can be no change in the 1st January 2020 implementation date”.

Source: www.imo.org

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Path Forward for Refineries

Topping Mode

- Pressure to find market for dwindling demand of HSFO products

Medium Conversion Mode

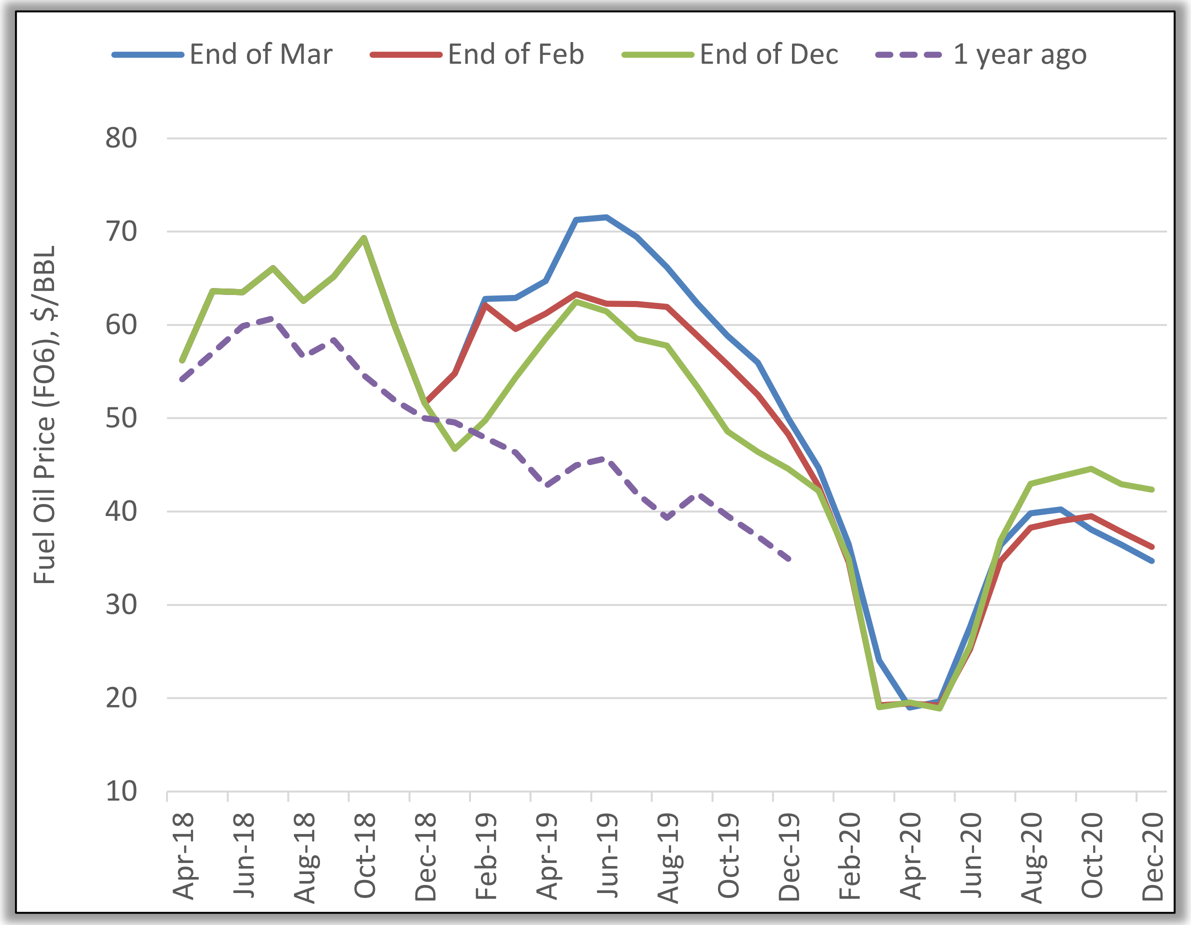
- Alternative solutions:
  - *Deeper gas oil cut points*
  - *Crude slate modifications*
  - *Asphalt Production*
  - ***Product Optimization***

High Conversion Mode

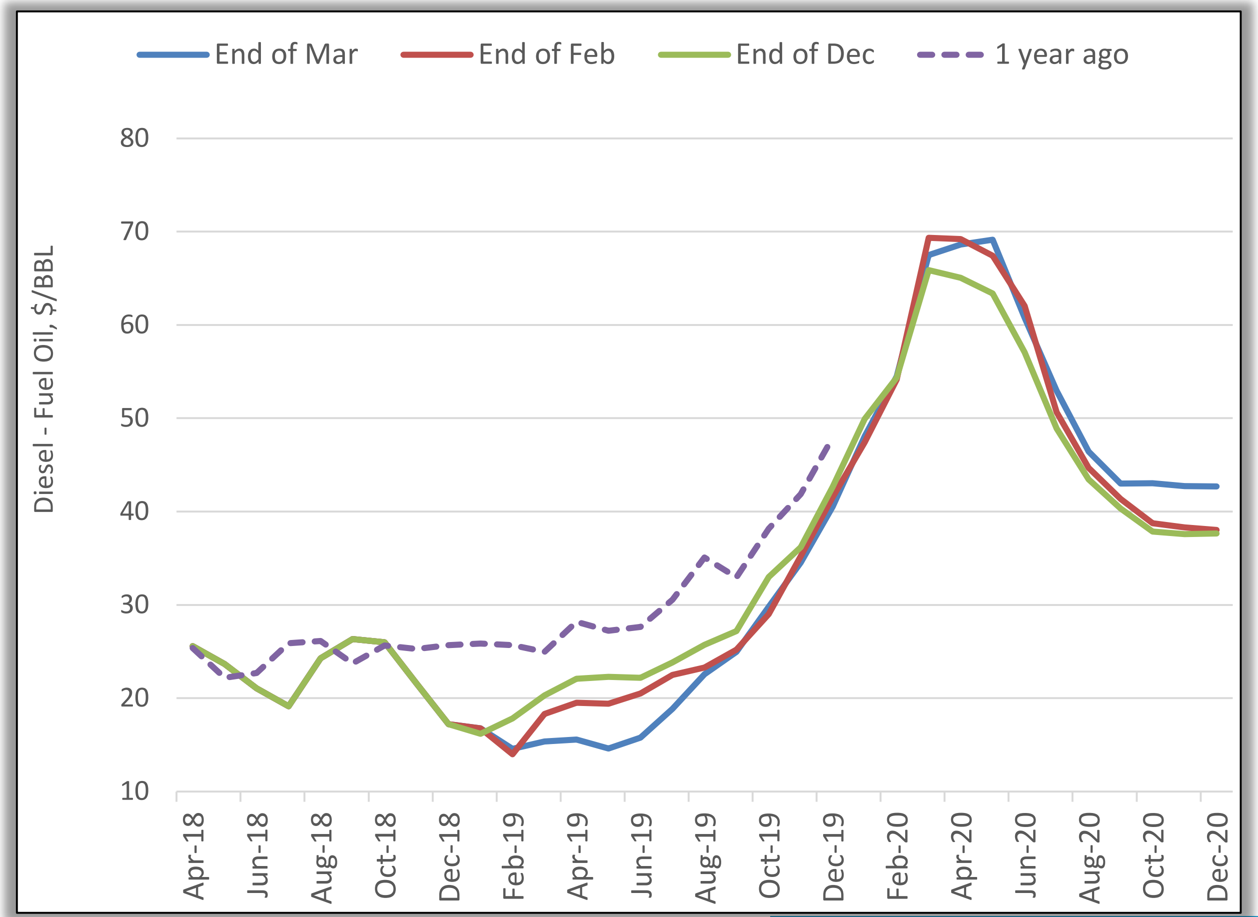
- Highest potential to capture margins in the medium to long term future
  - *Sweet and sour price differentials*
  - *Distillate pricing*
  - *Refinery configurations – debottlenecking coker capabilities*

Current market dynamics as reflected in forward pricing

Prices of high sulfur fuel is projected to be lower



Resulting in the spread between diesel and HSFO to widen



Source: IHS

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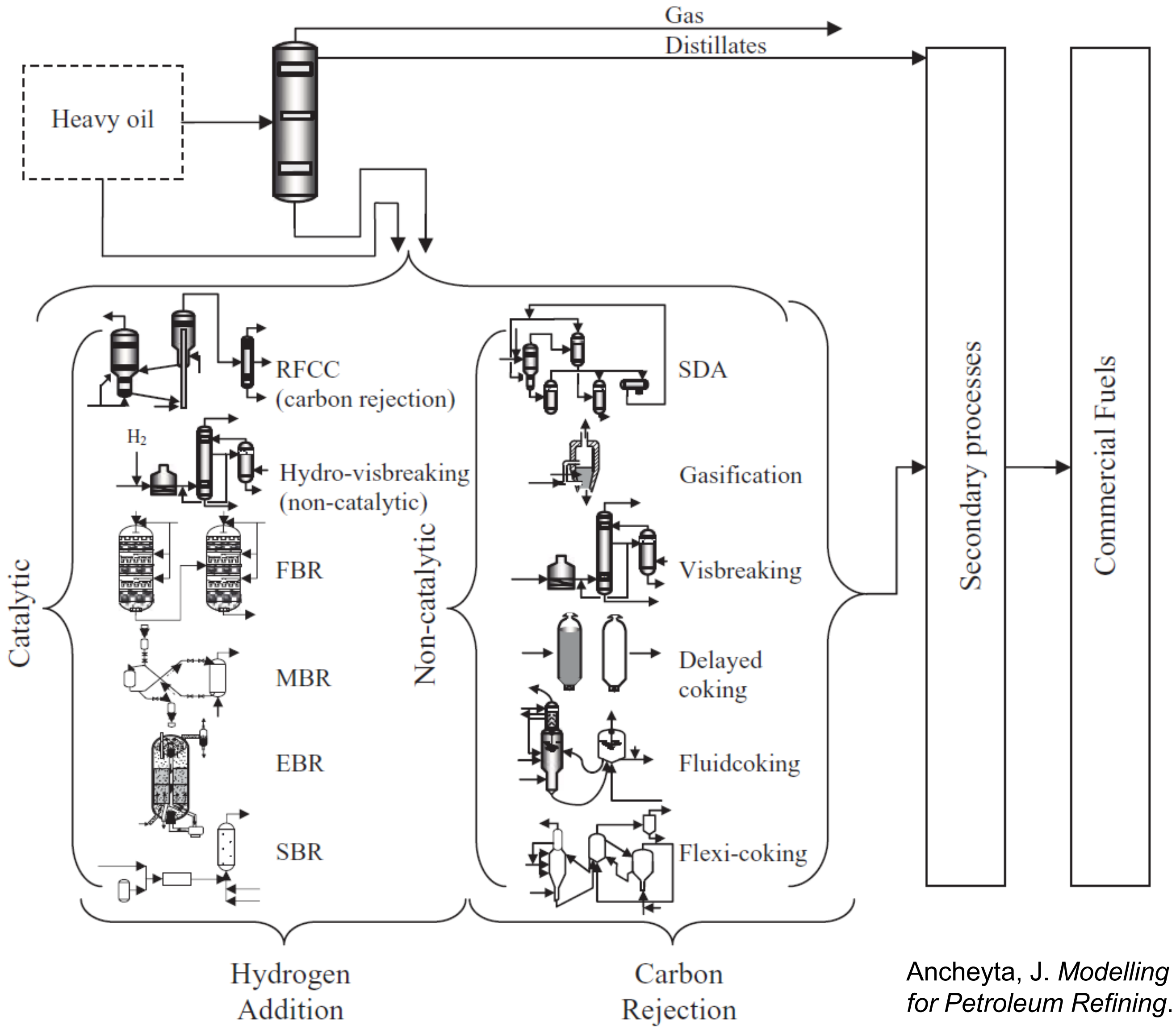
Process technology approach
What is the best one?



TREATMENT ROUTE:

- Potentially marine/bunker fuels with IMO specs.
- Moderate product price.

CONVERSION ROUTE:

- More oriented to transportation fuels or petrochemicals.
- Higher product price.
- Handling final residue is a challenge.

Ancheyta, J. *Modelling and Simulation of Catalytic Reactors for Petroleum Refining*. John Wiley & Sons, 2011

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Process Technology Approaches: Conversion Route

Type	Process	Pros	Cons
Non-catalytic	Deasphalting (technically a non-conversion technology)	Less Capex	Asphaltic Pitch. Further processing generally needed.
	Visbreaking	Less Capex	High Sulfur Fuel Oil. Further processing needed.
	Coking	Medium Capex	Product hydrotreatment needed. Pet-coke difficult to sell/trade.
Catalytic	Ebullated Bed Residue Hydrocracking	High value products	High Capex. Residue difficult to sell/dispose.
	Slurry Residue Hydrocracking	High value products	High Capex. Still not common technology. Residue difficult to sell/dispose.
	Fluid Catalytic Cracking (FCC)	**High value products Sellable/stable residue (Slurry Oil)**	Pre-treatment generally needed (depending on crude quality).

- **Refinery coking and resid hydrocracking represent 13.6% crude capacity in North America vs 3.2% in China**

Source: Oil and Gas Journal

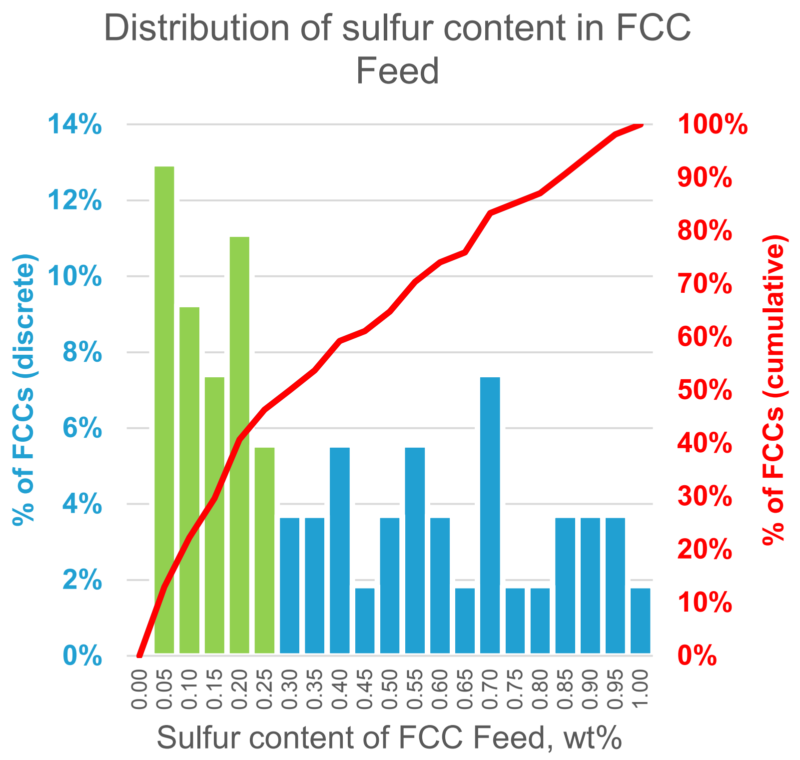
Focus on FCC: Maximizing Refining Margin via the Conversion Route

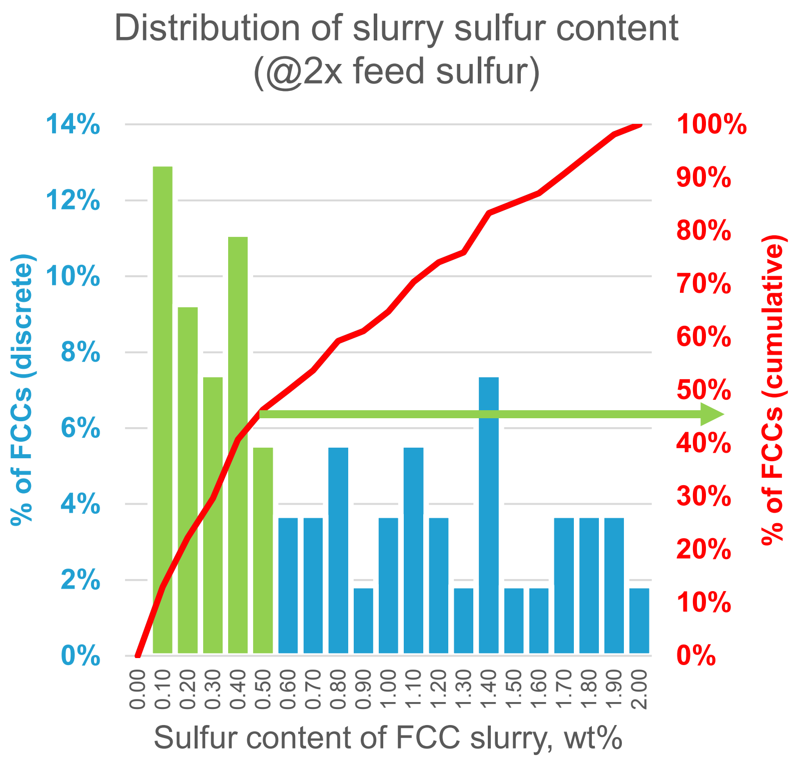
- High octane gasoline
- Alkylate precursors (butylenes and isobutane)
- Middle distillates (LCO, hydrotreatment is needed)
- Residue (Slurry Oil) has several options:
  - *Raw material for Carbon Black*
  - *Low Sulfur Fuel Oil component (after blending with low sulfur componen issues, unlike unconverted streams from other technologies)*
  - *Raw material for anode coke*

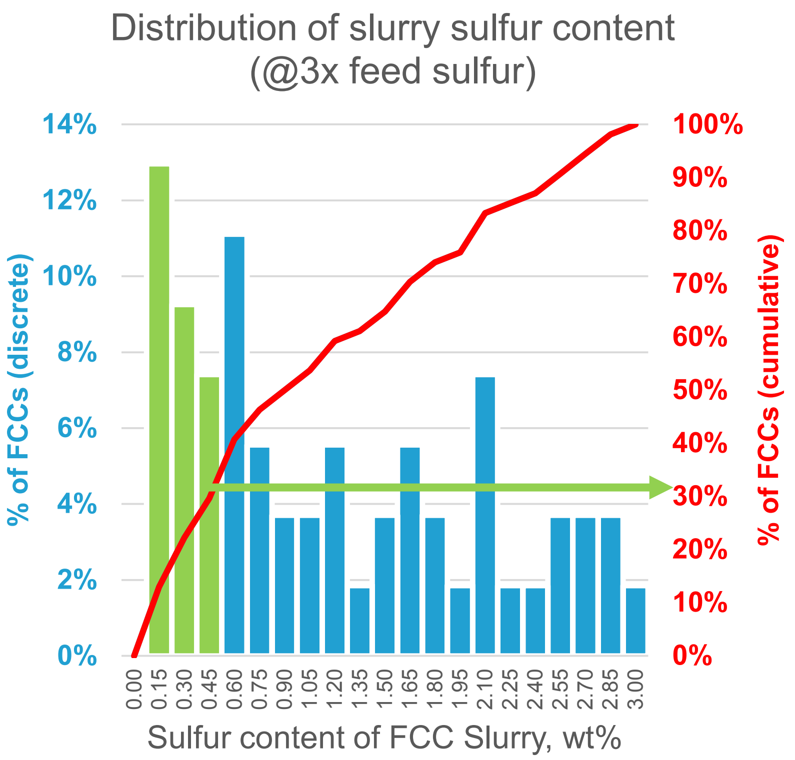
Current state of slurry sulfur content in FCC

1/3 to 40% of slurry products from FCC may meet the IMO hurdle

Reduction of slurry volume is key!







Contact your catalyst supplier for mitigation strategies.

Source: BASF Internal Database

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BASF contribution to overcome IMO regulations

High performance FCC Catalysts

- FCC units process VGO (either HTD or non-HTD) and resid blend
- Higher conversion and slurry upgrading technologies
- Unique BASF technologies:

Platform	FCC Catalyst
DMS	*Flex-Tec, Fortress NXT, Fourte, Luminate*
Prox-SMZ	*Aegis, Stamina*
BBT	*BoroFlex, BoroCat, BoroTec*

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Case Study 1

- Shell unit design targeting maximum conversion – gasoline and propylene make

Feed Properties	
Type	Atmospheric Residue, 35 kBPD
ConCarbon	**4.5 wt%**
Ni_{EQ}	10 ppm
V+Na	12 ppm
Catalyst	Flex-Tec

Product Yields	
Dry gas + H_2S (wt%)	5.6
LPG/ C_3= (wt%)	17.3/ 7.0 (*)
Total Gasoline (wt%)	50.0
LCO (wt%)	10.1
HCO+Slurry (wt%)	8.7
Coke (wt%)	8.3

(*) Low to medium ZSM-5 addition

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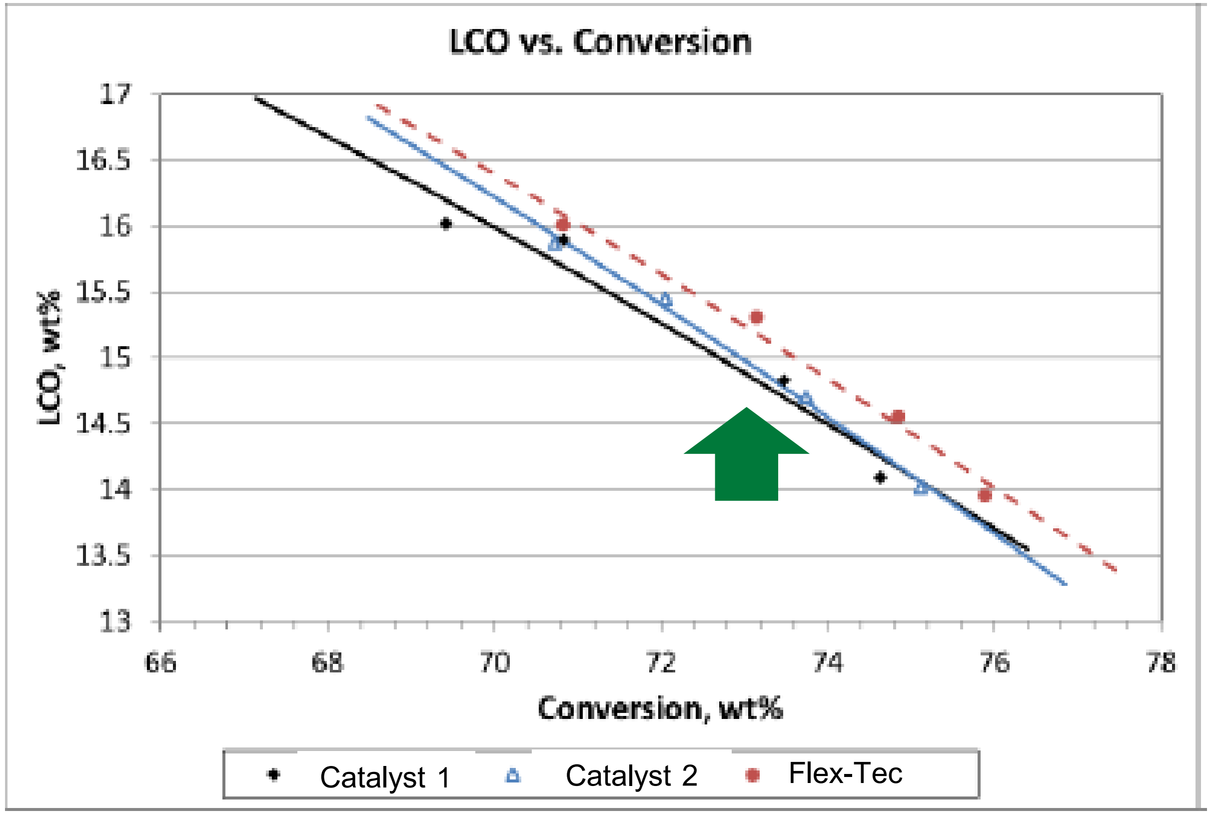
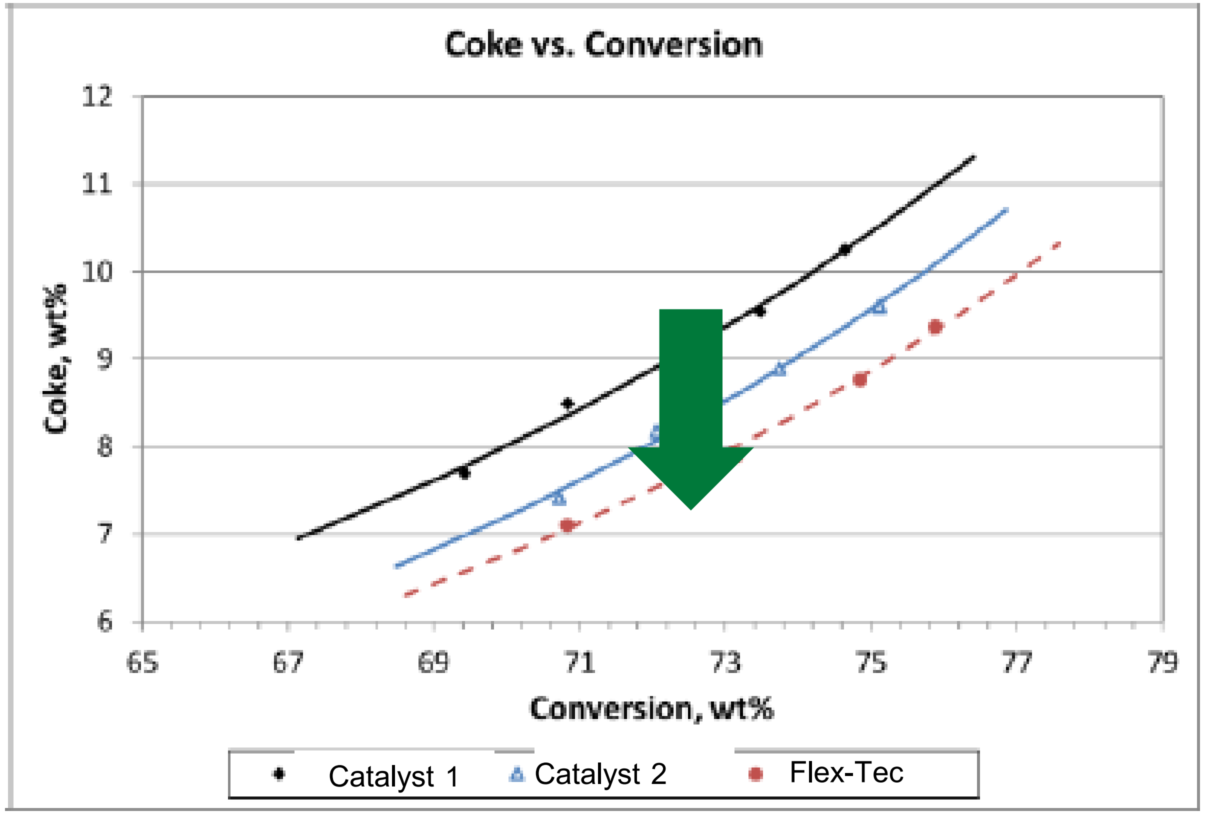
Case Study 1: Flex-Tec Delivered Improved Bottoms Upgrading and Coke Selectivity





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Case Study 2

- UOP unit design targeting maximum conversion – gasoline and propylene make

Feed Properties	
Feed	Atmospheric Residue, 70 kBPD
ConCarbon	**7.0 wt%**
Ni_{EQ}	25 ppm
V+Na	3 ppm
Catalyst	Fortress

Product Yields	
Dry gas + H_2S (wt%)	3.3
LPG/ C_3= (wt%)	18.0/ 6.6 (*)
Total Gasoline (wt%)	49.9
LCO (wt%)	8.7
HCO+Slurry (wt%)	10.4
Coke (wt%)	9.6

(*) Low to medium ZSM-5 addition

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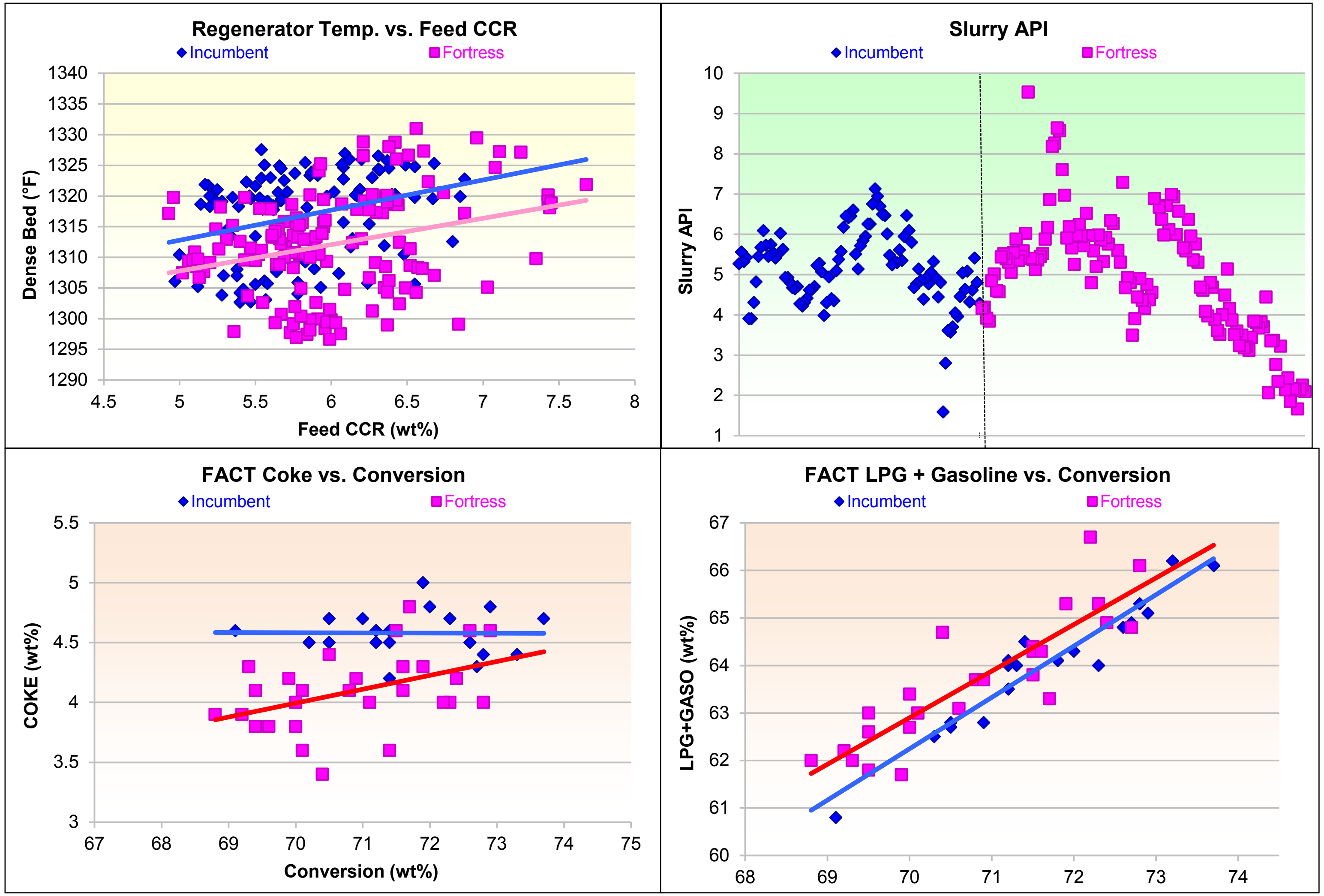
Case Study 2: Fortress Improved Coke Selectivity and Bottoms Upgrading

- Fortress improved coke selectivity, very important for the unit due to high feed CCR (7.0 wt%).
- As a consequence, lower regenerator temperature (higher Cat/Oil ratio) and higher conversion, with improved bottoms cracking (lower slurry API).
- Better coke selectivity and higher liquid yields was also supported by ACE testing.



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Conclusions and Takeaways

IMO regulation will be enforced by 2020. FCC is an excellent option for refiners, since the production of residual low value byproducts (slurry oil) is minimal, maximizing the refining margin under a highly constrained market.

BASF technology for FCC catalysts allows a wide range of catalytic solutions to process all kind of residues.

BASF FCC Catalysts are a high performance option for FCC units in their challenge to process high sulfur VGO, minimizing slurry and heavy fuel oil production with superior coke selectivity.

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