Increasing Refinery Product Slate Flexibility by Revamping the Cat Feed Hydrotreater (CFHT)

Advances in Mild Hydrocracking Technology

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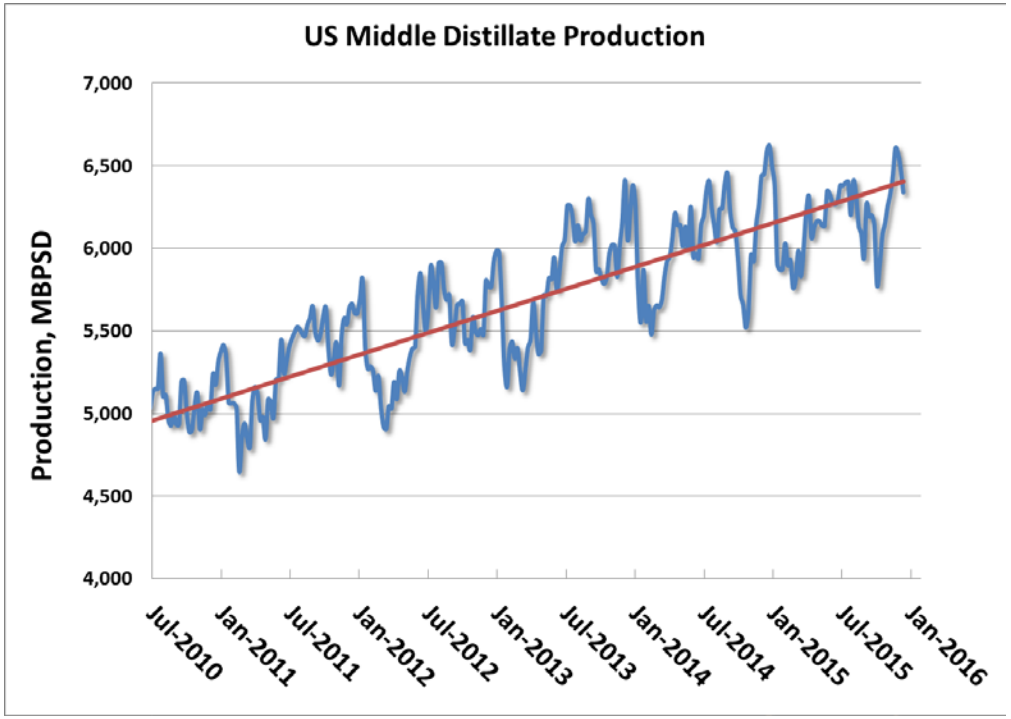
US Distillate Market Analysis

- **5% annual increase**
- **Result of various diesel projects**

Trend Projected to Continue



Source: EIA. www.eia.gov

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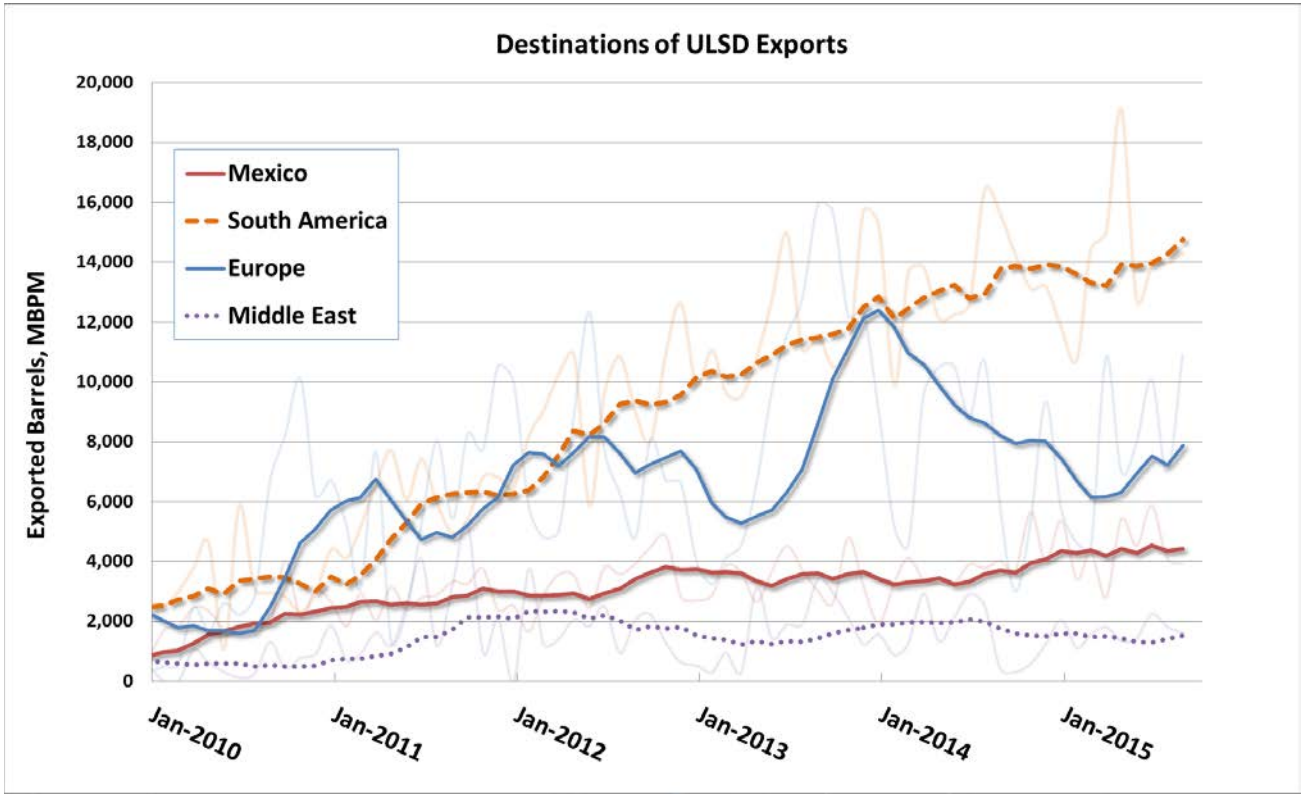
US Distillate Export Market



Source: EIA. www.eia.gov

Driven Mostly by Latin American Demand

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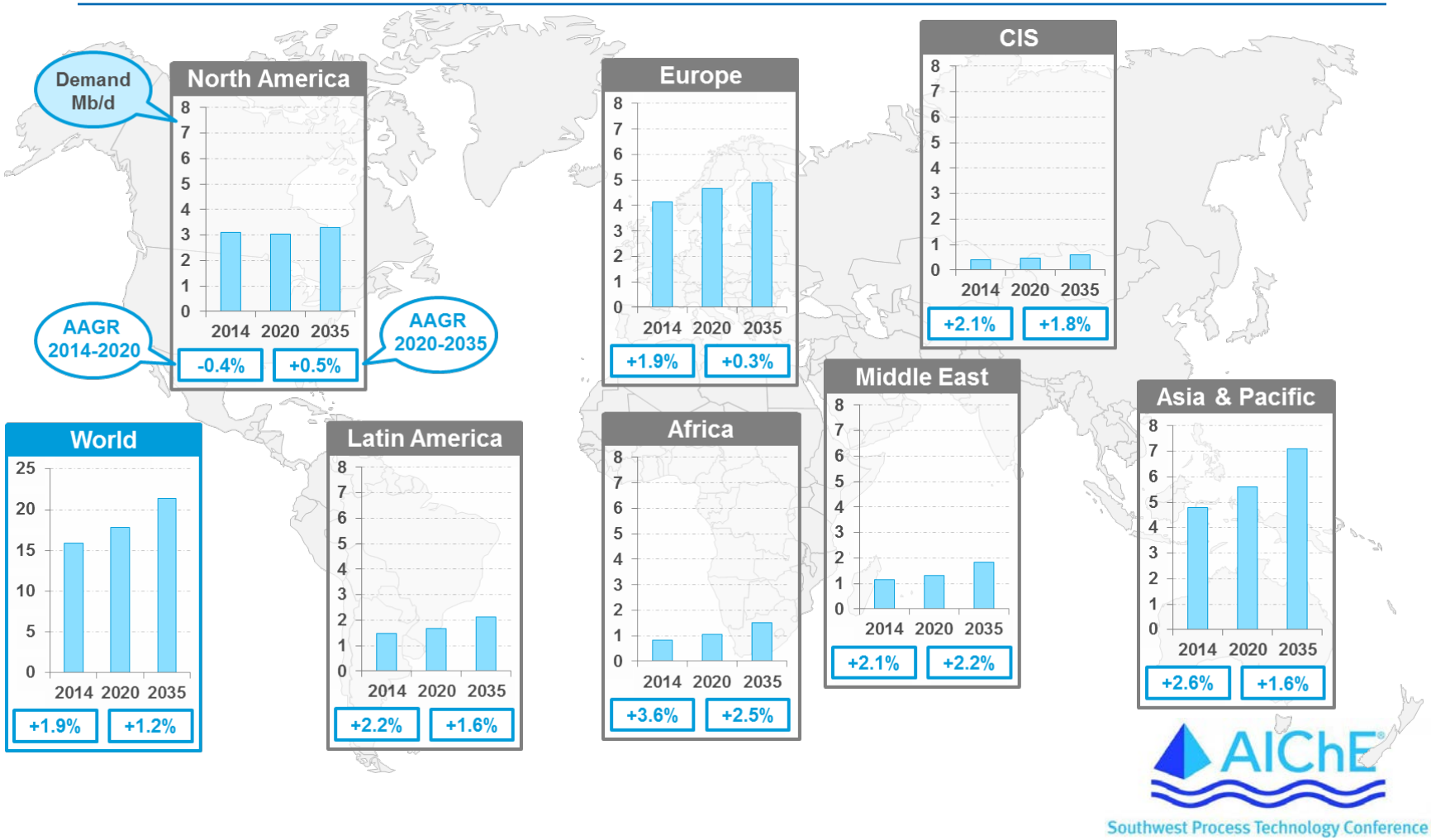
World On-Road Diesel Forecast



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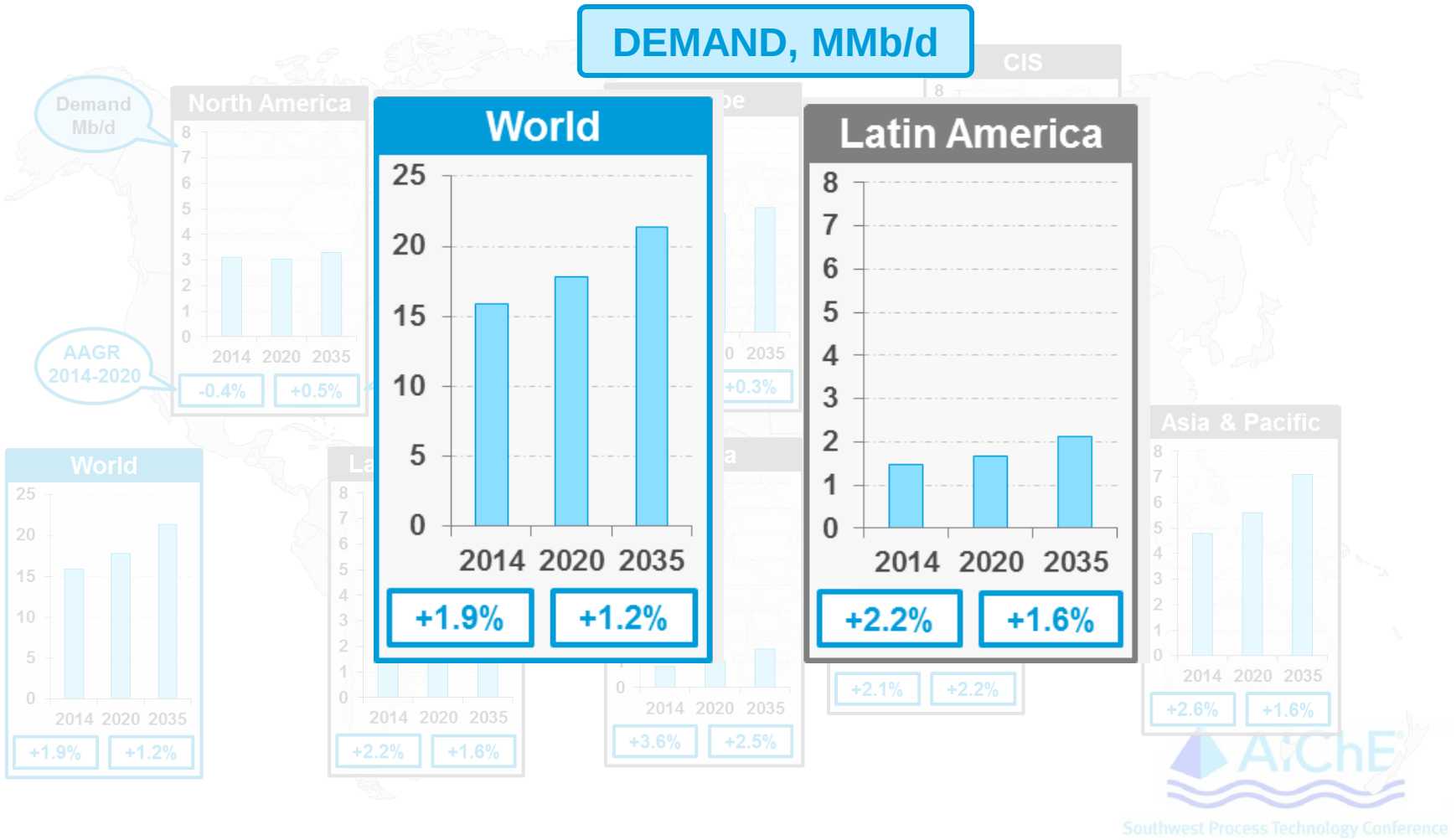
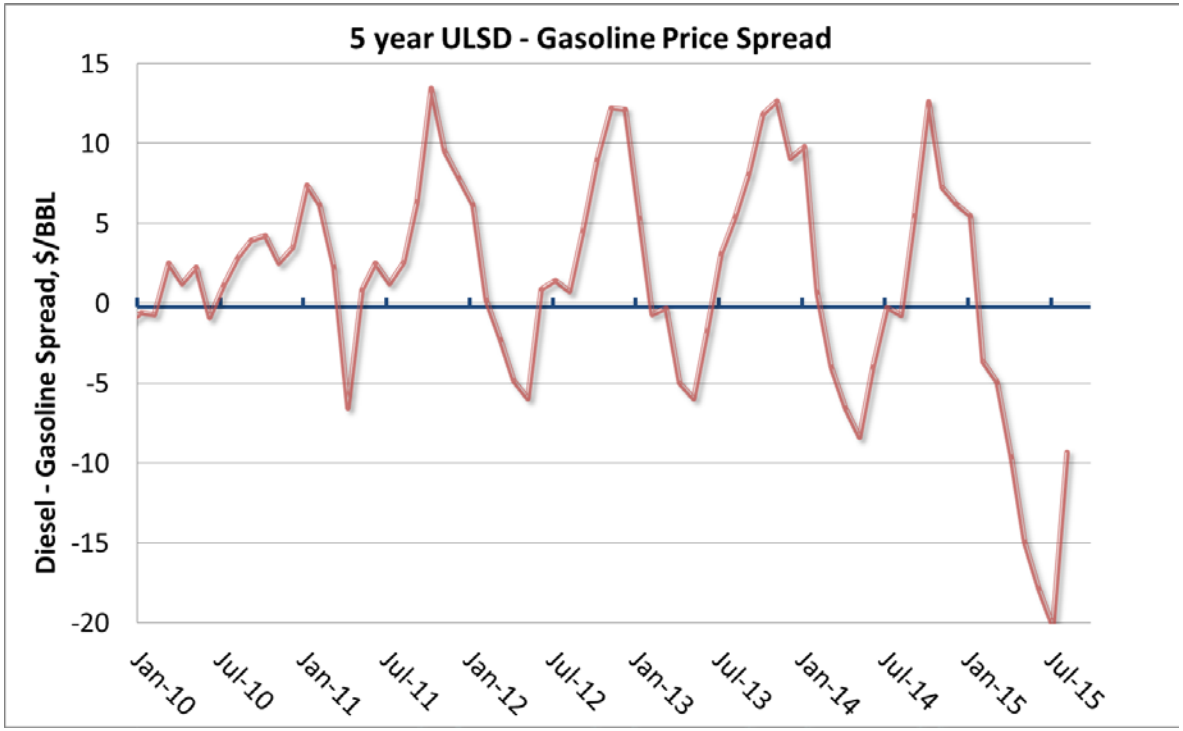
World On-Road Diesel Market



US Diesel v Gasoline Price



Product Slate Flexibility is Key for Profitability

- **$20/bbl** seasonal swings
- Median spread favors **diesel $2.25**
- >60% of the year, incentive to **swing to diesel**

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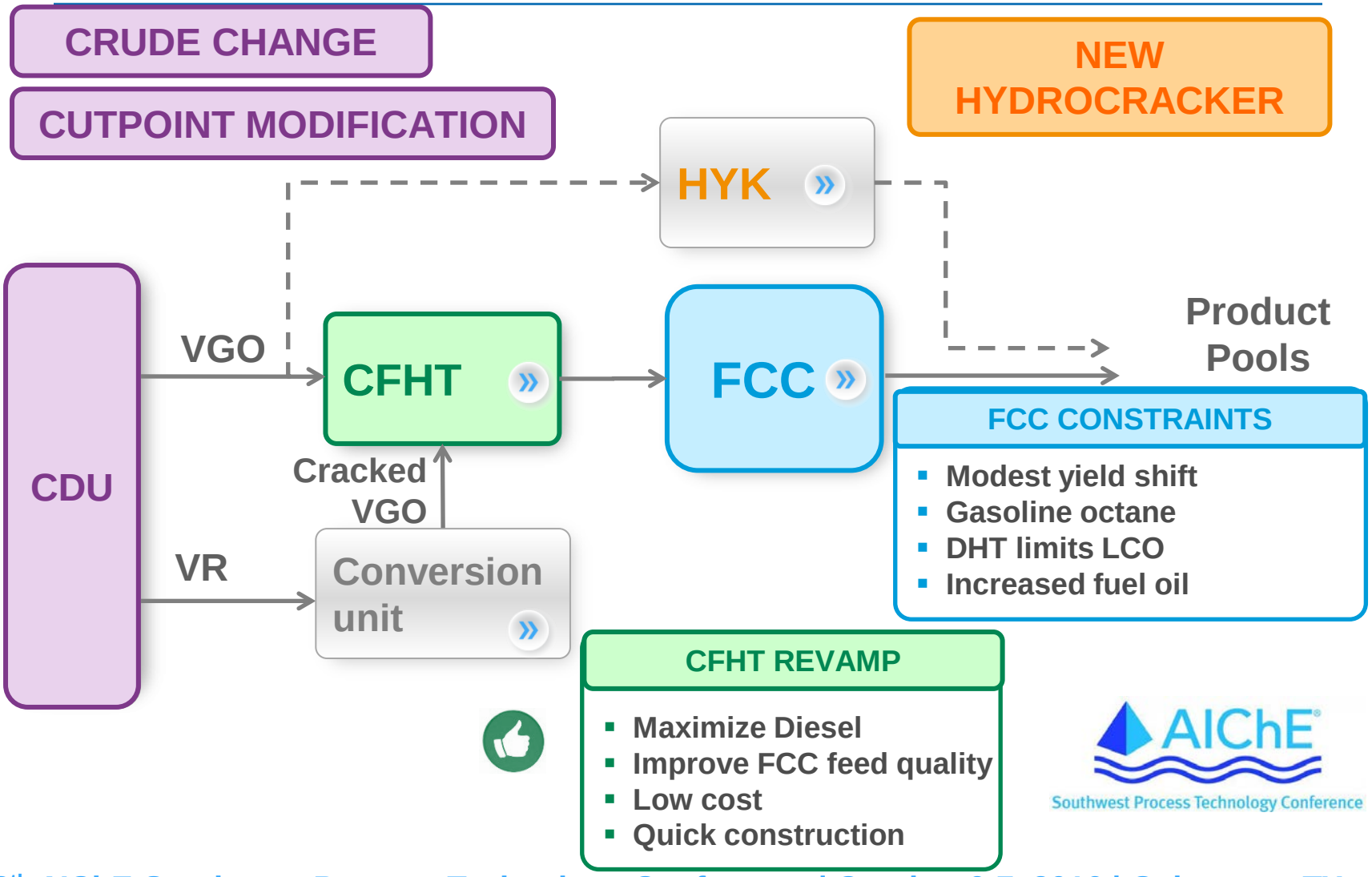
Options for Increasing Diesel



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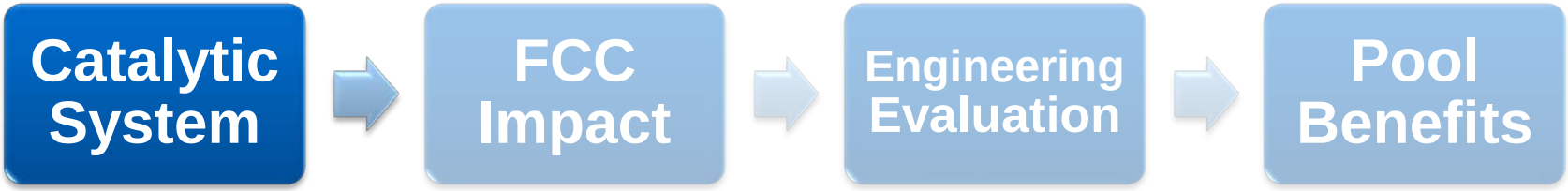
CFHT Revamp Considerations



Maximize Distillates

- Switch to **hydrocracking** catalyst load
- Conversion **15-35%** achievable in most **existing** reaction systems
- Excellent **selectivity** towards **diesel**

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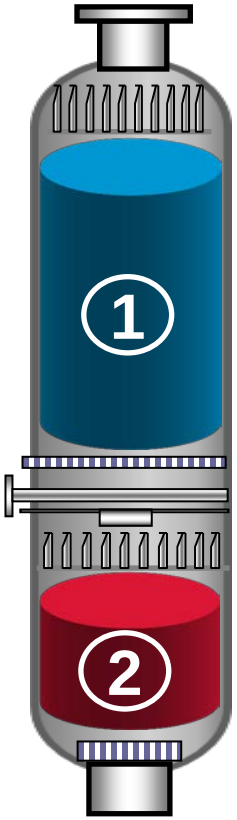
Catalyst Solutions



Pretreatment catalyst

Cracking catalyst

Sulfur removal

NiMo — Max HDN

CoMoNi — Max HDS

Conversion Activity

Nitrogen tolerance

HDK Series — Amorphous

HYK 700 Series — Zeolite

Tailor-made Solution Based on Objectives

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Catalyst Diesel Selectivity

Axens Catalysts Developed for the Diesel Market

- R&D Geared toward European Diesel Demands
- Excellent **Diesel Selectivity**
  - Commercial results demonstrate **10:1 Diesel to Naphtha yields**
- Variety of Feedstocks (SR, CGO, DAO, LCO)
- In-line with goal of maximizing **Diesel** in the US Market

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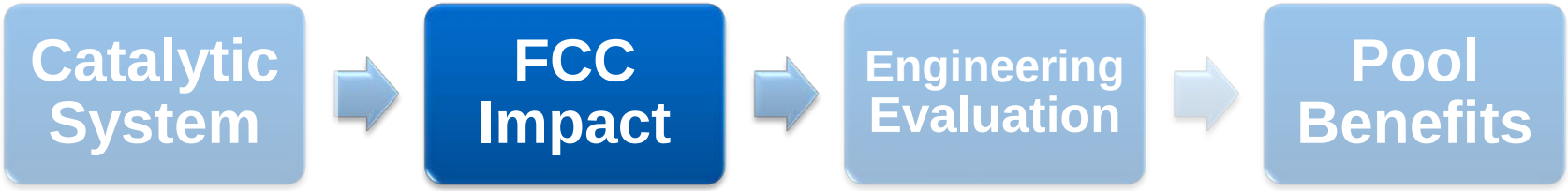
Revamp Considerations



Feed Quality & FCC Yields

- **Increased** FCC feed **quality** (aromatics saturation)
- **Increased selectivity** towards gasoline and LPG
- Decrease in LCO and Slurry
- **Increased** product **quality** (lower S, N)

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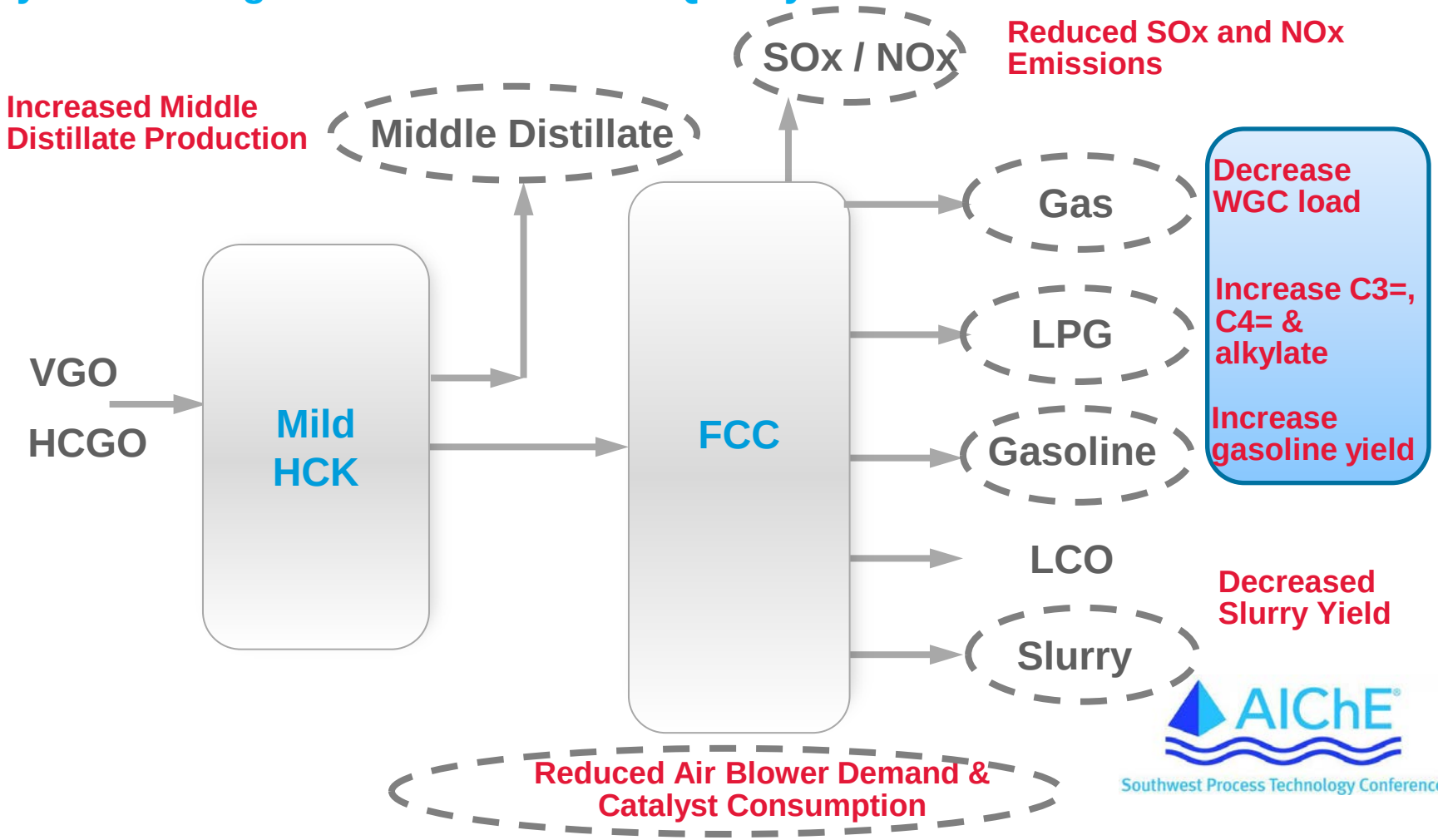
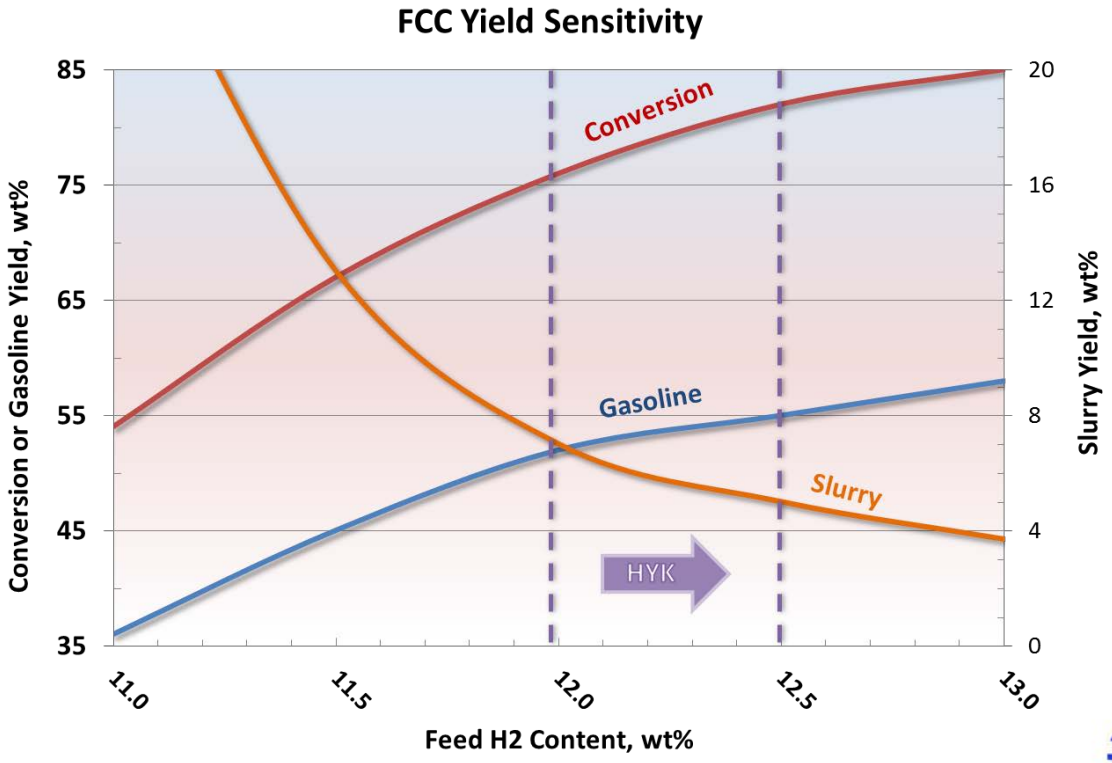
FCC and Alkylation Impact

Hydrocracking increases FCC Feed Quality



FCC Pretreating – H_2 Content

Hydrogen Addition Improves FCC Performance



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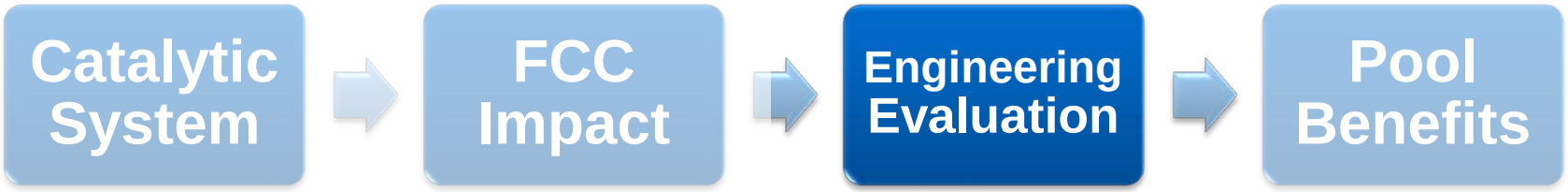
Revamp Considerations



Areas of Focus

- Reactor ΔP
- Reactor Internals
- Heater Limitations
- Compressors
- Stripper top Section
- **Fractionation**
- **SAFETY SYSTEMS**

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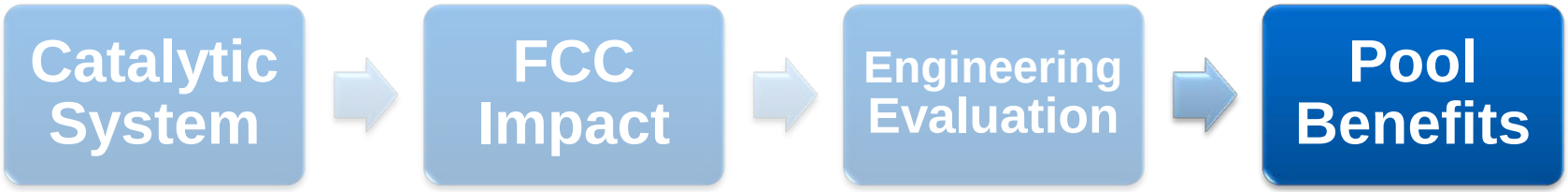
Revamp Considerations



Improvements

- Shift **D/G Ratio**
- **Increase** overall liquid yields (volume swell)
- Reduced FCC gasoline **post-treating** requirements

Case Study

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Axens Case Study Results

- FLEXIBILITY VIA **CFHT REVAMP** TO **MILD HYDROCRACKING**:
  - **Payout < 2 years**, independent of crude pricing
    - New (or Revamped) fractionator and M/U compressor
    - Modified catalyst load (Hydrocracking)
  - Maintain **continuous ULSD** production
  - **Maximize Octane-Barrels during summer** season

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Axens Case Study

1. Base Case (Current Operation)
   - Existing operation
   - FCC Feed S Target of 2,000 ppm
   - 36 month cycle in the CFHT
2. MHC Revamp Case (Distillate Mode)
   - Revamp CFHT to Mild Hydrocracker
   - Maximize Distillates
   - MHC Diesel treated in existing DHT unit
3. MHC Revamp Case (Gasoline Mode)
   - Mild Hydrocracker Revamp is complete
   - Minimize conversion & adjust cut-points
   - Maximize FCC gasoline production
4. HyC-10 Case (Integrated Diesel HDT)
   - Mild Hydrocracker Revamp is complete
   - Integrate new polishing reactor
   - Produce ULSD directly from the MHC

Constant Gasoline Pool RON for All Cases

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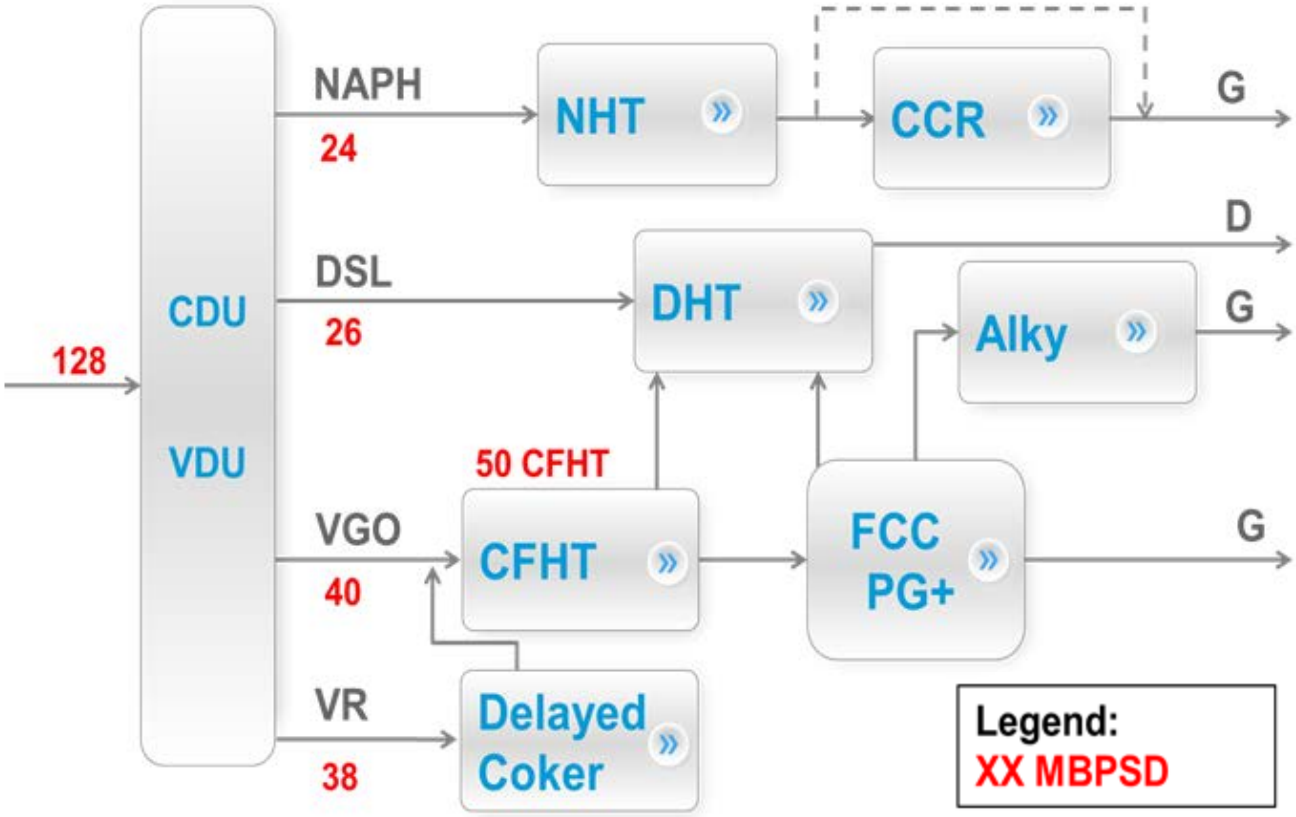
Case Study Configuration



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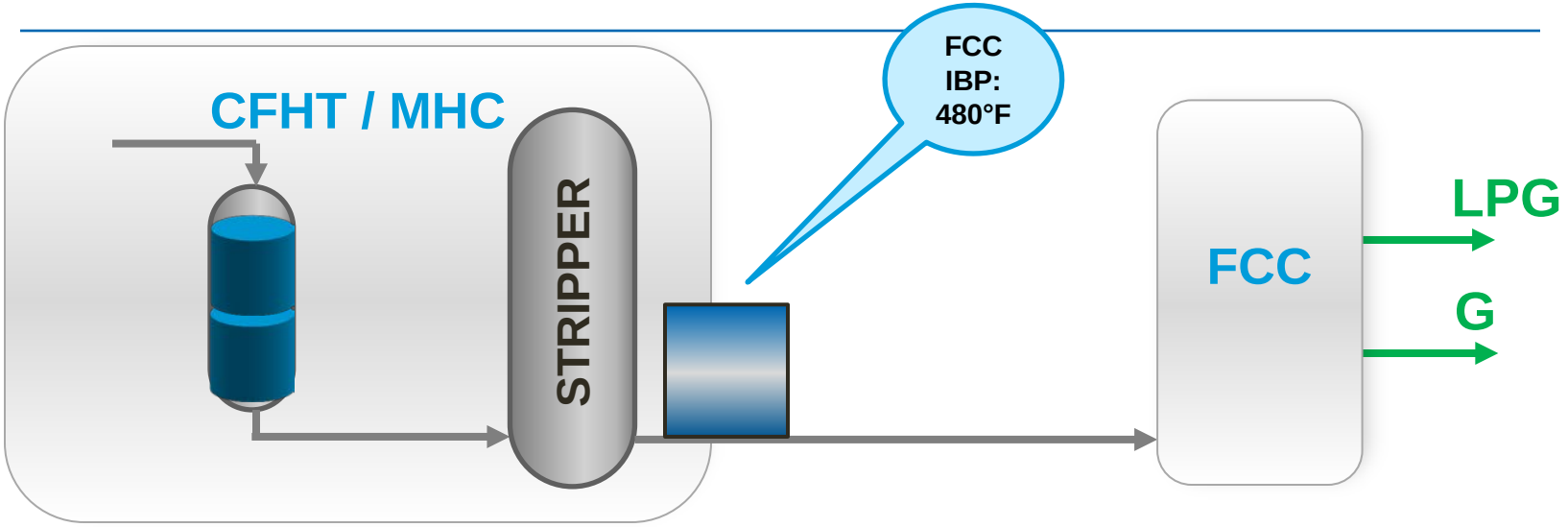
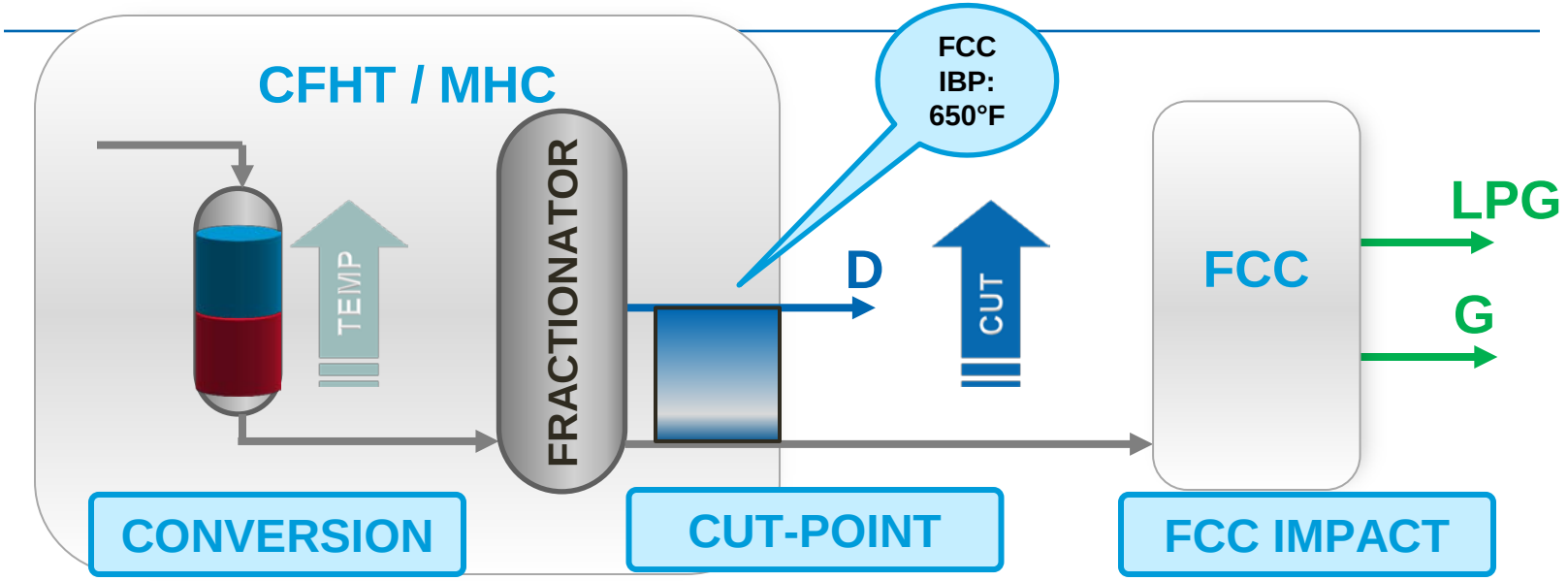
Revamp – Base Case



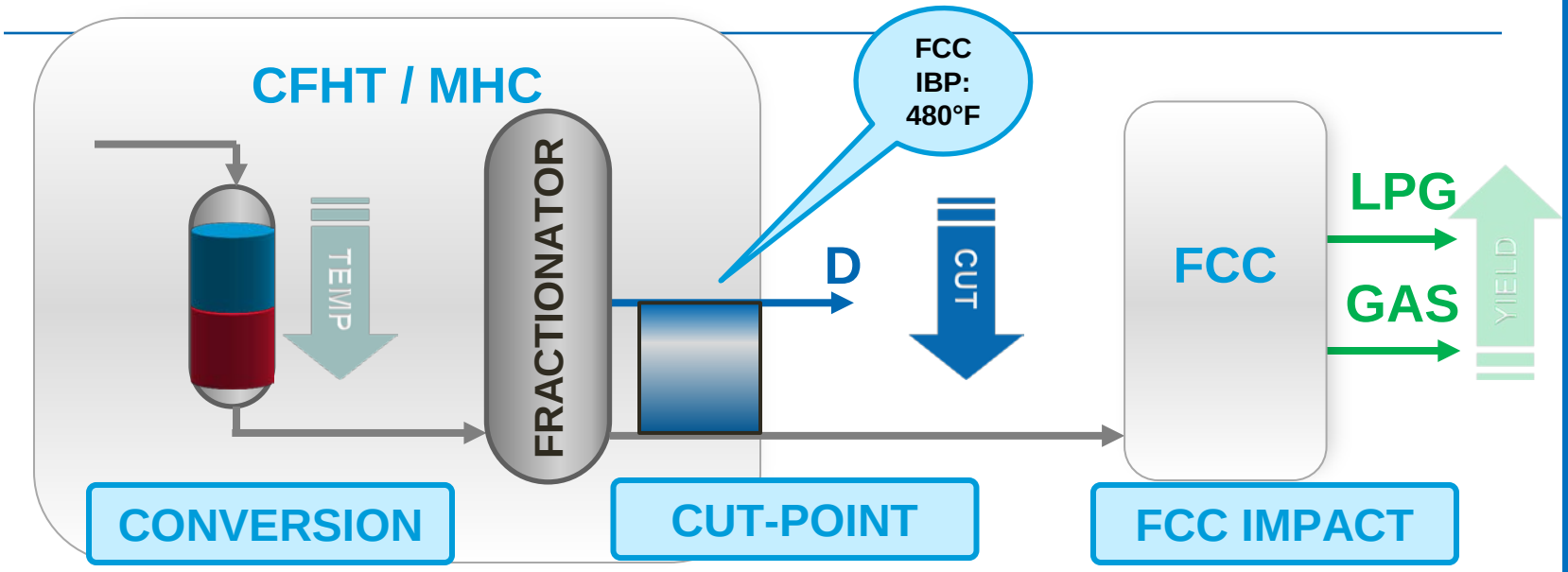
	Conversion	FCC Feed IBP	FCC Gasoline Yield
Base Case	10%	480 °F +	Base

Revamp – Max Diesel



	Conversion	FCC Feed IBP	FCC Gasoline Yield
Base Case	10%	480 °F +	Base
Max Diesel	27%	650 °F +	+5.4 v%

Revamp – Max Gasoline



	Conversion	FCC Feed IBP	FCC Gasoline Yield
Base Case	10%	480 °F +	Base
Max Diesel	27%	650 °F +	+5.4 v%
Max Gas	13%	480 °F +	+1.6 v%

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Case Study Results

	Base Case	MHC Case Max Diesel	MHC Case Max Gas
CFHT/MHC			
Conversion (650 +)	10	27	13
H2 Consumption, SCFB	Base	+ 300	+ 50
Diesel Recovery, BPSD	Base	+13,050	+400

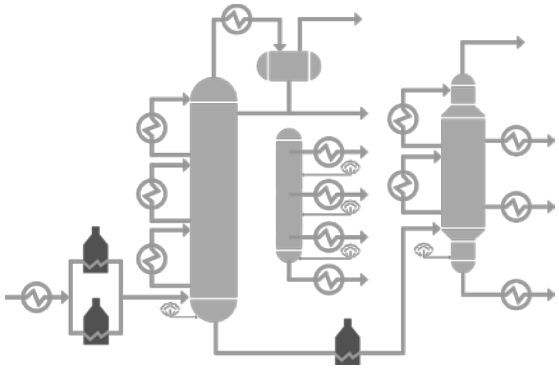
Case Study Results

	Base Case	MHC Case Max Diesel	MHC Case Max Gas
CFHT/MHC			
Conversion (650 +)	10	27	13
H2 Consumption, SCFB	Base	+ 300	+ 50
Diesel Recovery, BPSD	Base	+13,050	+400
FCC, PG+ and Alky			
FCC Feed Rate, %	Base	-30%	Base
FCC Feed H2, wt%	Base	+0.5	+0.1
FCC Gasoline yield, wt%	Base	+5.4%	+1.6%
Gasoline Production, BPSD	**Base**	**-8,400**	**+ 570**
ULSD Production, BPSD	**Base**	**+9,650**	**-320**
Total Trans. Fuels Pool, BPSD	**Base**	**+1,250**	**+250**
Refinery Fuel Yield, v%	**92.9**	**93.9**	**93.1**

Mild Conversion – ULSD Challenge

Mild Conversion achievable in existing units

- Shift the D:G Ratio
- Increase overall liquid yield



Flexibility achievable after revamp

- Return to Base Case D:G Ratio
- Extend reactor cycle

ULSD is not possible under mild conversion conditions

- **DHT capacity increase** is required

Axens Solution

- **HyC-10+ Process**
- **Integrated DHT Polishing Reactor**

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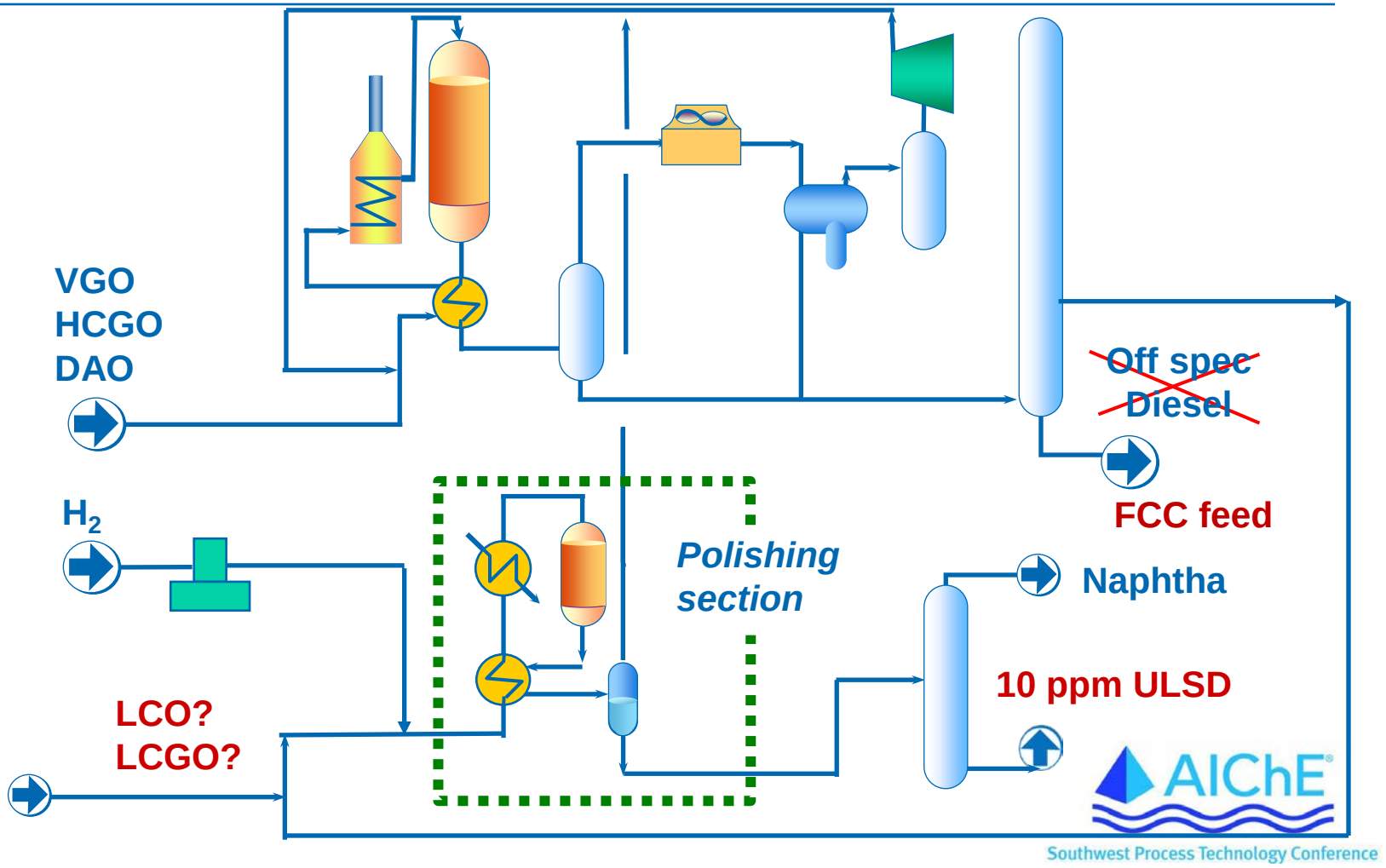
Axens HyC-10 Process



Axens HyC-10 Process

30% CAPEX Savings vs. New Unit

Polishing Reactor Operating Conditions

- Improved H_2pp due to pure make-up
- Lower reactor size due to less vapor flow and reduced H_2Spp

Major Equipment Savings vs. New DHT Unit:

- 2 compressors, 1 air cooler, HP amine absorber

Unit Integration

- Optimized H2 Usage
- Possibility for heat integration between two sections
- Maximize cycle length

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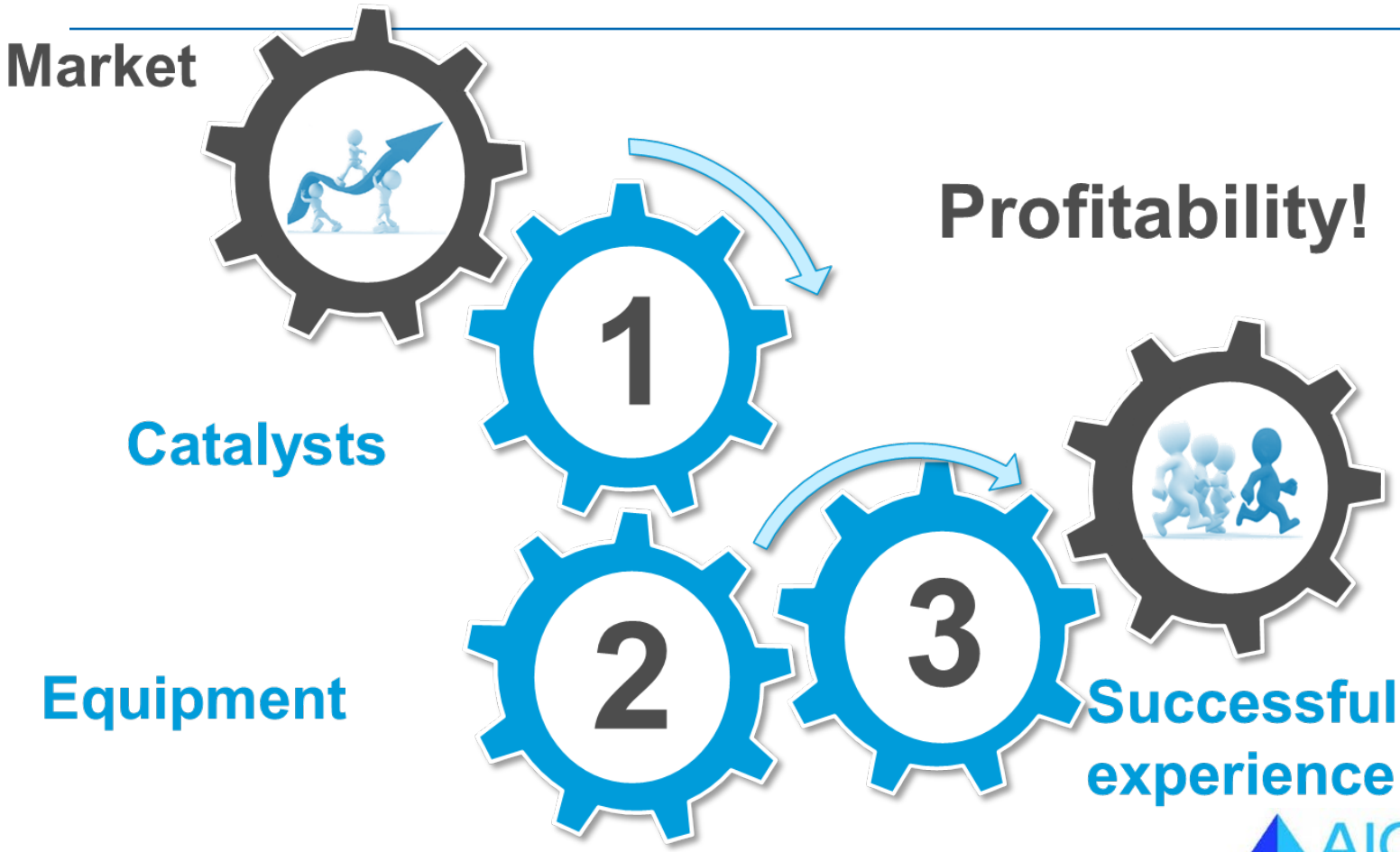
Commercial Results



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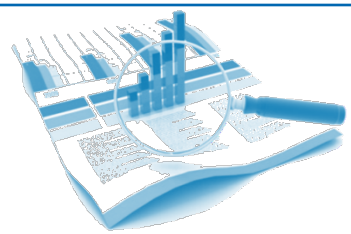
Commercial Revamp 1

Southern European Refiner

Axens Licensed Unit

- Capacity: 37,600 BPSD
- Start-up: 2005
- Catalyst loading: **100% Hydrotreating**



2010 Revamp Objectives:

- Net **conversion increase**
- Maximize **Euro V Diesel**
- Maintain feed rate
- Maintain cycle length

Axens Solution

- **Process Study to identify bottlenecks**
- **Add EquiFlow® Internals and new catalyst combination: HDT + Cracking Catalysts**

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Commercial Revamp 1

Southern European Refiner

- **Revamp completed: start-up May 2013**
- **Feedstocks:**
  - **SRVGO+ Aromatic Lube Extract**
  - **Polishing reactor treats:**
    - **MHC DSL + LCO + SRAGO + VB Naphtha**

Successful Revamp	Original Design	After Revamp
VGO Net Conversion, wt%	Base	+17%
Catalyst Cycle Length, months	31	On-going
MHC Euro-V Diesel Flowrate, BPSD	Base	+ 60%

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Commercial Revamp 2

Eastern European Refiner

2014 Revamp Objectives

- **Increase net conversion : Maximum Diesel Production**
- **Maintain Product Quality**
- **Maintain Cycle Length**
- **Minimize shutdown time**

Axens Solution

- **Process Study to identify bottlenecks**
- **New catalyst combination:**

HR 544+ HYK 732

CoMoNi Zeolite

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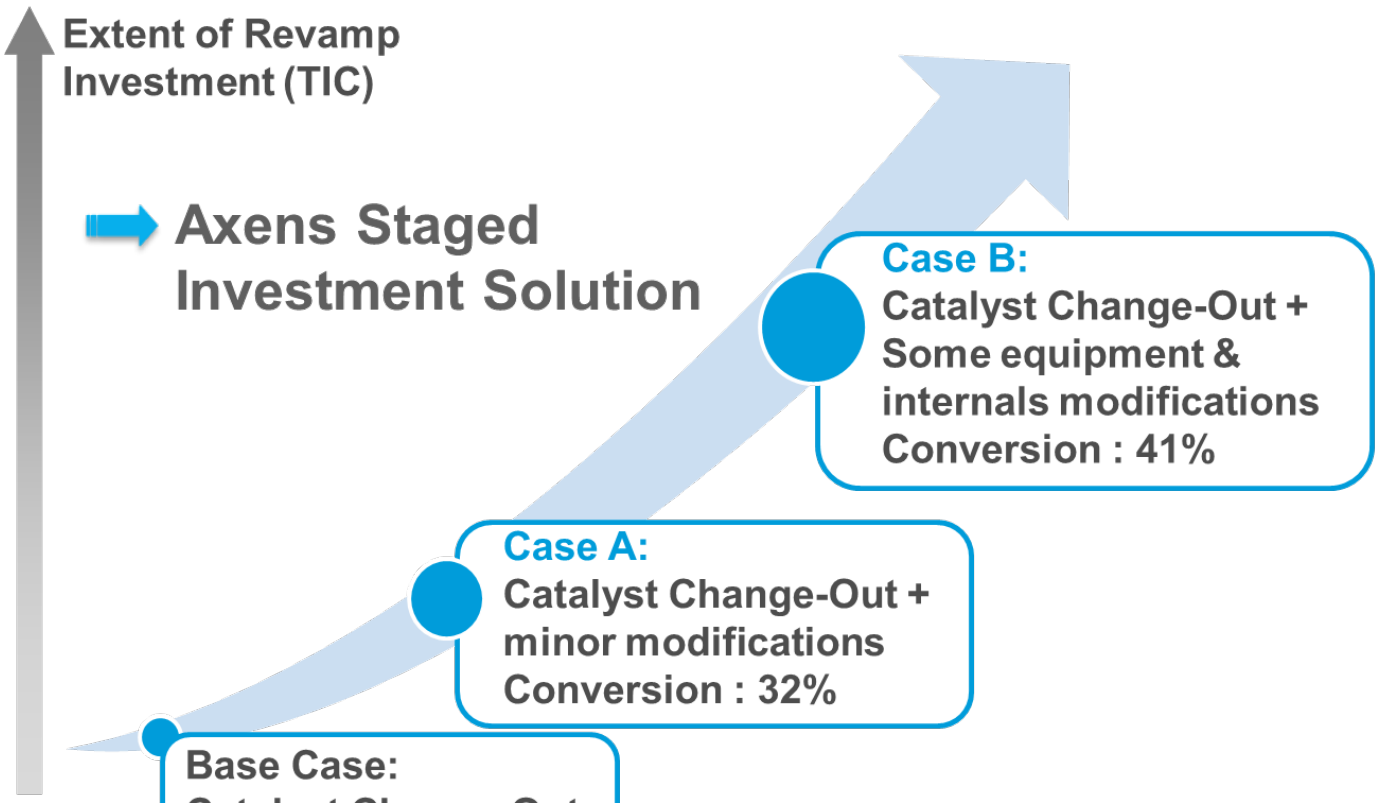
Commercial Revamp 2

Eastern European Refiner



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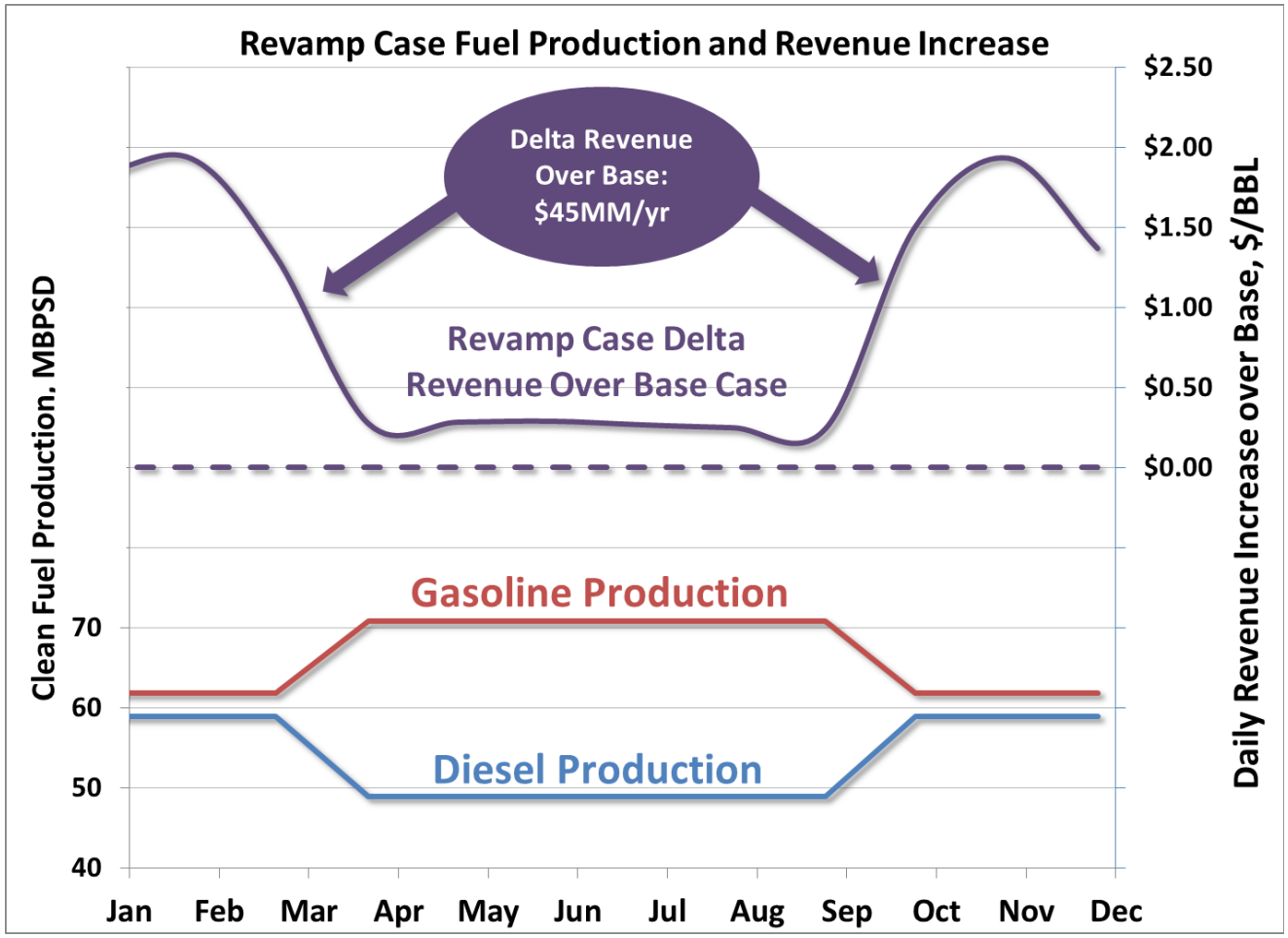
Revamp Economics



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2014 Fuels Pricing. Source: EIA. www.eia.gov

Revamp Economics

CAPEX

- New or Modified Fractionator
- Make-Up Compressor Mods
  - **Capacity increase**
  - **Increase stroke? New machine?**
- Reactor Internals

OPEX

- Limited utility consumption increase (< 8%)
- Increased H_2 Consumption

50,000 BPSD CFHT Unit

Flexible Mode MHC

- **CAPEX: $MM 30**
- **Increased Revenue: $MM 45/yr**
- **Simple Payout:**

< 10 months

Flexibility → **Profitability**

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Conclusion

Revamp CFHT to Mild Hydrocracker

- **Increase diesel** production
- **Flexible** operation for high gasoline **margin** periods
- Extremely **selective catalyst**
- **Fast-track** schedule

FAST SCHEDULE **FAST PAYBACK**

HyC-10 Option

- Maintain **ULSD production** for refiners short on DHT capacity

Reduced CAPEX

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