WOOD GROUP MUSTANG

A Financial Analysis for the Recovery of High Purity Propylene from Refinery LPG

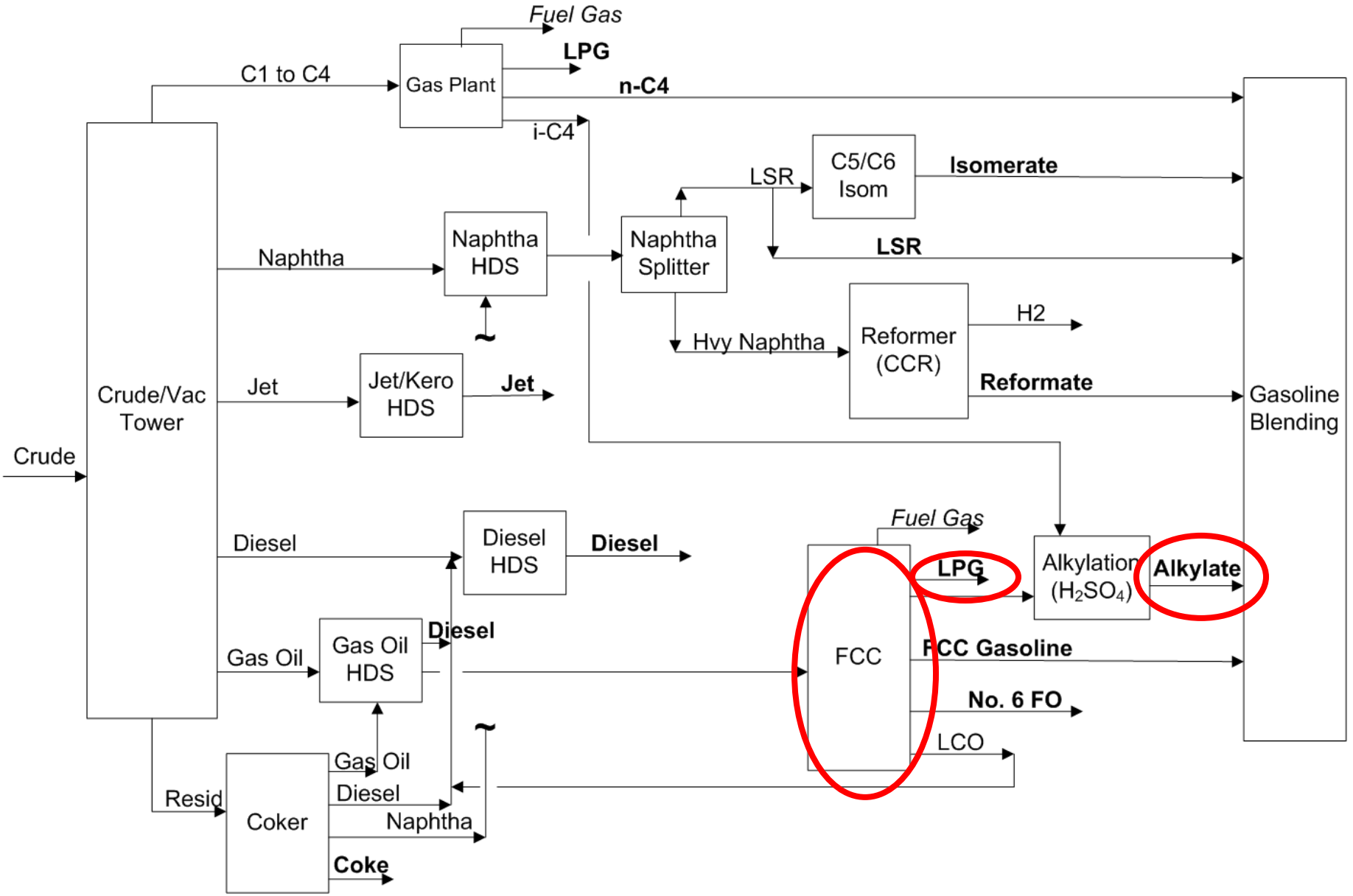
R.E. (Ed) Palmer
Ian M. Glasgow

2014 NSF Shale Monetization Workshop
La Toretta Resort – March 28th, 2014

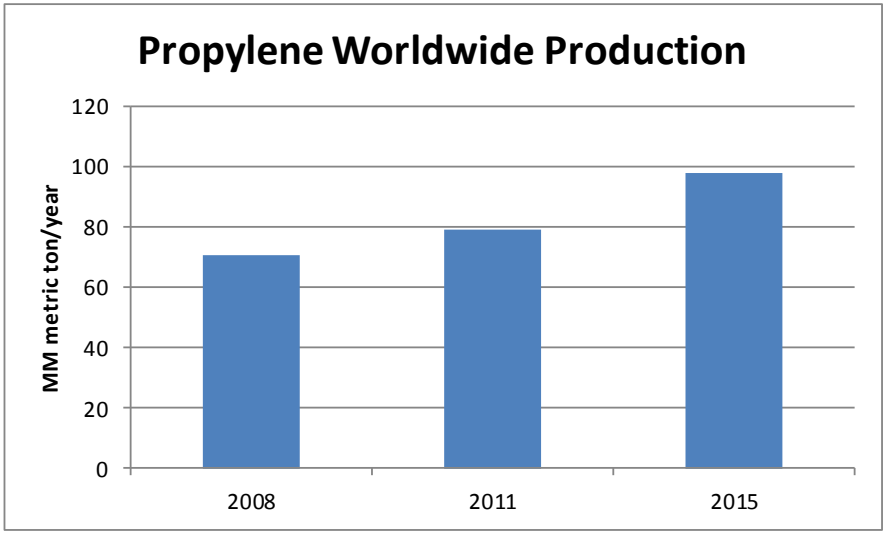
Presentation Highlights

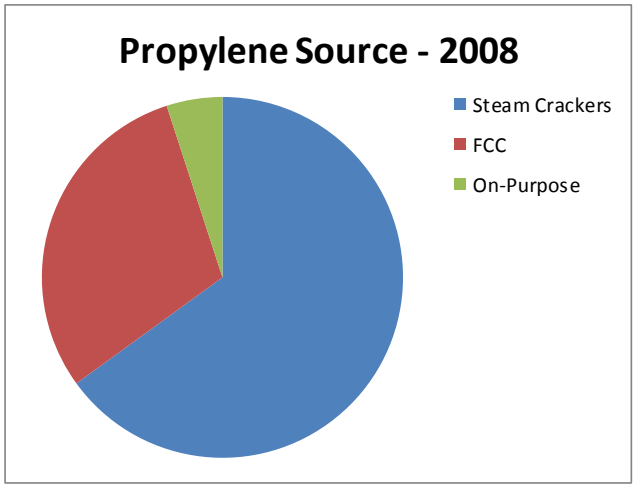
- Refinery Overview
- Propylene Market Background
- Propylene Splitter Design and Optimization
- Case Study and Financial Analysis
  - January 2012
  - March 2014
- Conclusions

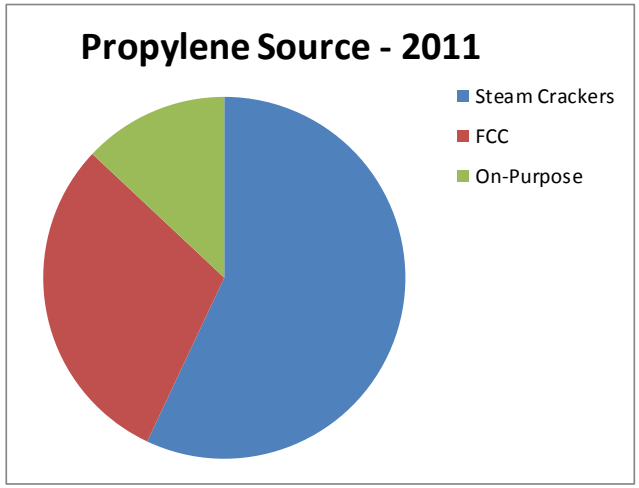
Refinery Overview

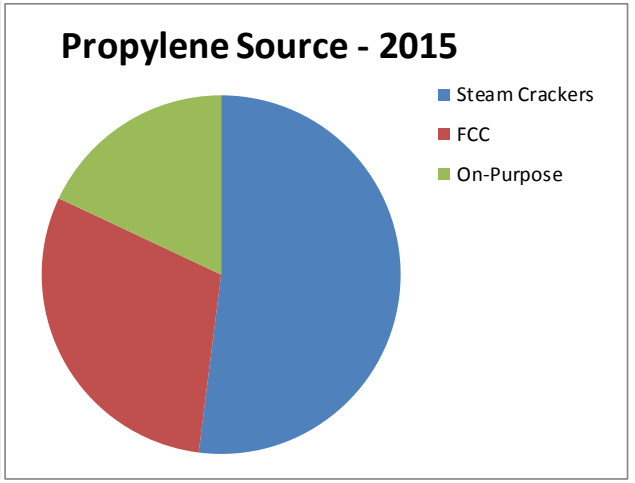


Propylene Market Background







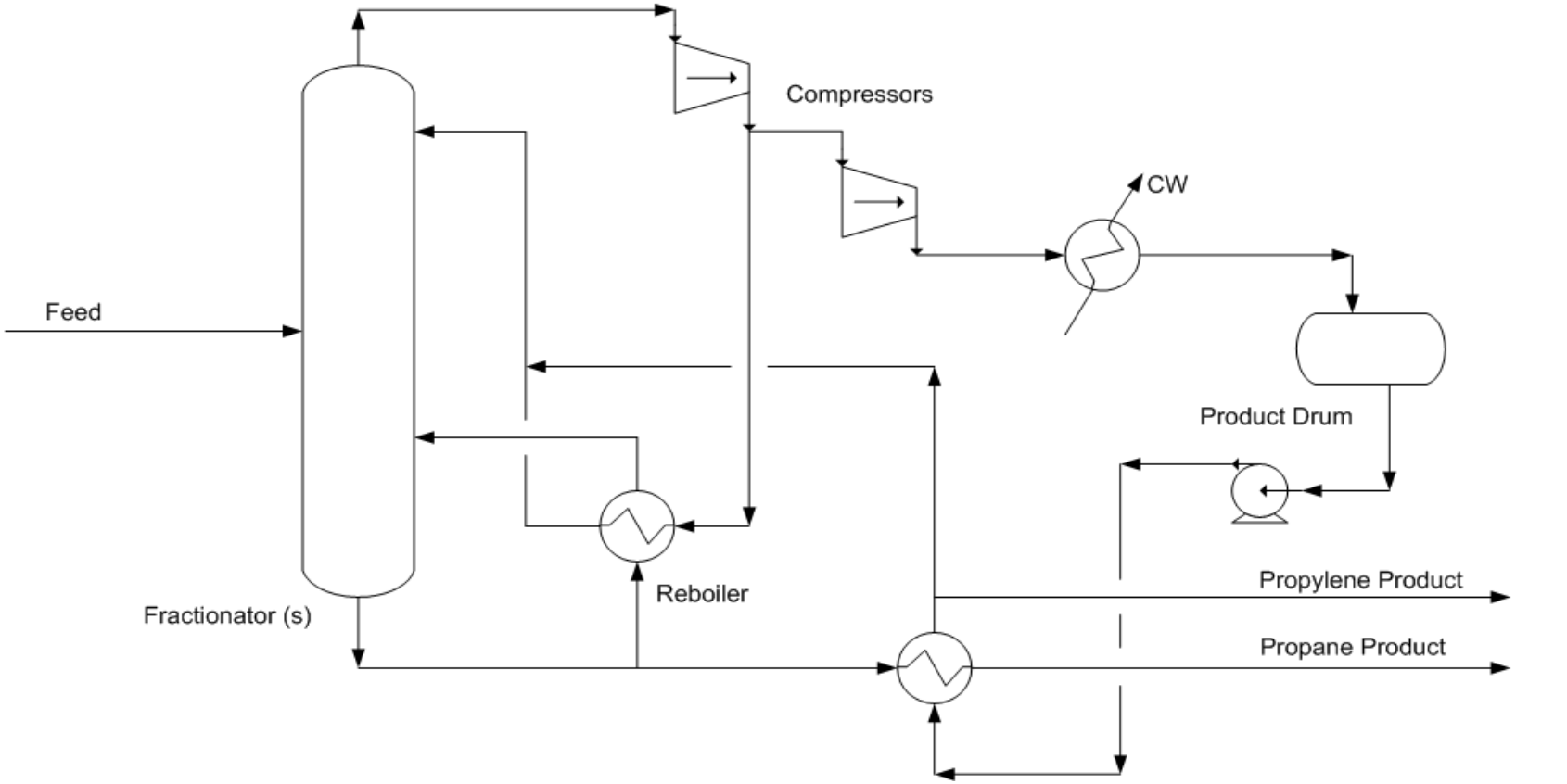


from Chuck Carr, World Petrochemical Conference, March 2011

Propylene Splitter Design & Optimization

Process Flow Diagram

Heat Pump < 125 psig



Design Basis

Arab Medium Refinery Capacity (MBPSD)	FCC Capacity (MBPSD)	PP Splitter Capacity (MBPSD)
85,000	25,000	3,000
165,000	50,000	6,000
270,000	80,000	10,000
400,000	120,000	15,000

Design Basis

- Propylene Splitter Feed Basis
  - 69% C_3=
  - 28% C_3
  - 3% C_2/C_4
- Product Purity Specs
  - Propylene – 99.5%
  - Propane – 95%
- Heat Pump v. Conventional Distillation
- Evaluated multiple Operating Parameters

Design Basis

Oper Press (psig)	Tower Trays	Reboiler ΔT (°F)	Tower Fabrication	Power Cost ($/MWh)	Steam Cost ($/lb)
35	150 210 270	10 15 20 25	Shop	0.05 0.07 0.09	3.90
85	150 210 270	10 15 20 25	Shop	0.05 0.07 0.09	3.90
150	150 210 270	10 15 20 25	On-Site	0.05 0.07 0.09	3.90
265	150 210 270	90	On-Site	0.05 0.07 0.09	3.90

two towers

one tower

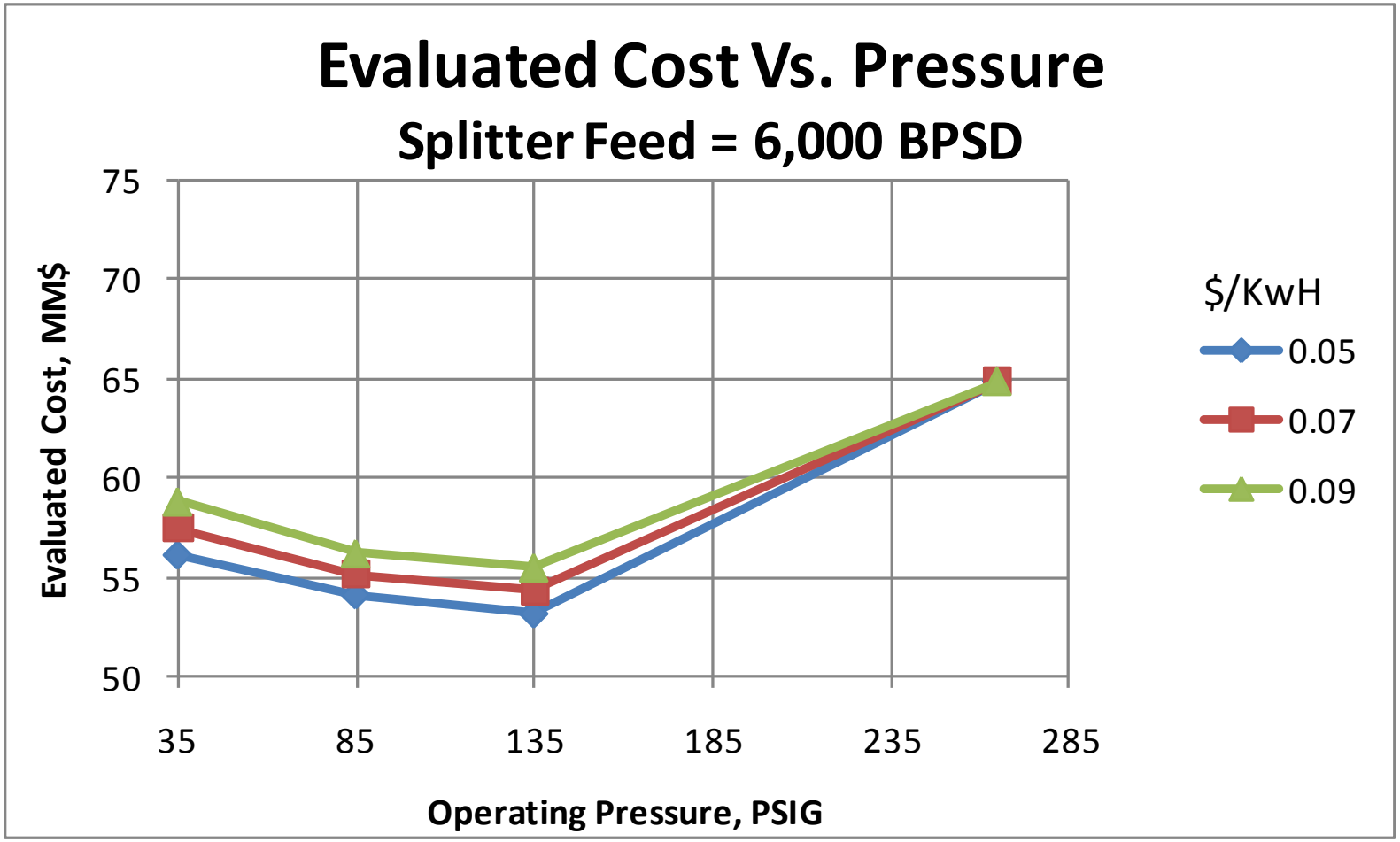
12 – 14 ft ID MAX

Heat Pump Design

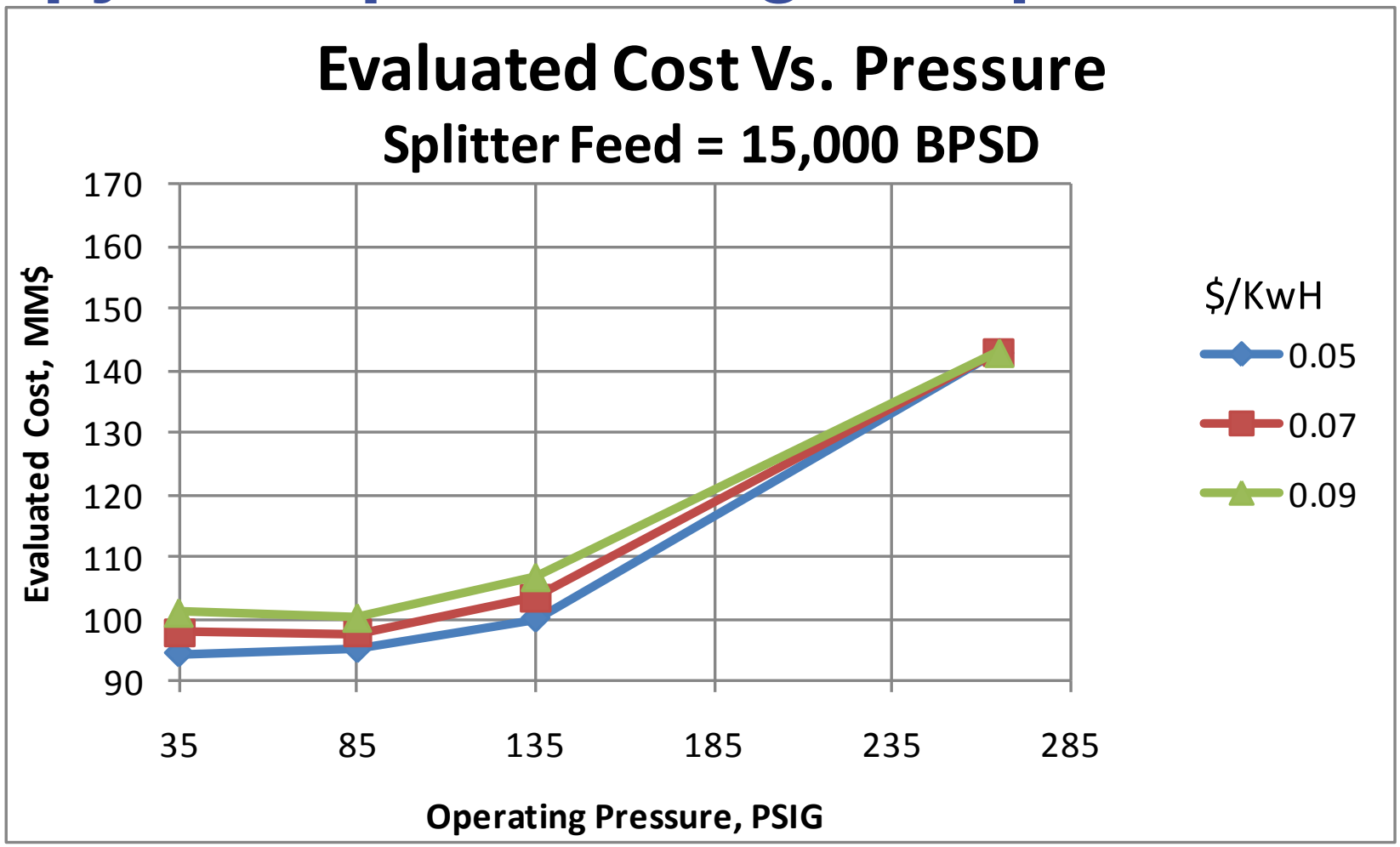
Single Reboiler is 30,000 to 35,000 ft^2 MAX

Conventional Distillation

Propylene Splitter Design & Optimization



Propylene Splitter Design & Optimization



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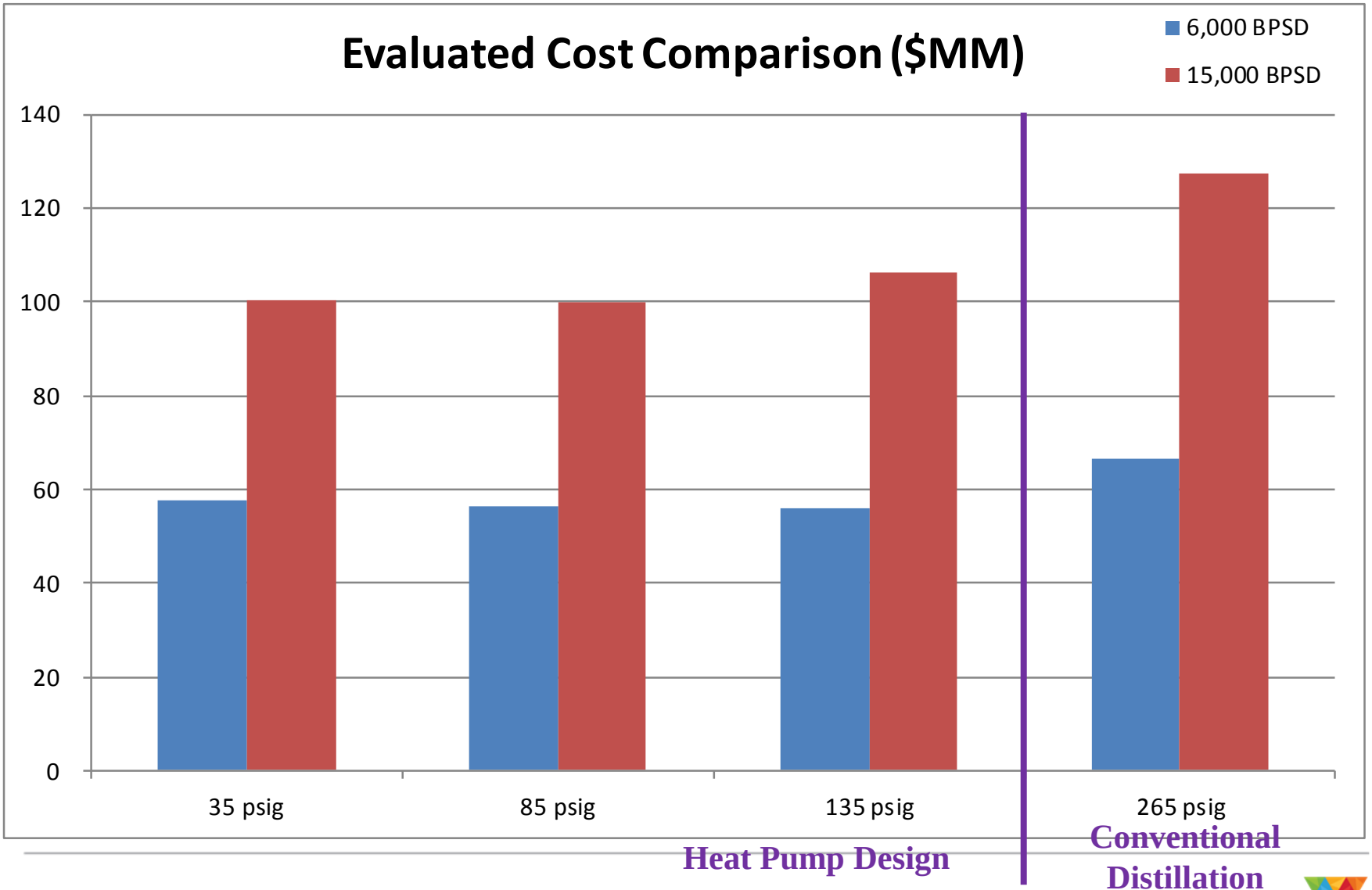
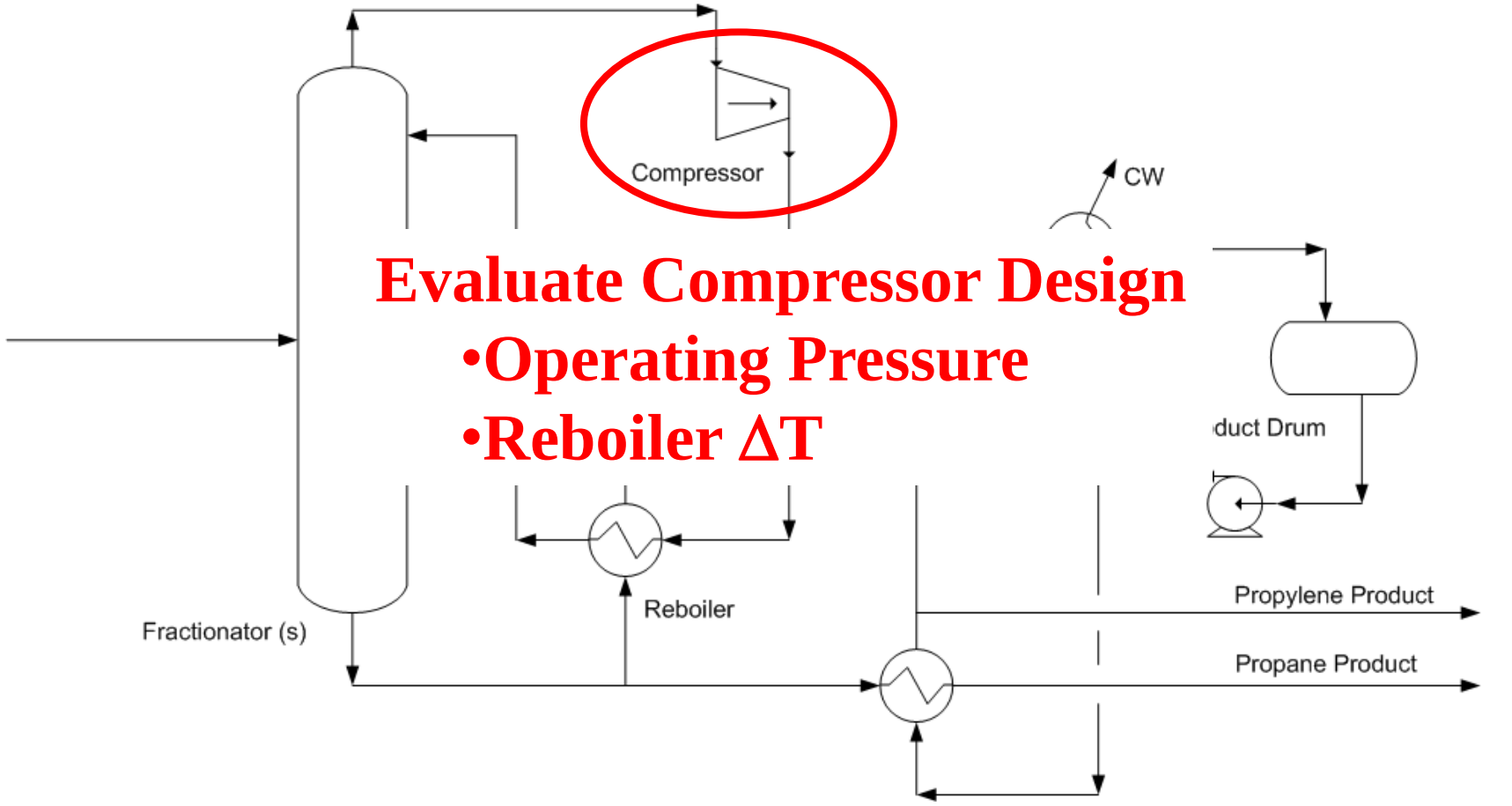


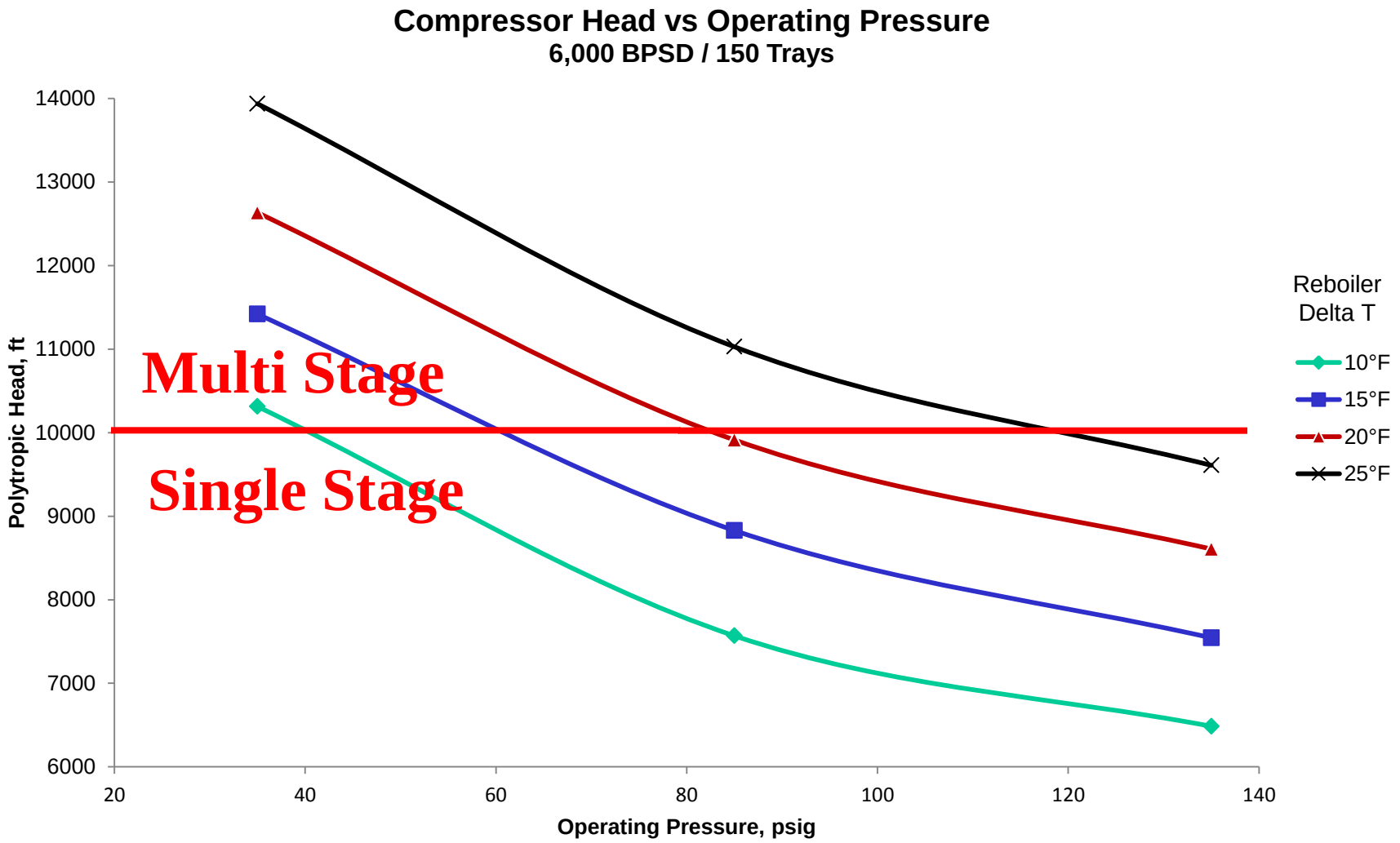
Propylene Splitter Design & Optimization

Process Flow Diagram

Heat Pump > 125 psig



Propylene Splitter Design



Propylene Splitter Design & Optimization

Process Flow Diagram

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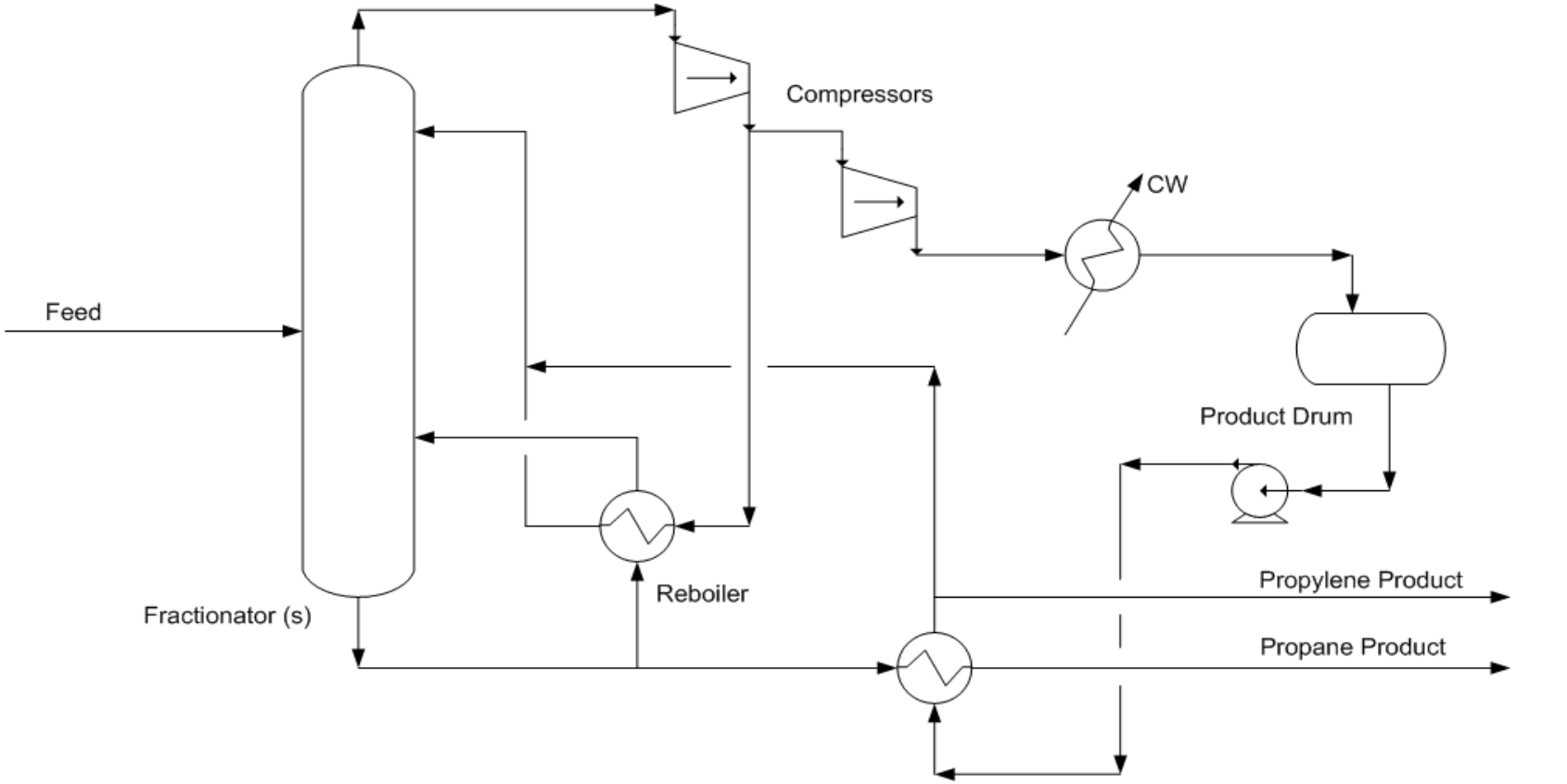


Propylene Splitter Design & Optimization

Single Stage Compressor → Maximize ΔT

Multi Stage Compressors → Minimize ΔT

Shop vs. On-Site Fabrication

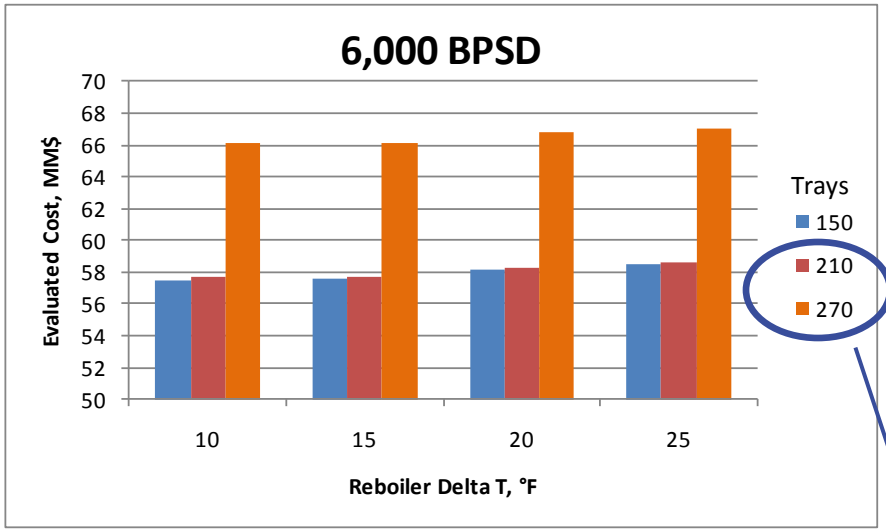
Optimize Design

Splitter Feed Rate, BPSD	3,000	6,000	10,000	15,000
Operating Pressure, psig	135	135	85	85
Number of Towers	2	2	1	1
Trays, Total	210	210	150	150
Dia/Length, FT	8.5/180	11.5/180	15/250	18.5/250
Compressor Stages	1	1	2	2
Horsepower	1,575	3,150	4,700	7,050
Number of Reboilers	1	1	3	4
Surface, FT^2 Each	12,350	24,700	28,000	32,000
Capital Investment, MM$	40.2	51.7	75.2	91.1

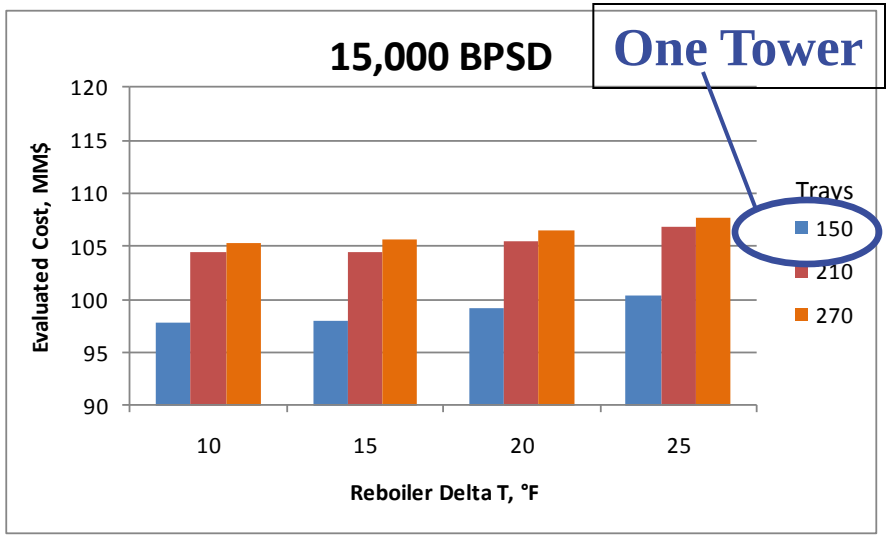
Propylene Splitter Design & Optimization

35 PSIG

Shop Fabricated Tower



On-Site Fabricated Tower

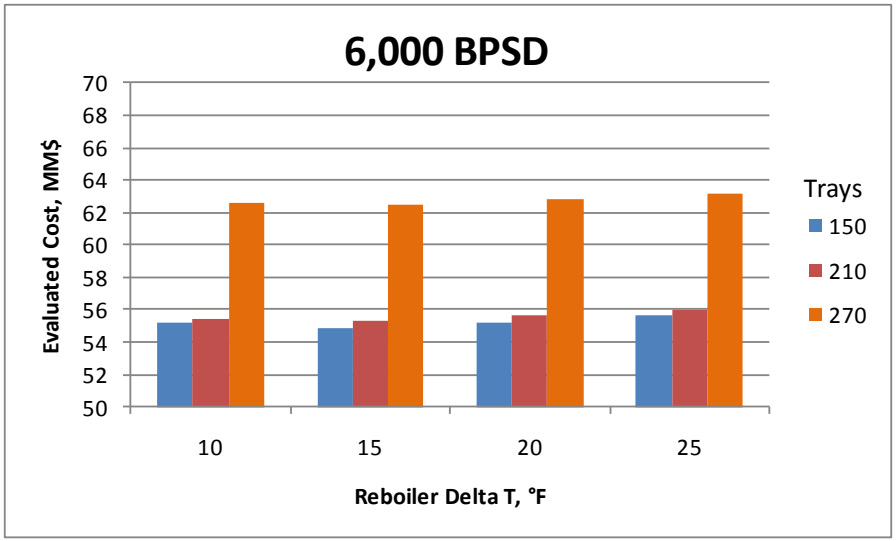


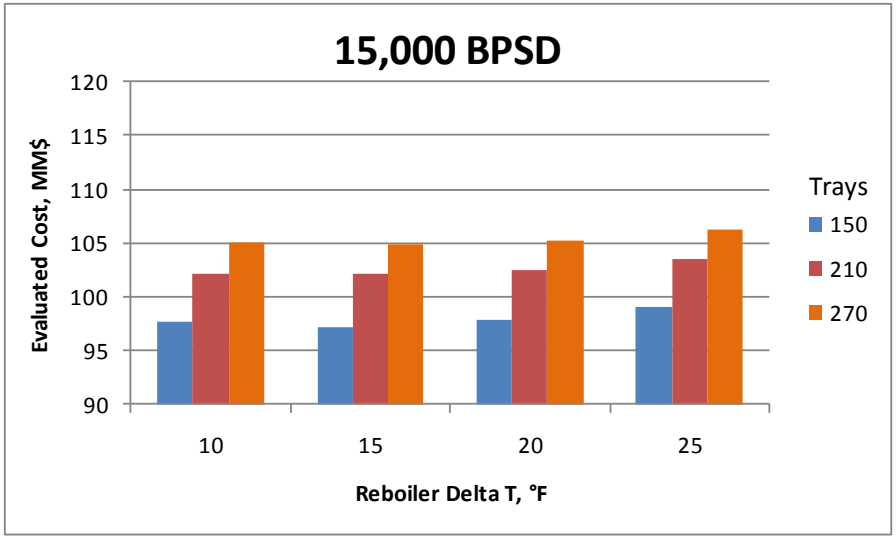
One Tower

Two Towers

Evaluated Cost

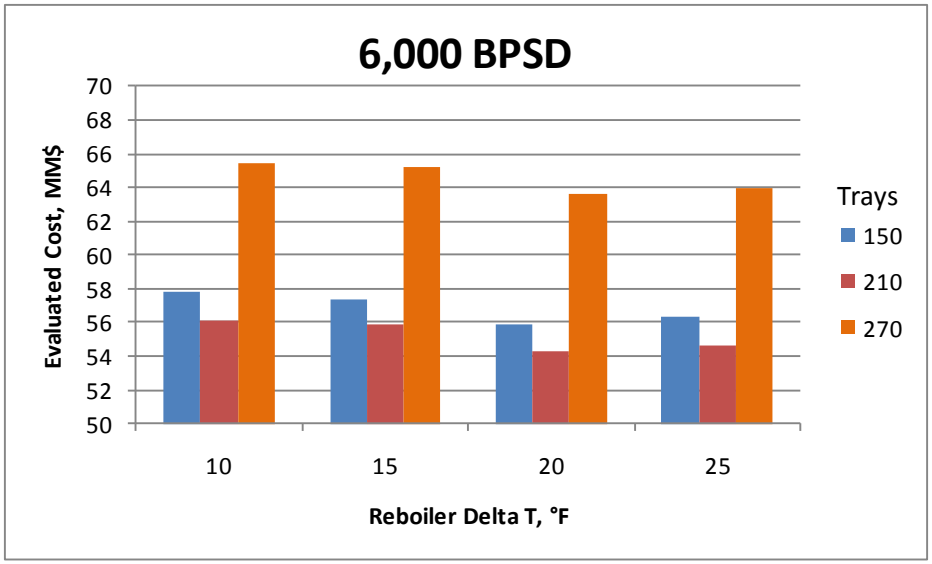
85 PSIG

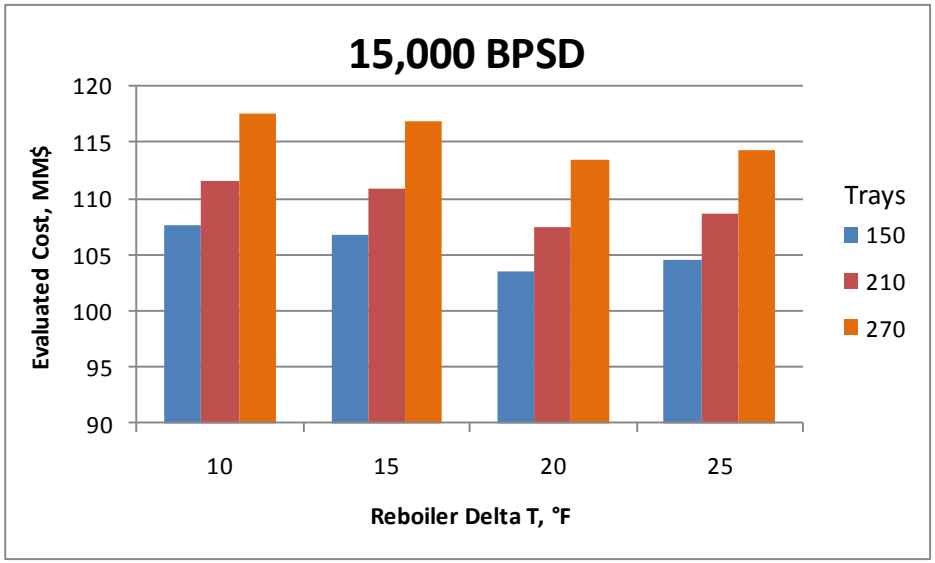




Evaluated Cost

135 PSIG





Propylene Splitter Design & Optimization

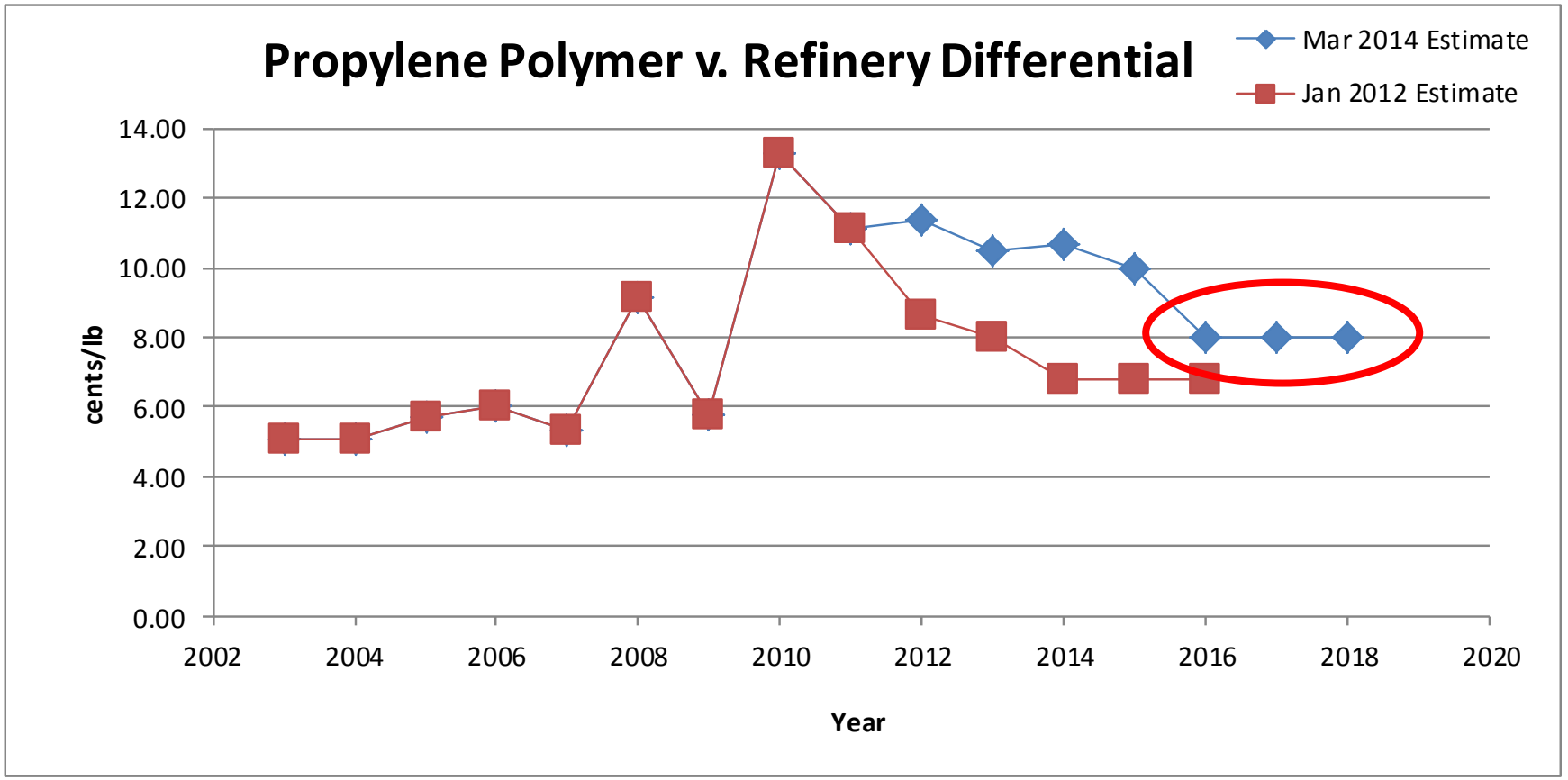
- Prefractionation:
  - Ethylene / Ethane
  - Butylenes / Butanes
- Treating:
  - Water / COS / Oxygenates: Mole Sieve / Alumina
  - Arsine / Phosphine: Copper Oxide
- Storage:
  - Bullets
  - Spheres
  - Refrigerated Storage

Case Study & Financial Analysis

	January 2012
Polymer Grade Propylene	60 to 80 cents/lb
Polymer/Refinery Grade Differential	5 to 10 cents/lb
Alkylate Price	$2.90 to $3.20/gal

Case Study & Financial Analysis

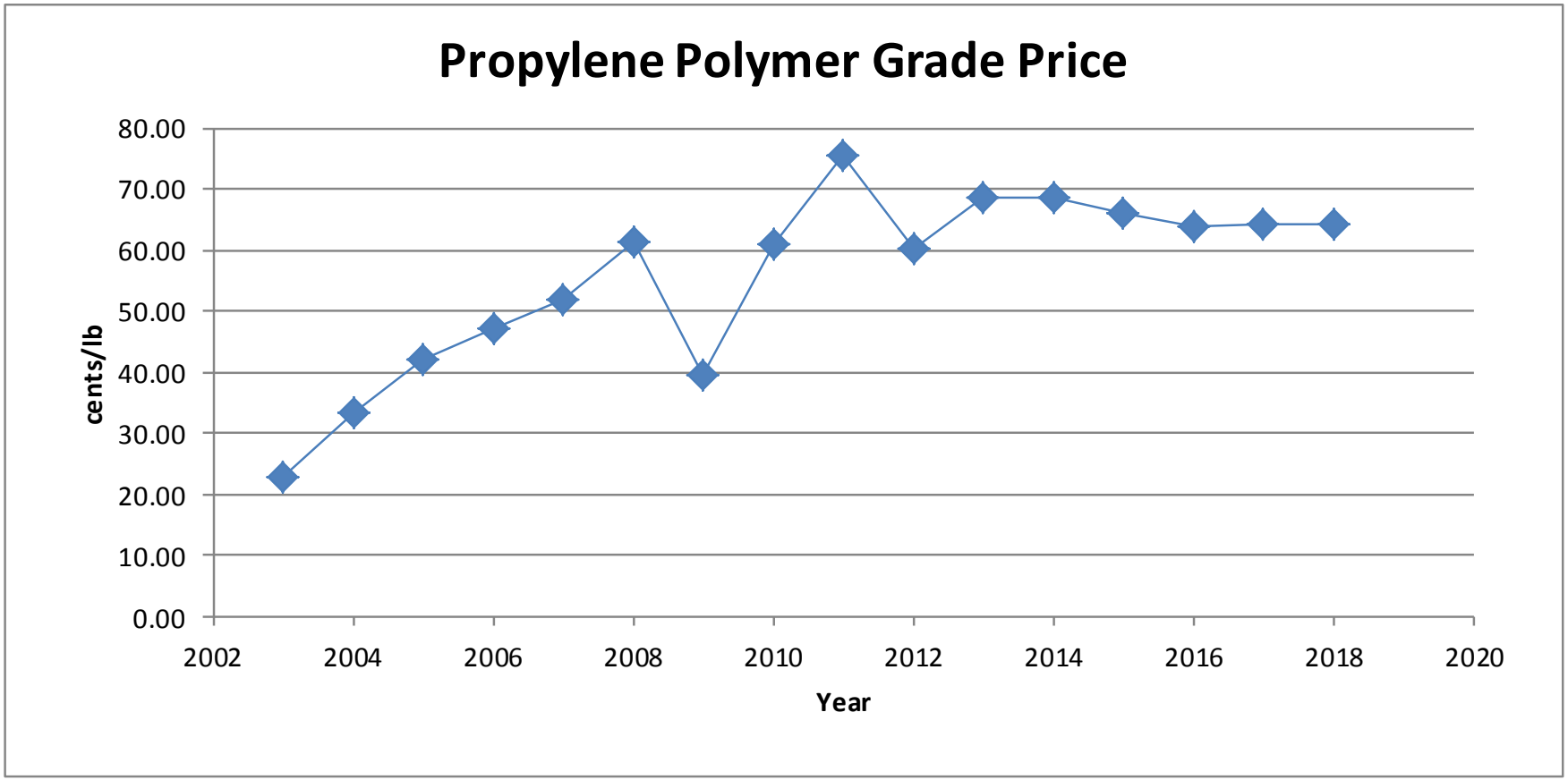
March 2014



Differential remained near 2012 MAX

from IHS Chemical

Propylene Market Background



Case Study & Financial Analysis

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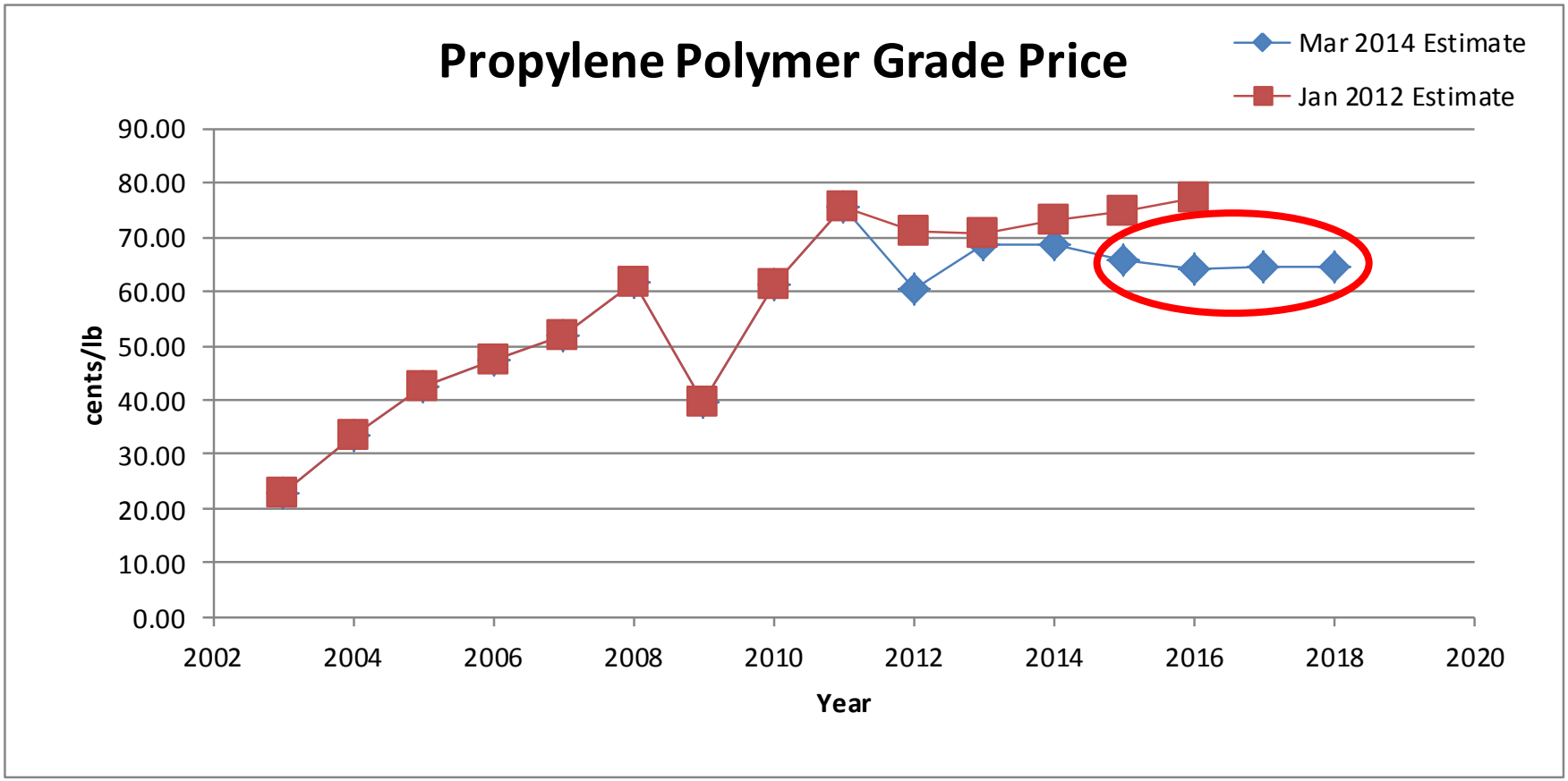
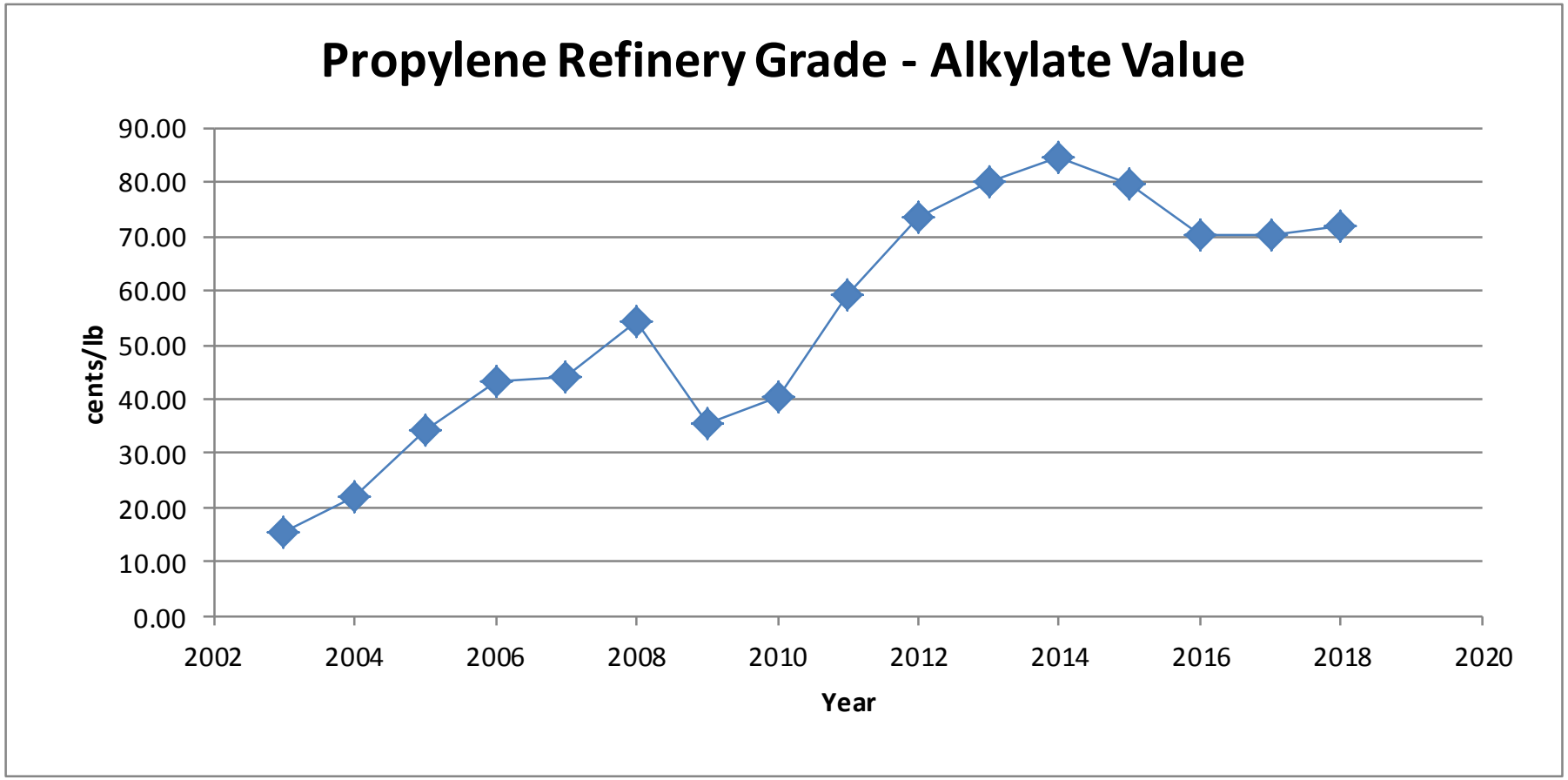


Price has fallen but stayed above 2012 MIN

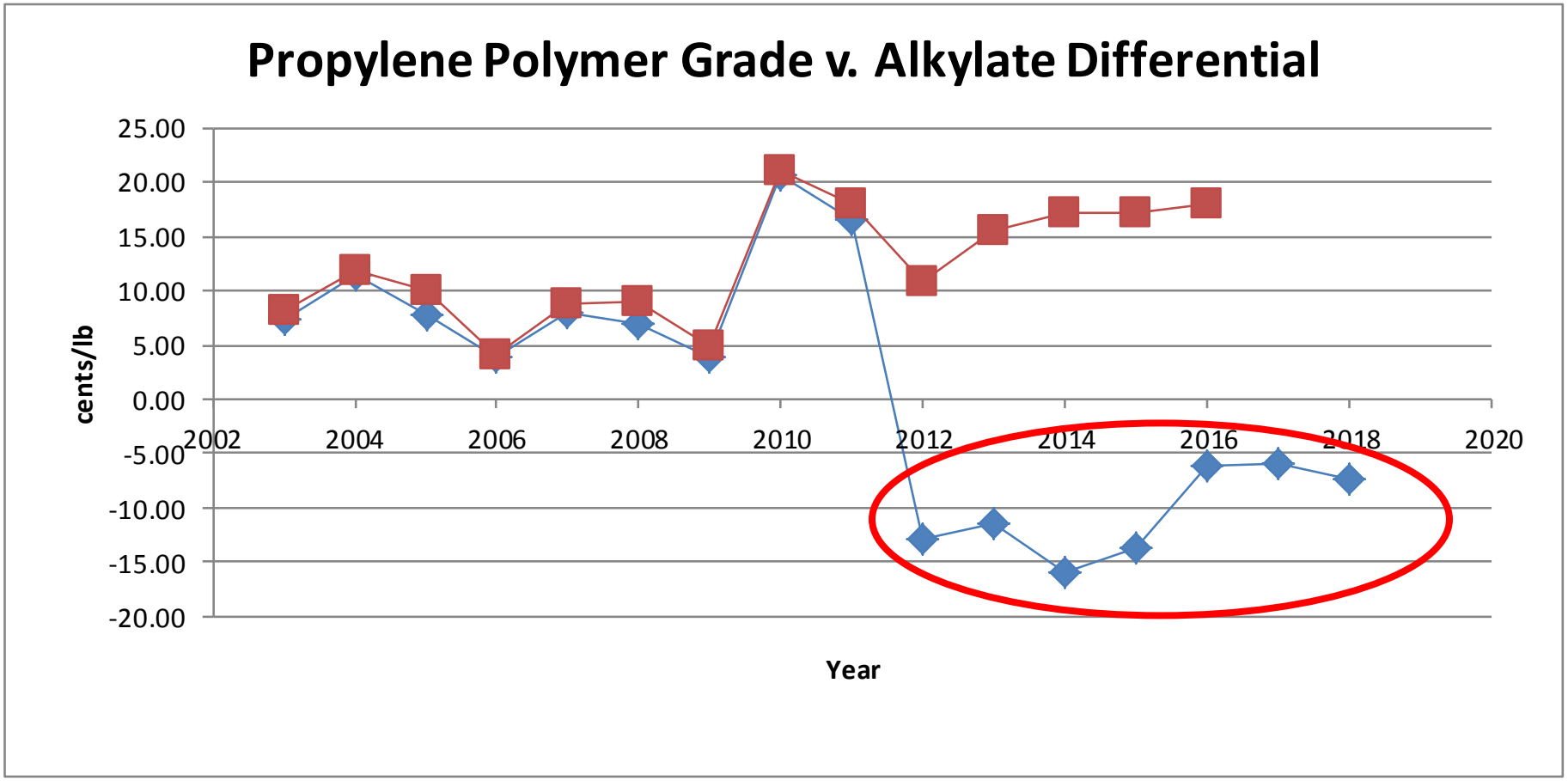
from IHS Chemical

Propylene Market Background



Case Study & Financial Analysis

March 2014

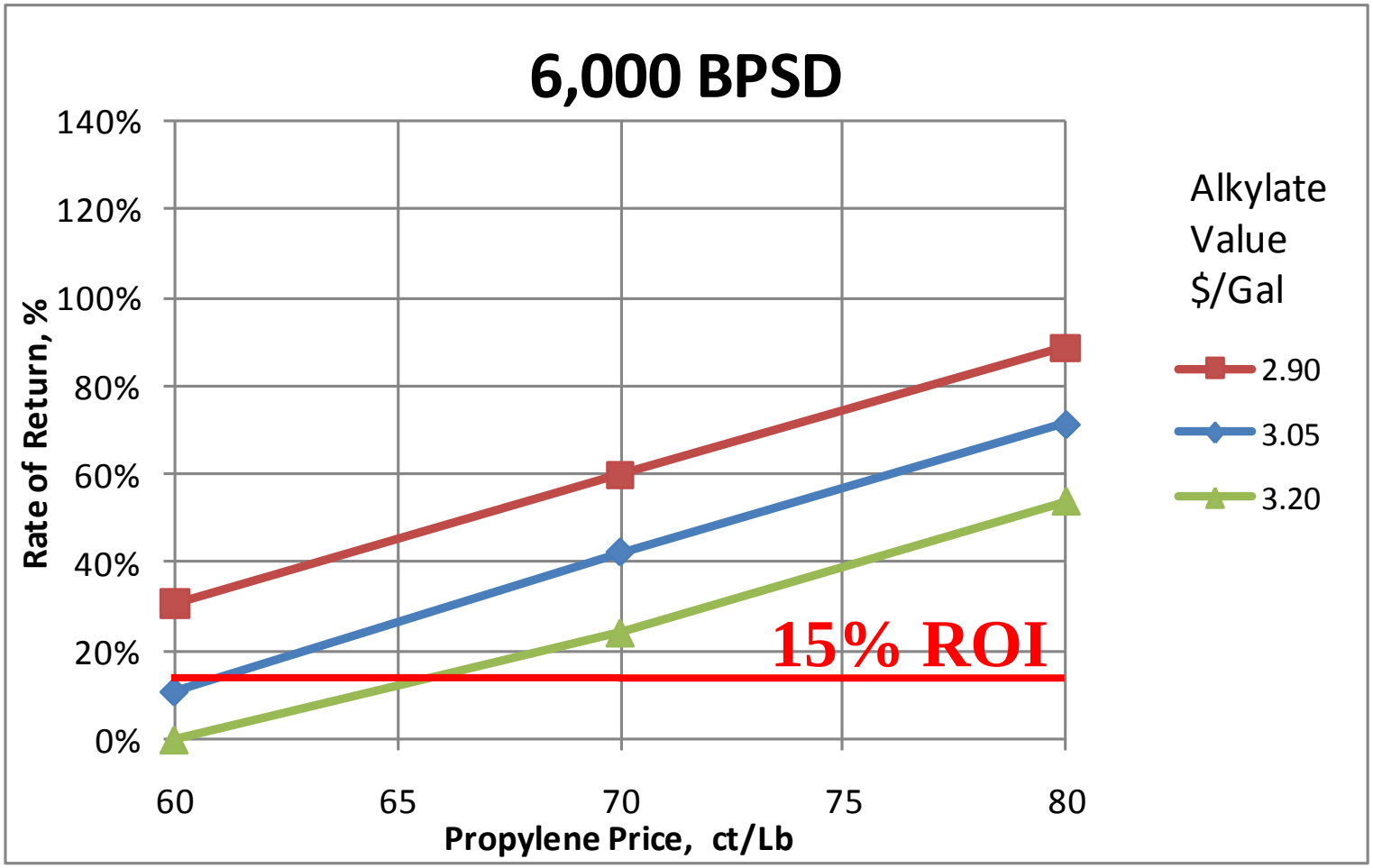


Alkylate is now a higher value product than Propylene

from IHS Chemical

Case Study & Financial Analysis

January 2012



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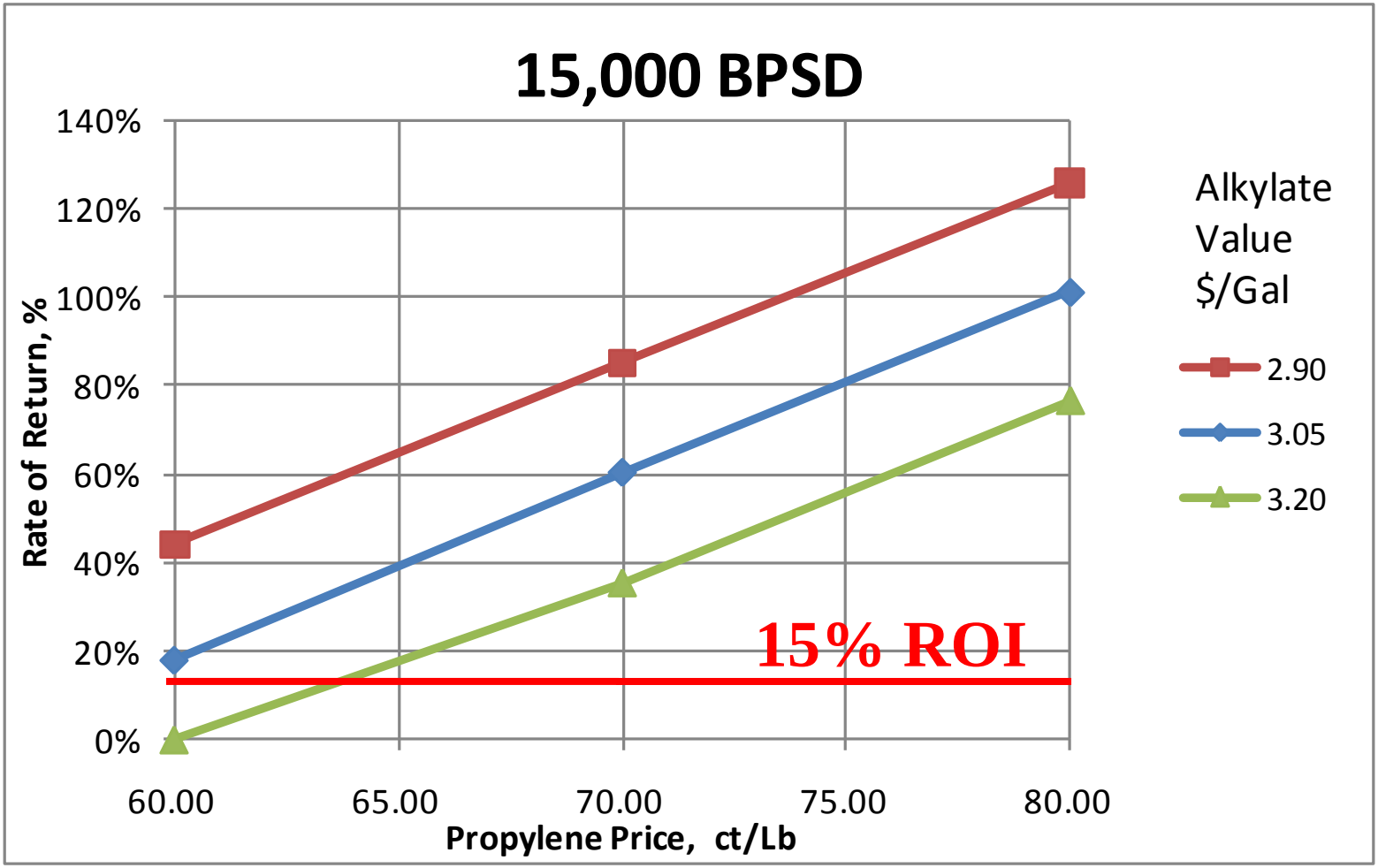

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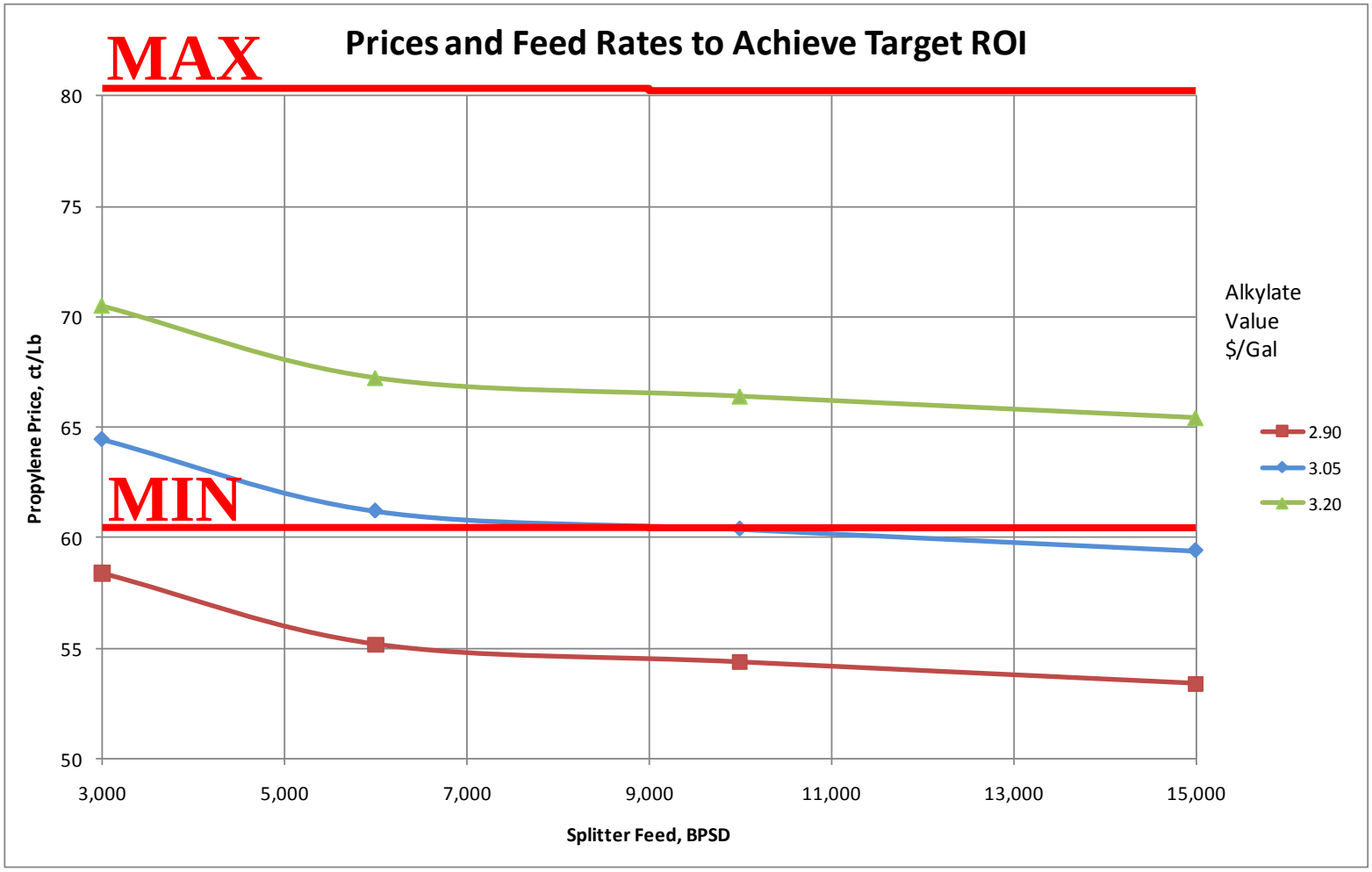

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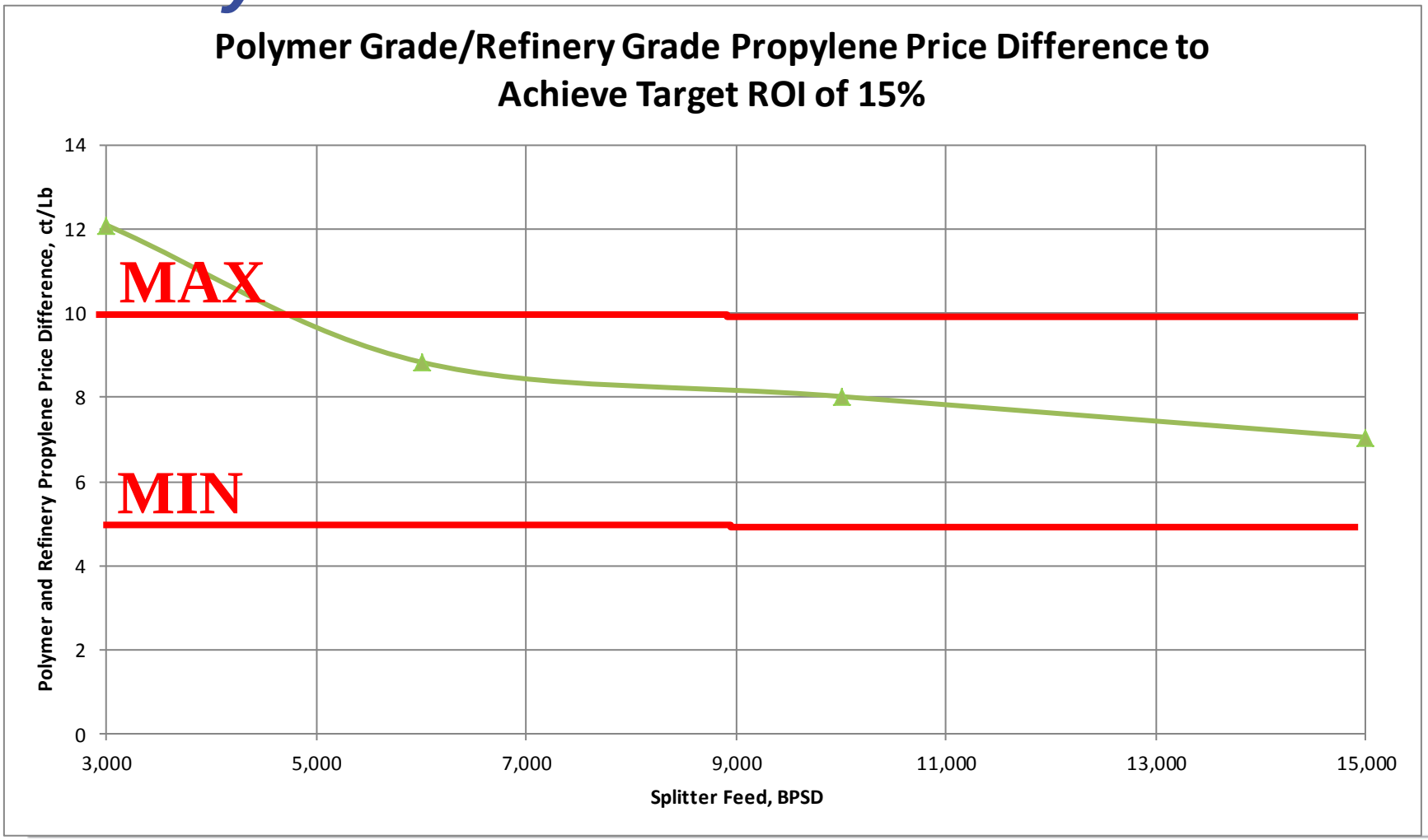

Conclusions

- Financial impacts from Shale are still in flux
  - In 2012 and 2014 converting Refinery LPG to Polymer Grade PP had positive economics
  - In 2014 Alkylate is a higher value product than Polymer Grade PP
- In current market if refiner has Alkylate Capacity, LPG should be converted to Alkylate
- If there is no Alkylate capacity, economics to make high purity PP from LPG still remain.
- Flux in economics likely continue as Shale economics continue to change

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