Mr. Joseph C. Gentry

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- Mr. Joseph earned a BS degree in chemical engineering from Auburn University and an MBA from the University of Houston. He is the inventor of several patented separations technologies and has specialized in the application of these for the petrochemical industry.

- He has previously worked for ARCO Chemical Company, and Lyondell Petrochemical Company as a process engineer in the olefins and aromatics areas and has authored several papers on licensing process technologies in refining and petrochemical applications.

- He is a specialist in GT-BTX and GT-Styrene, working in all areas of Technology, Licensing and Business Development.

Unlocking Value Potential from Naphtha Cracker By-Product Streams

Joseph C. Gentry • Director, Global Licensing

IOCL 2013 Petrochemical Conclave
March 18, 2013

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Introduction to GTC Technology

- Technology and global licensor for innovative solutions in:
  - Petrochemicals
  - Chemicals
  - Refining
  - Gas processing/Sulfur
- Global headquarters - Houston, Texas
- Regional subsidiaries in China, Korea, India, Singapore, the Czech Republic and Mexico
- Separations and Mass Transfer Solutions
- Process know-how, engineering, equipment, critical chemicals/catalysts and services

Naphtha Based Steam Cracker Operators - Increased global competition

Searching for added value in C5 –C12 Py-gas from the cracker

"I used to do pretty well just focusing on ethylene and propylene.

"Now I have to recover as many of the heavier co-products as I can to stay competitive globally.

"Increased competition from producers with cost advantaged feedstock and shale gas ethane in North America has not helped.

Fortunately my naphtha cracker makes some higher value products in the Py-gas stream.

I wonder if I can separate and market them?"

Typical Product Slate from Naphtha Cracker

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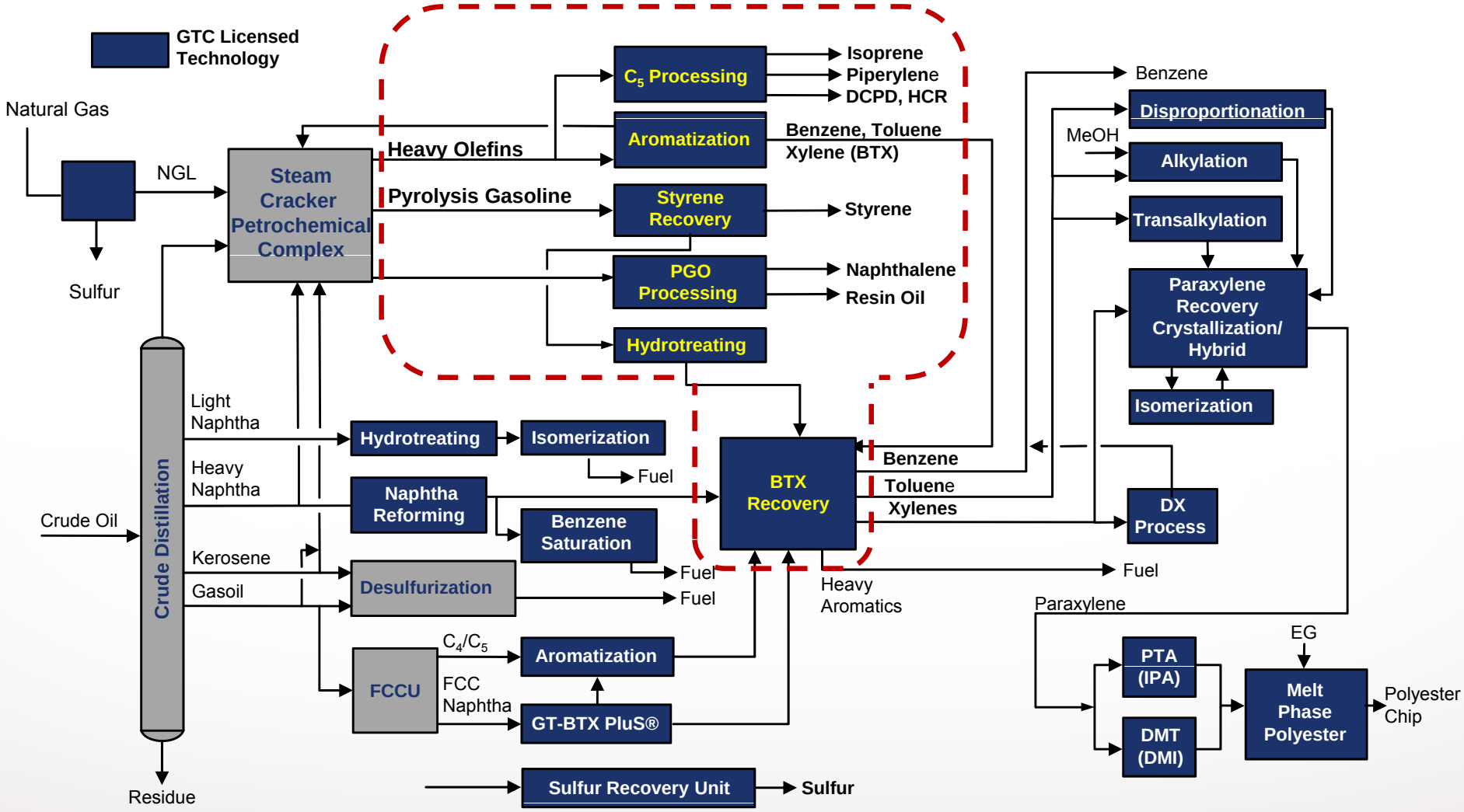
Product	Feedstock					
	Ethane	Propane	Butane	Naphtha	Atmospheric Gas Oil	Vacuum Gas Oil
Hydrogen - 95%	9	2	2	2	1	1
Methane	7	28	22	17	11	9
Ethylene	**78**	42	40	**34**	26	21
Propylene	2	17	17	16	16	14
Butadiene	1	3	4	5	5	5
Pyrolysis Gasoline, including:	**1**	7	7	**19**	18	19
Piperylene	**-**	-	-	**0.3**	1	1
Cyclopentadiene	**-**	-	-	**1.4**	2	2.5
Isoprene	**-**	-	-	**0.9**	2	2
Benzene	**1**	3	3	**7**	6	4
Toluene	**0**	1	1	**3**	3	3
Xylene	**-**	-	-	**1**	1	0.8
Styrene	**-**	-	-	**1**	1	0.8
Other, C9+	**0**	3	1	**6**	2	0
Fuel Oil	0	1	2	5	18	25
Balance	0	0	6	11	5	6

*** Values obtained at high severity and with recycling unconverted E/P Stream, Chauvel & Lefebvre 1989**

GTC Portfolio in Refining, Petrochemical, Gas Processing/Sulfur & Polyester Industries



Unlocking Value in the Py-gas Stream from every carbon molecule, C5-C12

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C5 – Diolefins

- Piperylene (1,3 pentadiene) “Pip’s” → Hydrocarbon Resin “HCR”
- DCPD → HCR, Unsaturated Polyester Resin
- Isoprene → Rubber

C6 - Benzene → EB → Styrene

C7 – Toluene

- Xylenes
- Toluene (Methylation with MeOH) → Paraxylene

C8 – Xylenes → Paraxylene → PTA → Polyester

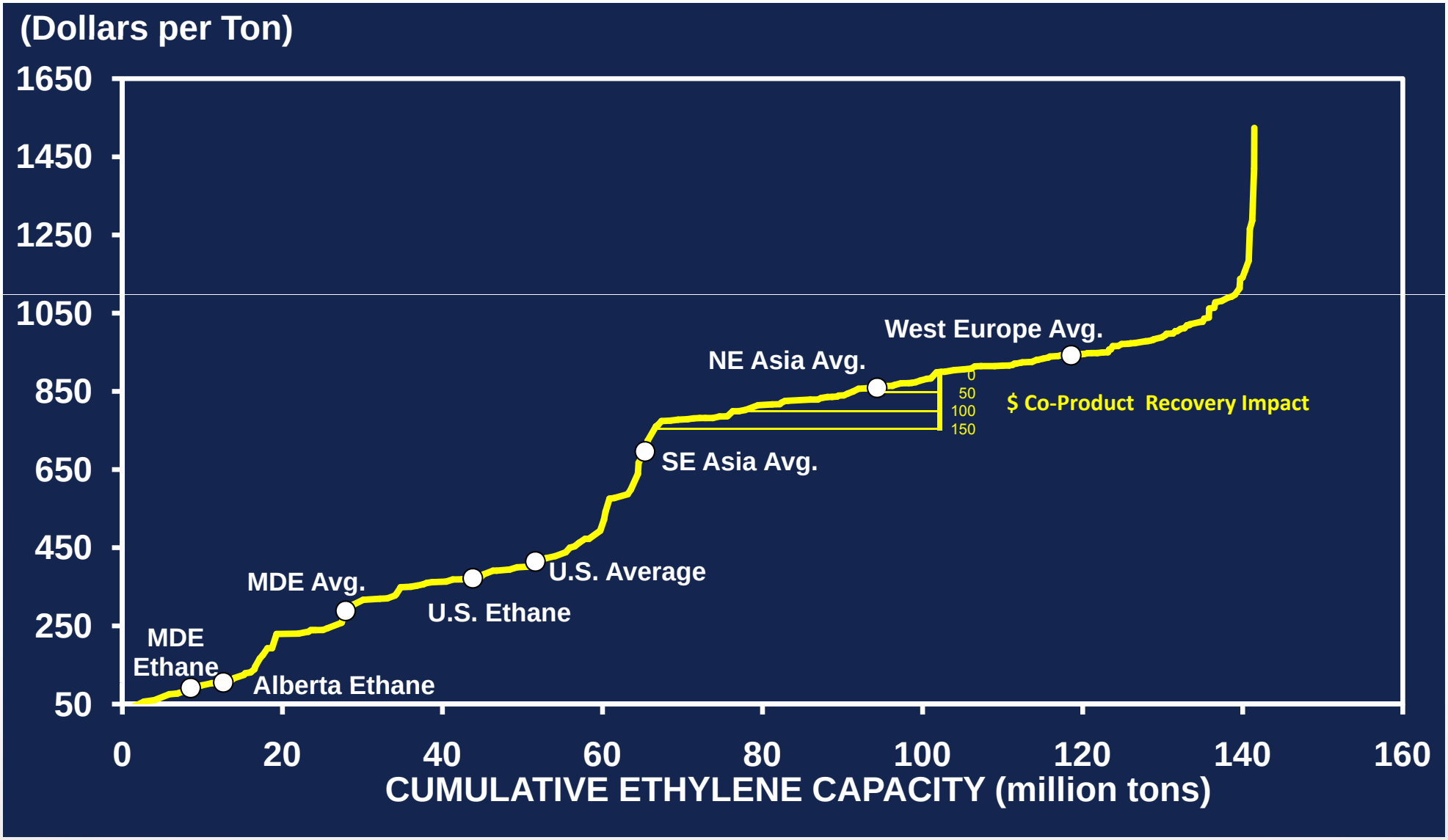
- Styrene (Extraction) → SBR, PS, Rubber

C9 – Resin Oil → HCR → Inks, Adhesives

C10 – Naphthalene → Naphthenic Derivatives

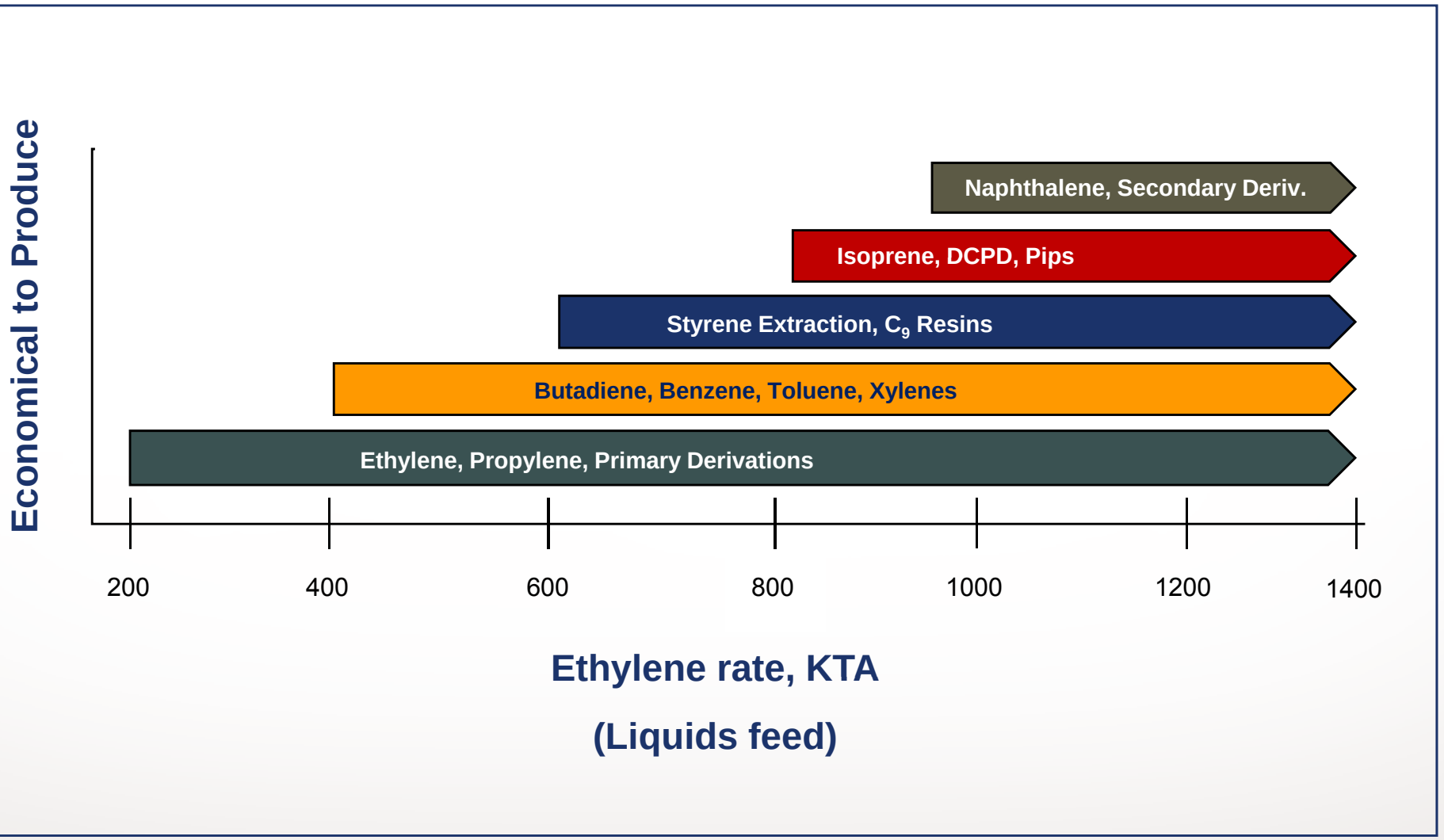
C11–C12 – Aromatic Solvents

2012 Global Ethylene Cash Costs

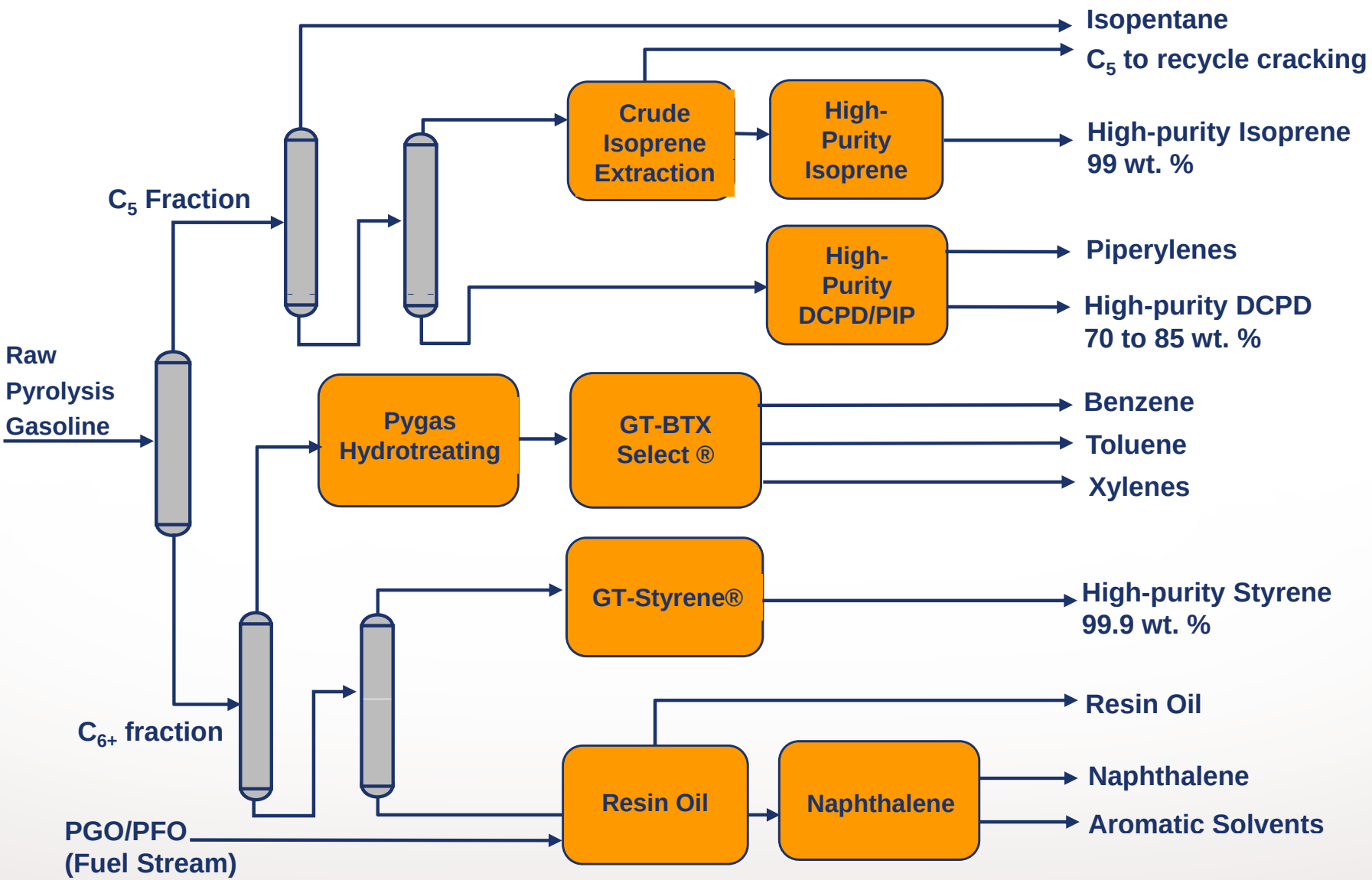


Data provided courtesy of IHS/CMAI

Economical Ethylene Capacity for Recovering By-products



Primary By-products from Pygas



Naphtha Cracker By-products – C5s

- For naphtha cracking, by-product C5s are of 0.13-0.18 /ton of ethylene
- Diolefin C5 petrochemicals have much higher value than hydrotreating and recycle cracking
- Composition of C5s from a high severity naphtha cracker:
  - 15% isoprene
  - 16% CPD, DCPD
  - 11% pips
  - 8% n-pentene
  - 11% isopentene
  - 4% cyclopentane, cyclopentene
  - 33% pentanes
  - 2% acetylenes, others

Naphtha Cracker By-products – C5s Molecules and Applications

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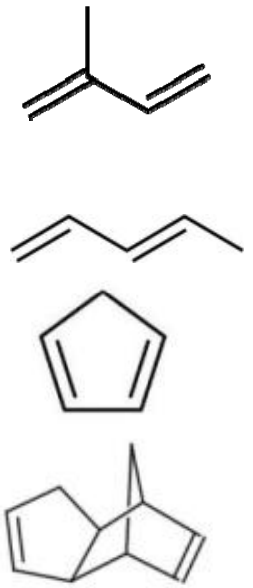
Primary Components of Interest

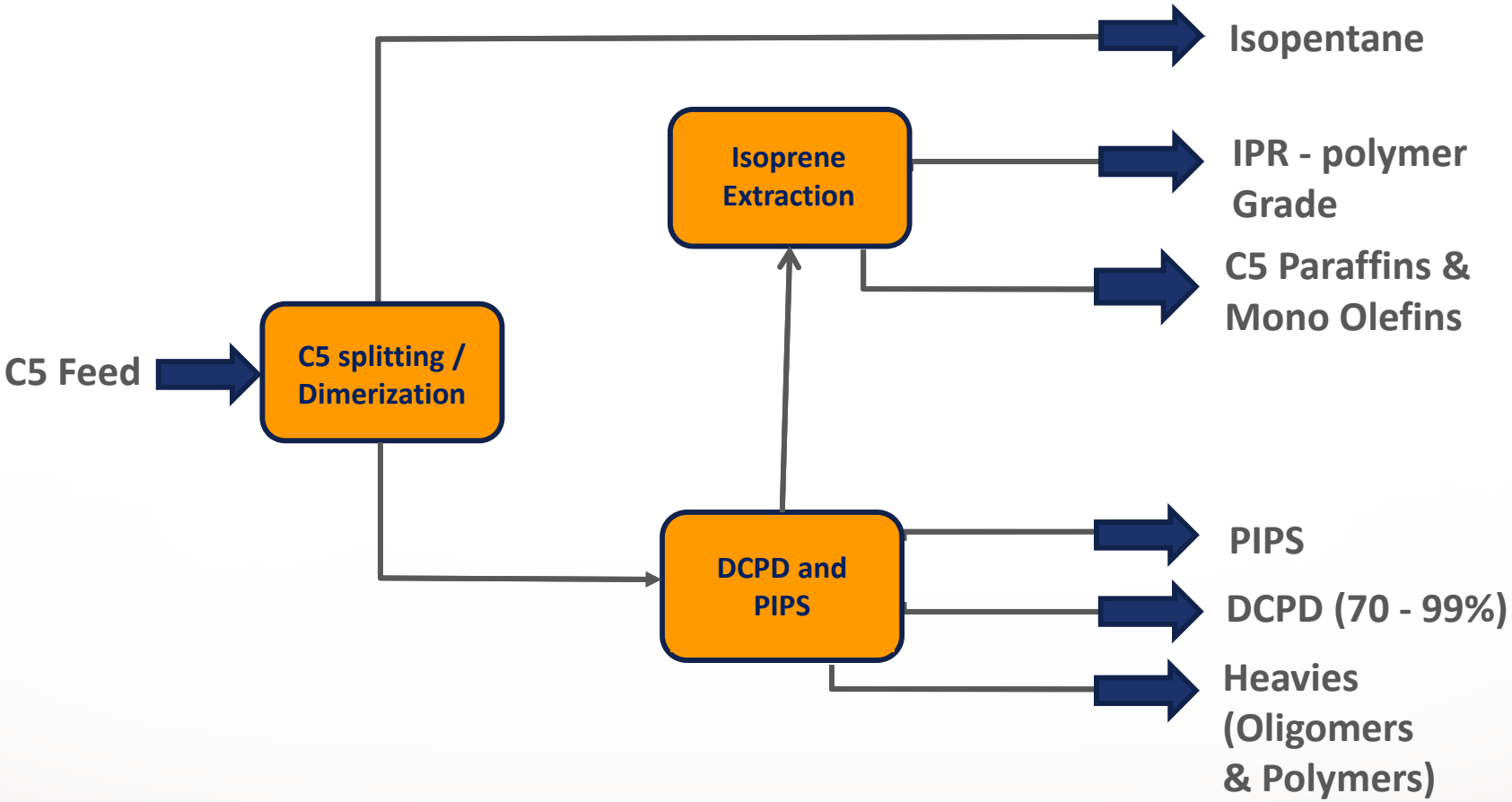


- Isoprene - 2 methyl-1,3 butadiene
- Piperylenes - cis, trans/1,3 pentadiene
- CPD - cyclopentadiene
- DCPD - dicyclopentadiene

Other Components

- Isopentane- Gasoline blend-stock
- C5 Mono-olefins - TAME, catalytic cracking, aromatization, resin feedstock
- Paraffins - Solvents, refrigeration, cracker feed

C5 Separation



C5s to HCR
Benefits of GTC's Advanced C5 Process

- Lower energy and capital cost for C5 separation
  - Improved CPD/DCPD dimerization
  - State-of-the-art separation
  - High value intermediates created for HCR
- Integrated C5 recovery/HCR product synergies
  - Improved feedstocks enhance performance of the HCRs
  - Improved system economics via pipeline return of non-reactives
  - Option for product off take of PIP's and DCPD, with optional production of isoprene if desired
  - Reduced energy and capital by matching PIP/DCPD spec to HCR plant needs

Naphtha Cracker By-products – BTX

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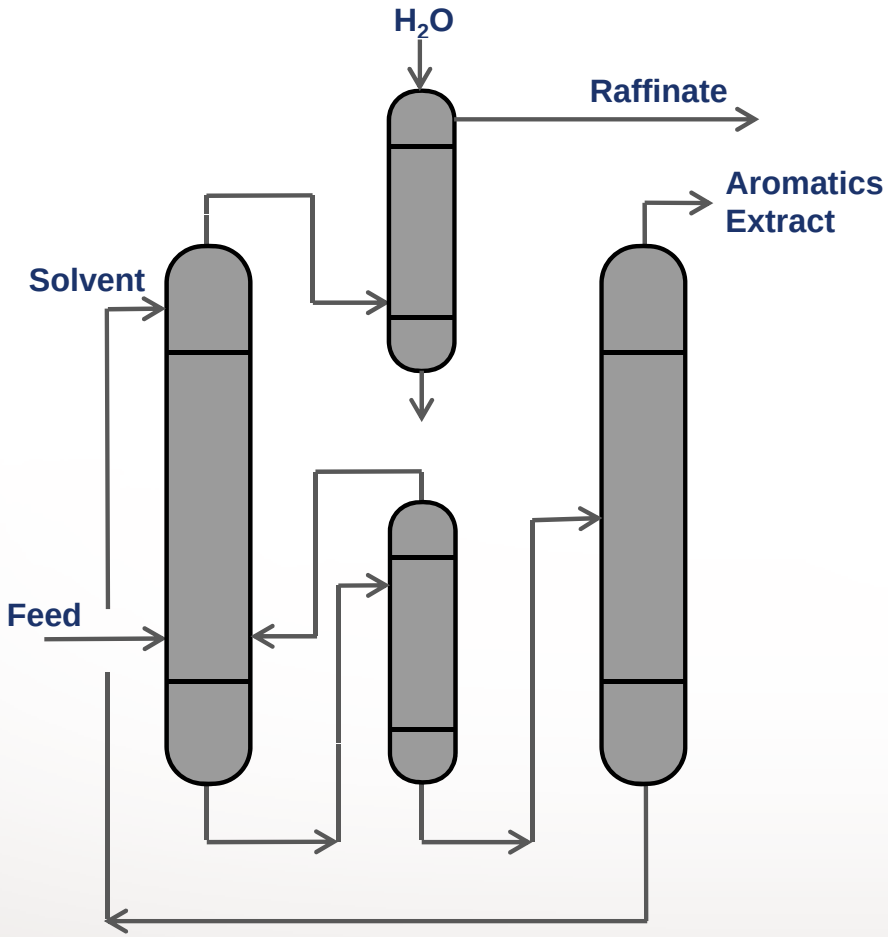
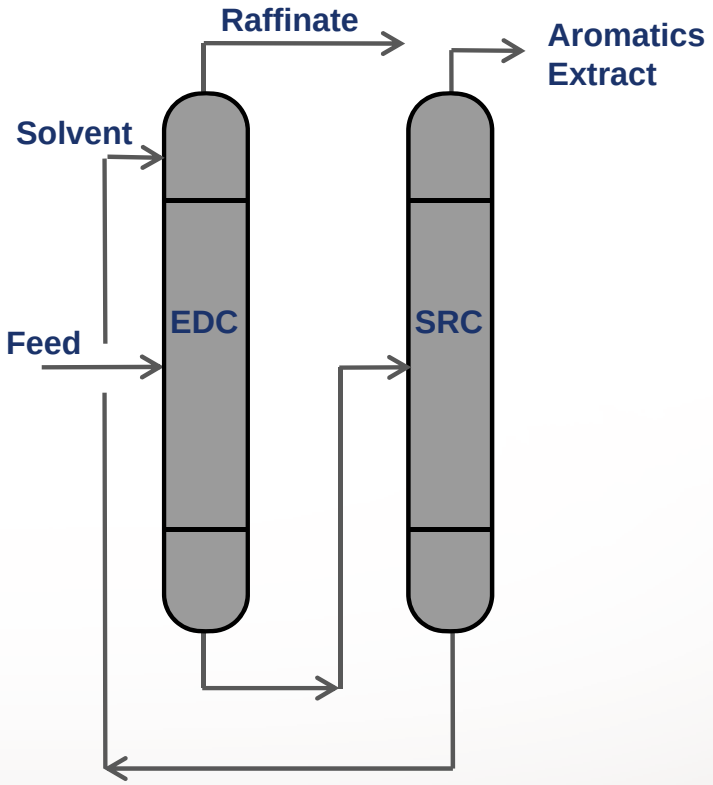
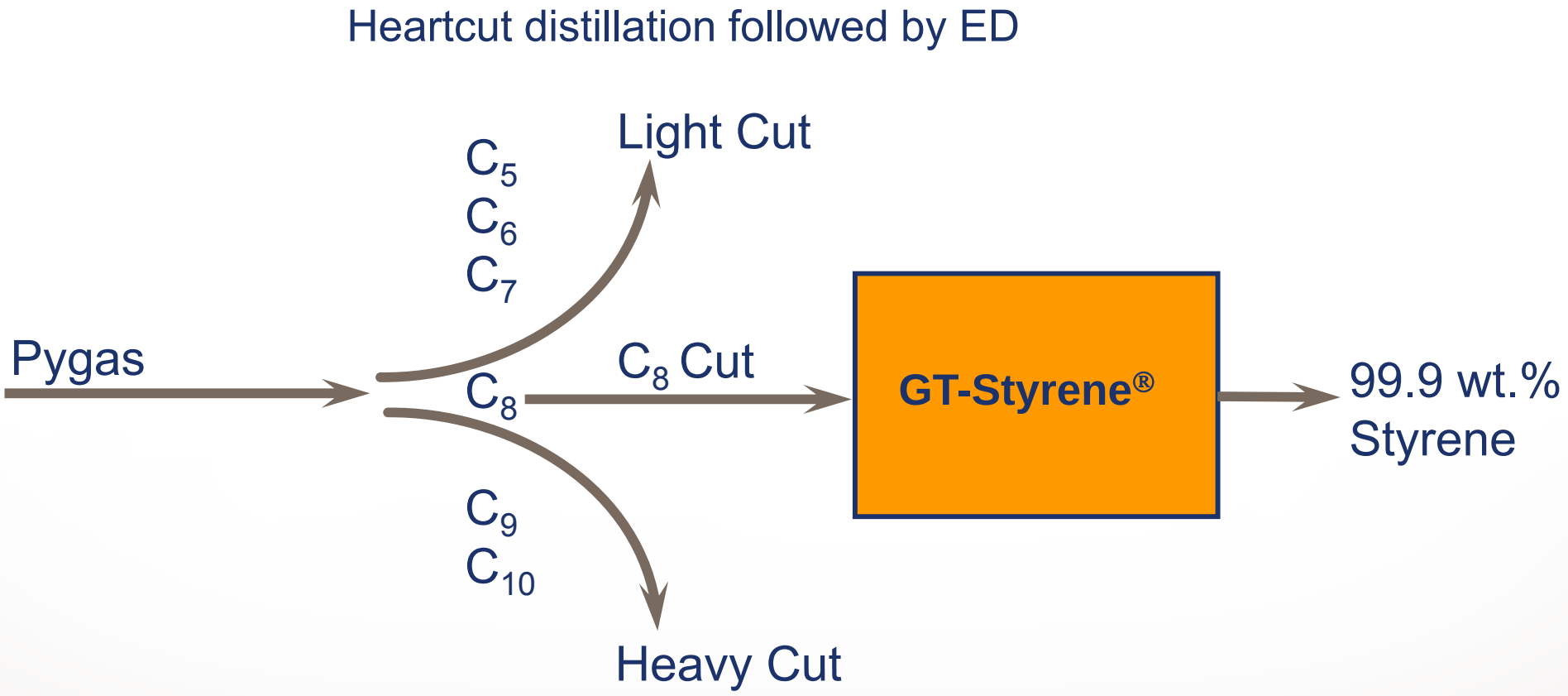
Liquid-Liquid Extraction



Extractive Distillation



Naphtha Cracker By-products - Styrene



Naphtha Cracker Styrene from Pygas - Economics

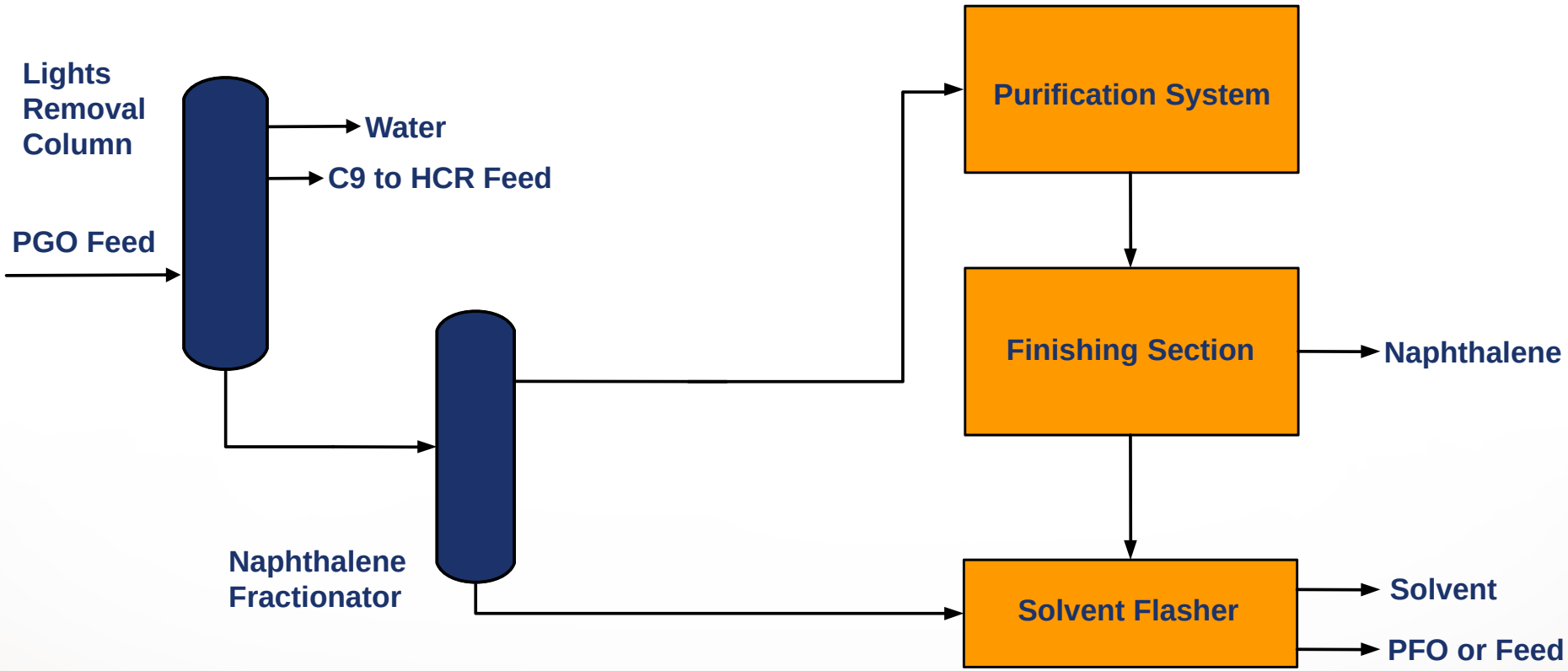
Parameters	GT-Styrene®
Capital Cost	$30 MM
Net Feedstock Cost, $/ton	$800
Processing Cost, $/ton	$250
Total Production Cost, $/ton	$1050
Sales Price, $/ton	$1550
Net Margin	$12.50 MM
Pre-tax Contribution Margin	42%

- Basis: 25,000 MT/yr Styrene

Pygas Byproducts – C9 – C12
Naphthalene & Aromatic Solvents

- C9s - Hydrocarbon resin feedstock
- C10 – Naphthalene and derivatives (additive for concrete modifiers)
- C11 & C12 - Heavy aromatic solvents

Naphtha Cracker Pyrolysis Gas Oil (PGO) Co-products - Naphtha & Solvents



Naphtha Cracker By-products Value Summary – 1000 KTA ethylene

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Summary of Upgrade Options			
C5 - C12	Product Area	Capital MM$	~ Payback (years)
C5	Piperylene/DCPD - GT-C5 for HCR GT-Isoprene™	25 35	3
C6	Benzene (GT-BTX®)	30	2
C7	Toluene (GT-BTX®) GT-TolAlk™	10	2
C8	Styrene (GT-Styrene®)	30	2
C9	Resin Oil, Solvents	10	1
C10	Naphthalene, Solvents	15	2
C11 - C12	Aromatic Solvents	5	1

GTC Technology is the only global licensor which offers all required technologies, and can assist in product placement.

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