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Development of the EIA's Liquid Fuels Market Module (LFFM)

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EIA's LFFM Workshop

September 2009

AGENDA

- “Shotgun” approach similar to White Paper
- Background = Refinery Modeling Development
  - Project Oriented (The LP is a TOOL)
  - Single Client, Multi-Client
  - Local, Regional, International
- Expertise is LP ➔ Paper is LP focused

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LP Model Types - Overview

- Configuration Types
  - Regional Configuration Models
    - Ex: PADD 3, USA, Texas Inland
    - Supply/Demand; Strategic
  - Generic Configuration Models
    - Ex: Lt Sweet Cracking, Heavy Sour Coking
    - Technology; Strategic
  - Specific Configuration Models
    - Ex: ExxonMobil, Baytown
    - Not Recommended for EIA
- Very difficult to get one model to “do everything”

Recommended LP Tool Kit

- LP Software & Data
  - Refinery Optimization Software (ex: GRTMPS, PIMS)
  - Refinery Technology Database
  - Crude Assay Software Development & Cutting (ex: HCAMS)
  - Crude Assay Database Library (ex: Chevron, BP)
- LP Models
  - Regional
  - Generic Configuration
- LINK to NEMS
  - Quantitative and/or Qualitative
  - Offline, Online

LP TOOLKIT = Models + Assays + Database

GENERIC CONFIGURATION MODELS			
PADD	TYPE	CRUDE	PRIORITY
PD3	CRK	LT SWT	1
PD3	COK	MD SOUR	2
PD3	COK	HVY SOUR	1
PD3	COK/HYK	HVY SOUR	2
PD2	CRK	LT SWT	1
PD2	COK	MD SOUR	2
PD2	COK	HVY SOUR	1
PD2	COK/HYK	HVY SOUR	2
PD1	CRK	LT SWT	1
PD1	COK	MD SOUR	2
CAL	COK/HYK	HVY SOUR	1
PD5 ex CAL	CRK	LT SWT	2
PD5 ex CAL	COK	HVY SOUR	2
PD4	CRK	LT SWT	2
PD5	CRK	HVY SOUR	2

REGIONAL MODELS	
REGION	PRIORITY
PD1	1
PD2	1
PD3	1
PD4	2
PD5	2
CAL	1
USA	1

REFINERY TECHNOLOGY DATABASE

- Delta-Based Model
- Recursion
- Pooling
- Generalized
- Transparent & Stable

FOREIGN CRUDES		DOMESTIC
arabian light	kuwait	ans
arabian med	marlim	belridge s.
arzew/saharan	maya	colorado swt
azeri lt	merey	cymric
basra lt	olmeca	elk hills
cabinda	oriente	kern
cano limon	peace p/l sour	lls
doba	qua iboe	lost hills
forcados	rabi lt	mars
furrial	syncrude	montana mix
hamaca	wcs	myton
hardisty lt mix		thums
hibernia		wti
interprovincial swt		wts
isthmus		wyoming sour
		wyoming sweet

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SIDE TOPICS

- Over-Optimization
  - Likely exists in Regional Configurations
- Differential Analysis
  - Calibration ➔ Base Case ➔ Scenarios
- Seasonal Issues
  - Summer/Winter (specifications, pricing, sup/dem)
- Marginal Value Analysis
  - “Marginal values are reported for a reason … use them”

REFINERY CRUDES & CUTS

- Swing Cuts
  - Optimize operations; Simplifies code & logic
  - Naphtha/Jet; Jet/Diesel; Diesel/VGO
- Stream Pooling
  - Stream ABC + Stream XYX = Pool PF#
  - LP model tracks qualities & quantities
- Crude Assays
  - Consistent with LP code and Technology database
  - Crude assay data is where the LP begins … Important

MODEL SOPHISTICATION

- Sufficiently complex to answer the question
  - Low End = “Black Box”
  - High End = “Process Simulator” derived: Base & Delta-shifts

STRAIGHT RUN (SR) FEEDS	HYDROTREATED (HDT) FEEDS
HIGH CONVERSION BASE VECTORS (MAX GASOLINE)	
HC FCC Base	HC FCC Base
HC FCC High	HC FCC High
HC FCC Low	HC FCC Low
LOW CONVERSION BASE VECTORS(MAX DIESEL)	
LC FCC Base	LC FCC Base
LC FCC High	LC FCC High
LC FCC Low	LC FCC Low
SHIFT VECTORS	
SR Feed Sulfur	HDT Feed Sulfur
SR Fd Nitrogen Shift	HDT Fd Nitrogen Shift
SR Fd Density Shift	HDT Fd Density Shift
SR Feed CCR Shift	HDT Feed CCR Shift
SR MBP Shift	HDT MBP Shift
SR Diesel Shift	HDT Diesel Shift

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TECHNOLOGY DATABASE

- Generalized Database
  - Starting point for all models; Average operations
- Robust & Agile
  - “Look around the corner” using shifts to handle a range of operations (Lt Sweet to Hvy Sour)
- Recursive Pooling
  - Enhances LP code, crude assays & cutting, logic, & analysis
- Evergreen
  - Maintenance is necessary

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PRODUCT BLENDING

- Average Quality
- Gasoline Blending – CG, RFG, Oxy, Reg, Prem, BOB's
  - Non-Linear: RVP, Octane, Distillation (V/L, DVI)
  - Complex Equations
  - Linear: Olefins, Sulfur, Aromatics, Bz, Density
- Distillate Blending
  - Non-Linear: Viscosity, Flash, Freeze, Pour, Cloud
  - Linear: Cetane, Sulfur, Density

INDUSTRY EVOLUTION

- How to Model Expansion & Investments
  - The Refinery LP Model CAN optimize investments
  - A Little Guidance is Recommended
  - Combine Qualitative & Quantitative Techniques
  - Generic Configurations well-suited for new process technologies
  - Regional Configurations

MARKET, CRUDE PRICE & PRODUCTON

- We use off-line models to forecast:
  - Crude, other feed & product prices (gross margin)
  - Variable consumptions (variable margins)
  - THEN, analyze exogenous forecast with LP models
    - Including Marginal Value Analysis (ex: ULR, ULP)
  - Quantitative Risk Analysis
- World Marker Price (WTI, LLS, Brent)
- Upstream production models add value

OTHER TOPICS

- Transparency & Stability
  - Transparency & documentation is critical
  - Stability often boils down to code
- Size & Complexity
  - US Demand Model ~ 25K Rows 25K Columns
    - » Solve Time > 20 minutes
  - Hvy Sour Coking Model ~ 5K Rows, 5K Columns
    - » Solve Time < 1 minute
- Flexibility
  - Generalized Database as starting point

LOW CARBON FUELS STANDARD (LCFS)

- CO_2 loadings
  - Crude CO_2 loadings (off-line analysis to feed LP input)
  - Product CO_2 loadings
  - Refinery CO_2 loadings from operations (FCC, H_2, Fuel Burn)
- LP can accommodate CO_2 price (tax) and tiers to optimize operations

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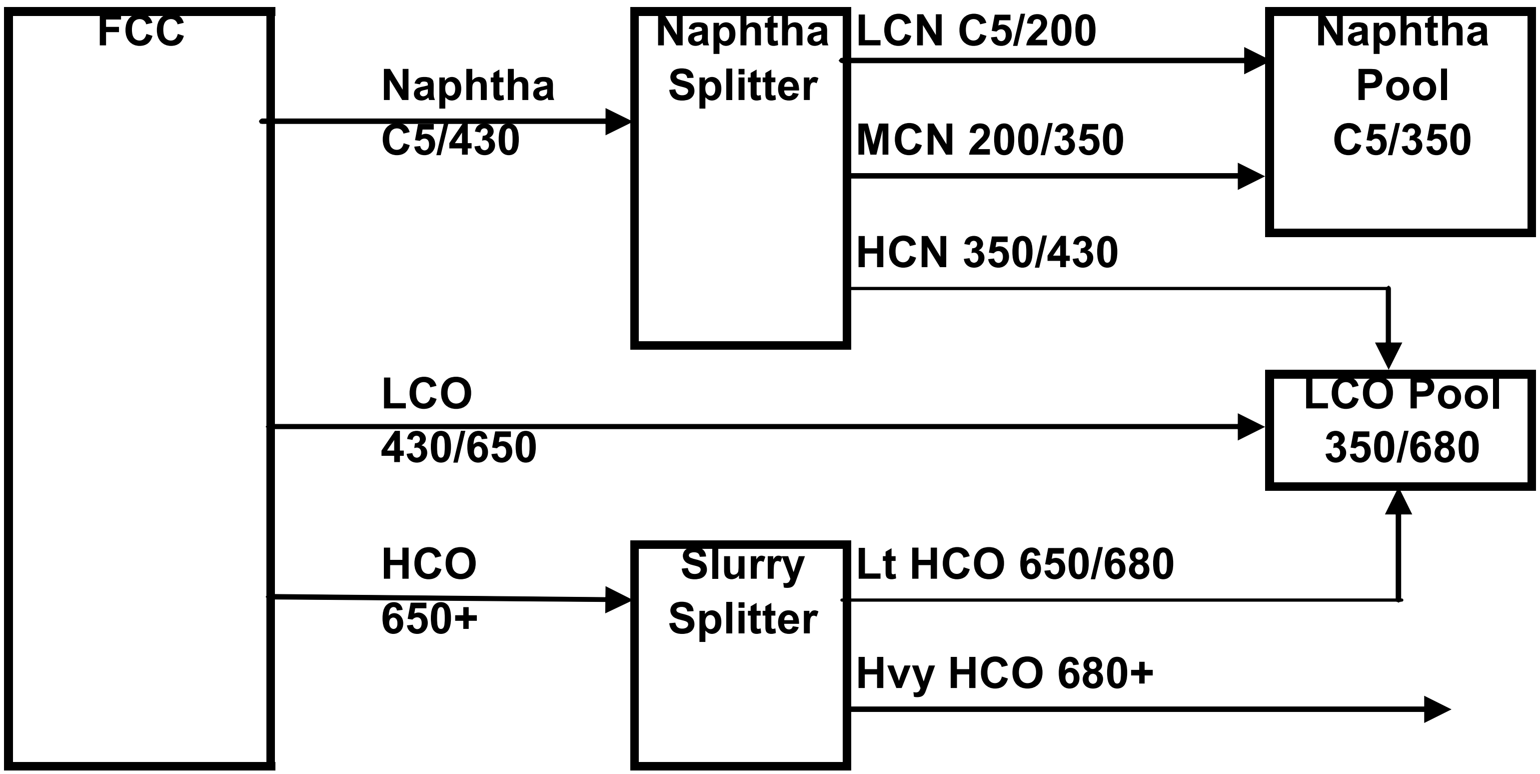
Maximum Diesel

- Swing Cuts
  - Naphtha/Jet; Jet/Diesel; Diesel/VGO
- Downstream Splitters
  - FCC Naphtha
  - Coker Gasoil
  - FCC Slurry
- Catalyst Changes
- Capital Changes (Mild HYK, Severe HYK)

Diesel Maximization; Splitters; Swing Cuts



FINAL TOPICS

- Declining heavy fuel oil demand
  - Qualitative & Quantitative analysis including robust technology database
- International liquids market representation
  - Qualitative & Quantitative analysis
  - Off-line assessment + LP assessment
- Refinery Cost Issues
  - Fuel Use, Energy Efficiency
  - Simulate High, Average, and Low refinery efficiencies

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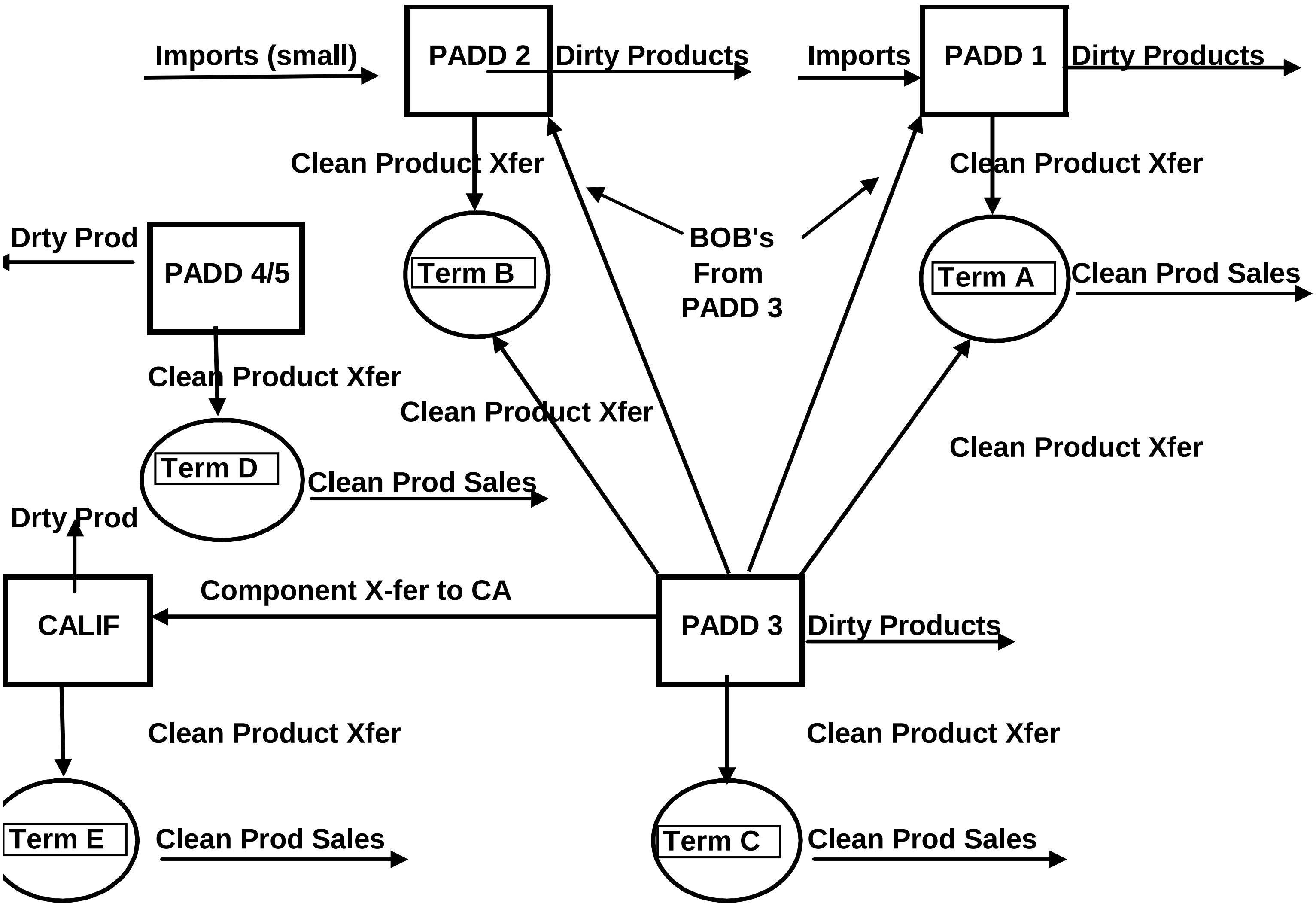
APPENDIX SLIDES

DIVITA'S DOGMAS for RUNNING LP's

- Unless building a nuclear device, ensure you have a material balance
- Banish "the LP said so" from your vocabulary
- The LP dilemma: too much detail can be chaotic…too little detail can be catastrophic
- Shadow prices and marginal values are reported for a reason…use them
- Correlation does not mean causality, AND regression without reason is unacceptable
- The LP will always find an answer
- The LP will turn the world upside down for a penny
- LP's are premise laden and assumption driven
- Before you run an LP, define the question
- GIGO
- A fractionator or splitter must quality balance
- LP studies observe the 80/20 rule…know when to quit
- Formal LP training school will NEVER replace the school of hard knocks…Experience Counts
- Most refinery LP's are least cost producers of octane
- Never calculate economics with an LP when a spreadsheet will do
- Stay focused on the goals you seek with the LP
- The LP is an economic tool, not a simulator
- LP users must be good translators
- The volumetric sum of marginal values for products across a process unit should exceed the feeds
- Determine what is driving the bus
- Don't change too much at once
- Anticipate the results from successive runs
- Gasoline recipes and limits on RFG/premium help convergence
- Watch volume gains and weight balances
- Sub-optimal solutions do appear in LP's
- Don't worry about convergence until it counts

Large US Regional Supply/Demand LP Model



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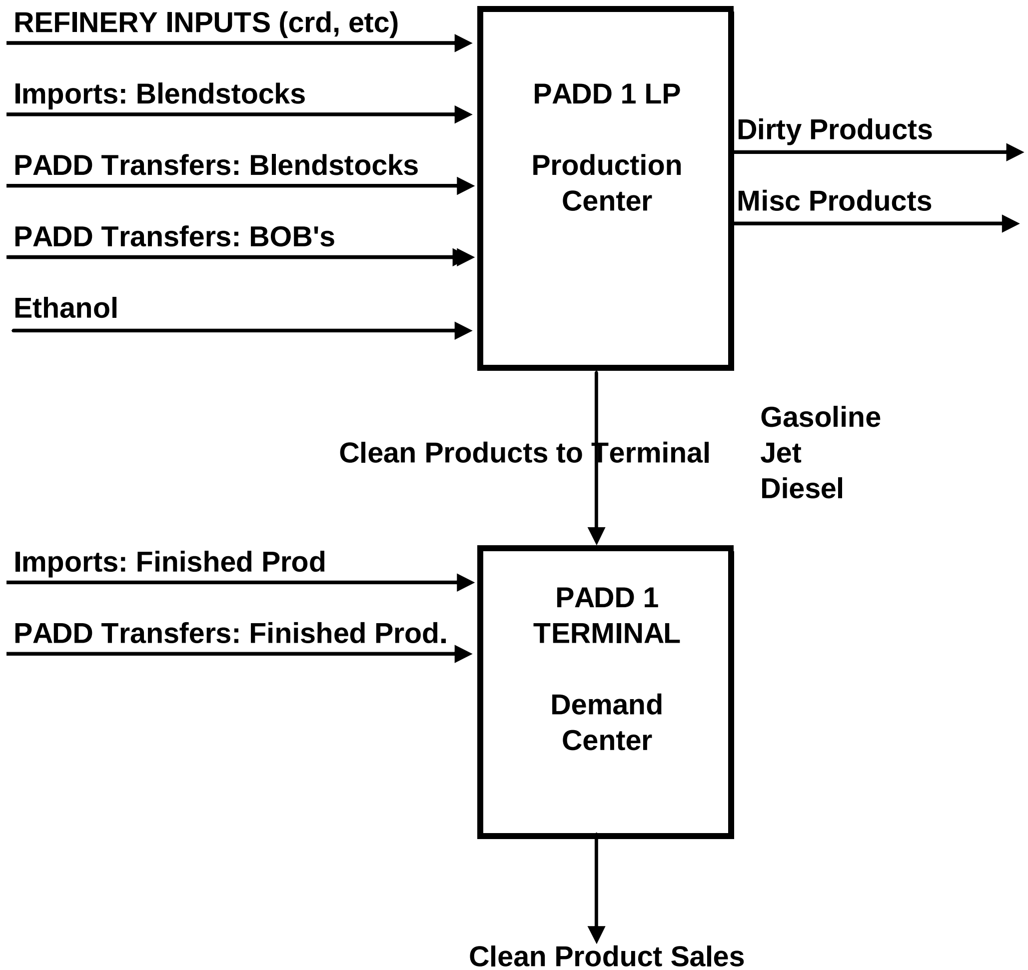
Regional Demand Center



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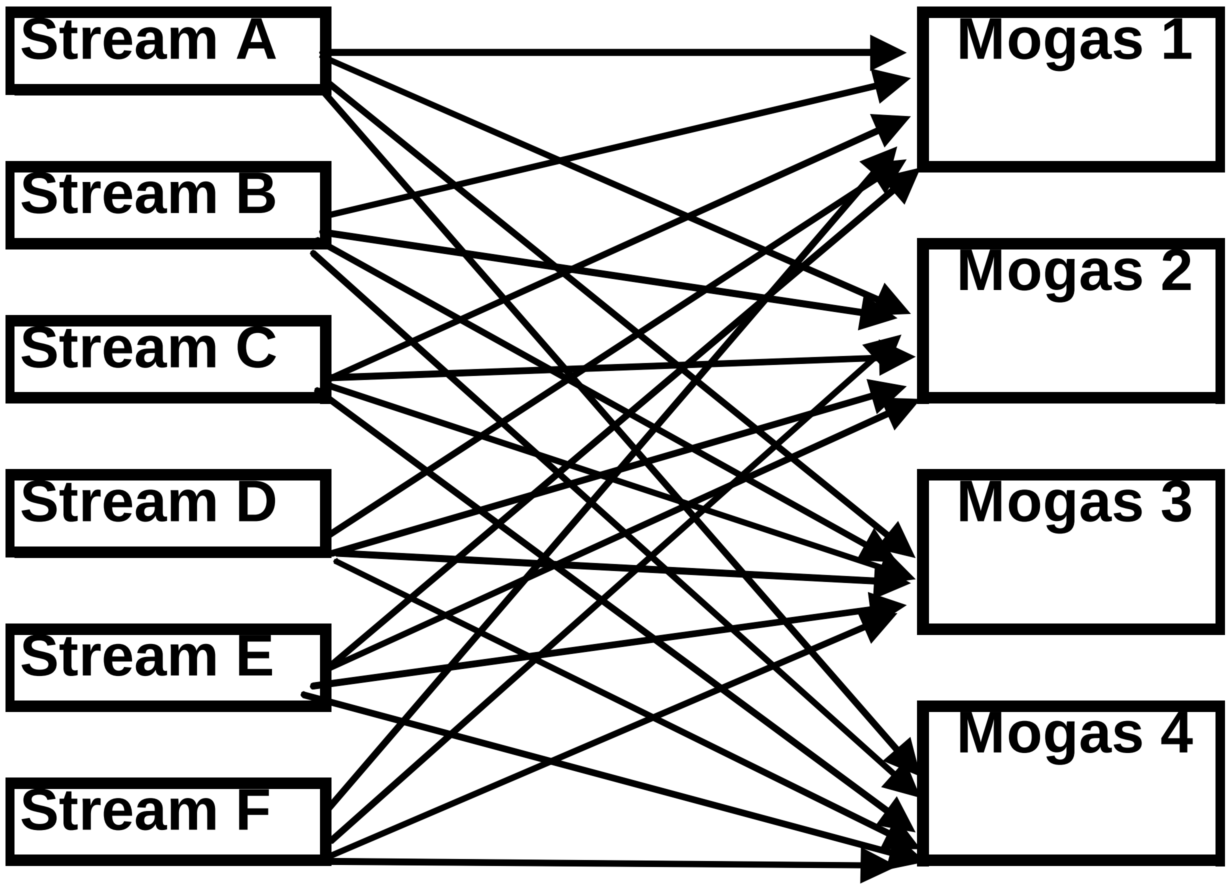
Too much detail can be chaotic ...



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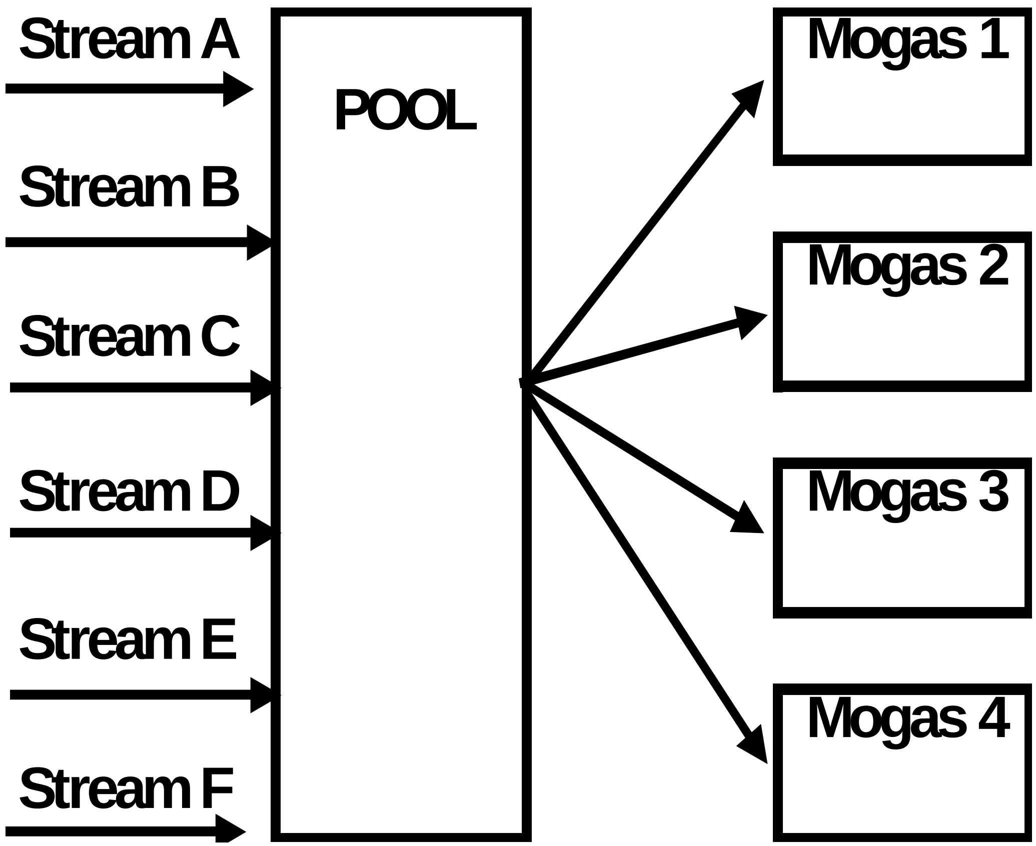
Simplified, but not catastrophic



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EXAMPLE: STREAM QUALITIES

QUALITY	Lt Lt St Run Naphtha	Lt St Run Naphtha	Hv St Run Naphtha	Nap / Kero Swing	St Run Kero	Kero/ Dsl Swing	St Run Diesel	St Run AGO	Atm Resid	LVGO	HVGO	Vac Swing	Vac Resid
All Streams													
Specific Gravity	1	1	1	1	1	1	1	1	1	1	1	1	1
Sulfur, wt%	1	1	1	1	1	1	1	1	1	1	1	1	1
Sulfur, wppm	1	1	1	1	1	1	1	1	1	1	1	1	1
Heat Content (MMBTU/Bbl)	1	1	1	1	1	1	1	1	1	1	1	1	1
Molecular Weight	1	1	1	1	1	1	1	1	1	1	1	1	1
Gasoline Streams													
Reid Vapor Pressure, psi	1	1	1	1									
V/L	1	1	1	1									
Research Octane No	1	1	1	1									
Motor Octane No	1	1	1	1									
Road Octane No	1	1	1	1									
Dist: T10	1	1	1	1									
Dist: T50	1	1	1	1									
Dist: T90	1	1	1	1									
Driveability Index	1	1	1	1									
Dist: % Evap at 200F	1	1	1	1									
Dist: % Evap at 300F	1	1	1	1									
Benzenes, vol%	1	1											
Benzene Precursor Index	1	1	1	1									
Napthenes	1	1	1	1									
Oxygen, wt%	1	1	1	1									
Alcohol, Vol%	1	1	1	1									
Gasoline/Distillate Streams													
Parrafin	1	1	1	1	1	1	1	1					
Olefins, vol%	1	1	1	1	1	1	1	1					
Aromatics, vol%	1	1	1	1	1	1	1	1					
Distillate & Heavier Streams													
Freeze Point, degF				1	1	1							
Cetane Index D976				1	1	1	1	1					
Cetane Index 4737-A				1	1	1	1	1					
Cetane Index 4737-B				1	1	1	1	1					
Pour Point, degF				1	1	1	1	1					
Cloud Point, degF				1	1	1	1	1					
Flash Point, degF				1	1	1	1	1	1	1	1	1	1
Viscosity, CST at 122F				1	1	1	1	1	1	1	1	1	1
Viscosity, CST at 210F				1	1	1	1	1	1	1	1	1	1
Vanadium, wppm								1	1	1	1	1	1
Nickel, wppm								1	1	1	1	1	1
Naphthenic Acid kOH/mg				1	1	1	1	1	1	1	1	1	1
Concarbon								1	1	1	1	1	1
Nitrogen or Basic Nitrigen								1	1	1	1	1	1
FCC crackability (user defined)								1	1	1	1	1	1

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Examples: Swing Cuts & Stream Pools

- Swing cuts & stream pools are designed into LP code

Swing Cut Example

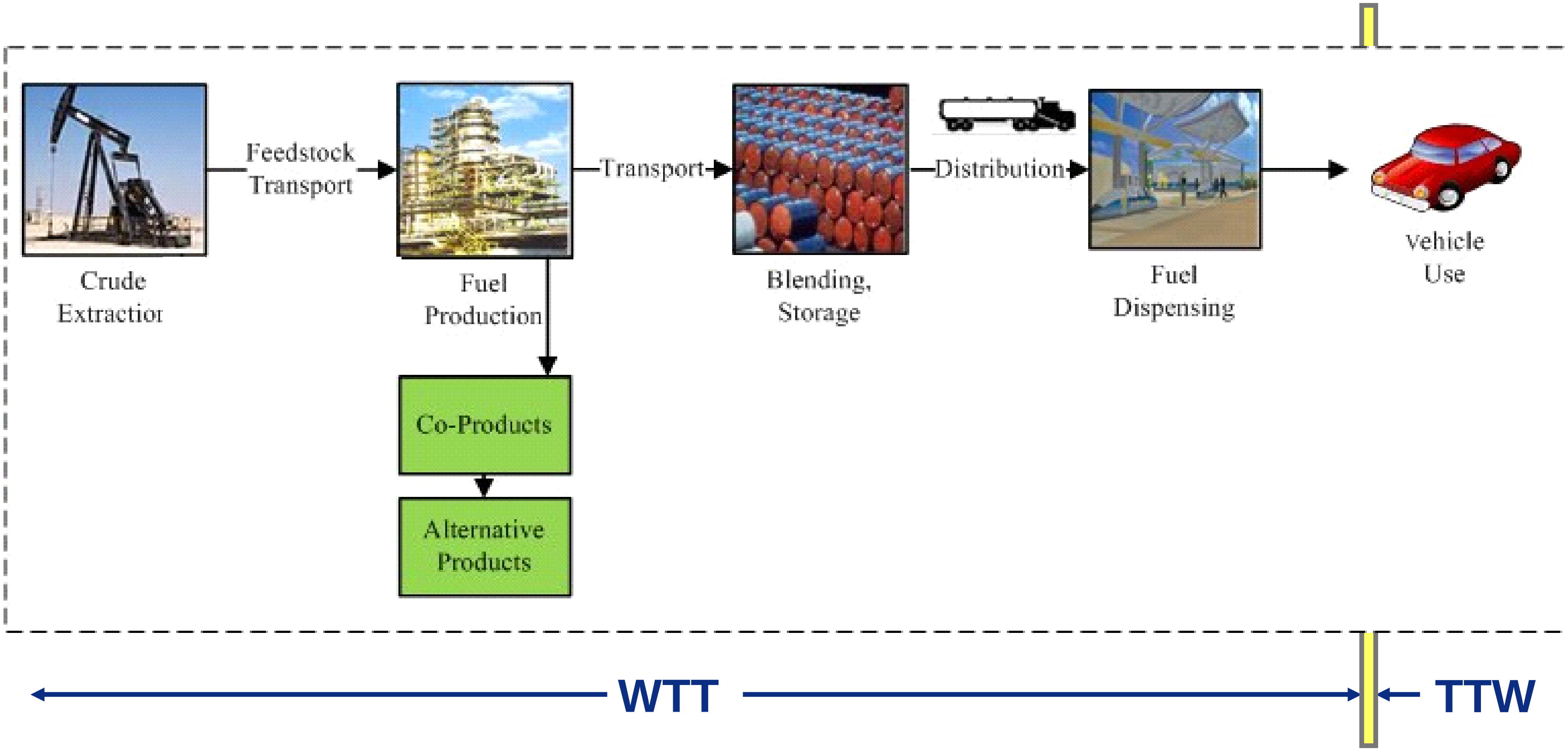
	Initial BP (F)	Final BP (F)	
Light Straight Run	49	160	
Lt Naphtha	160	220	
Hvy Naphtha	220	350	
Naphtha/Kero Swing	**350**	**400**	**Swing**
Kerosine	400	525	
Kero/Diesel Swing	**525**	**550**	**Swing**
St Run Diesel	550	650	
St Run Atm Gasoil Swing	**650**	**690**	**Swing**
LVGO	690	850	
HVGO	850	1000	
Vacuum Resid Swing	**1000**	**1025**	**Swing**
Atm Resid	690+		
Vacuum Resid	1025+		

	Crd #1	Crd #2	Pool	Pool AGO swing
Percent	50%	50%	100%	
BPD	50,000	50,000	100,000	
				50/50
Crude Vol%	Vol%	Vol%	Vol%	
SR Diesel	0.1103	0.1071	0.1087	0.1391
AGO	0.0567	0.0647	0.0607	
LVGO	0.0948	0.1296	0.1122	0.1425
Crude MBPD				
SR Diesel	5,515	5,355	10,870	13,906
AGO	2,836	3,235	6,071	0
LVGO	4,740	6,478	11,219	14,254
Total			28,160	28,160
SpGr				
SR Diesel	0.8425	0.8777	0.8601	0.8653
AGO	0.8681	0.8997	0.8839	
LVGO	0.8909	0.9162	0.9036	0.8994

	DHT in	DHT out
BPD	13,906	13,766
SG	0.8653	0.8497

	CFH in	CFH out
BPD	14,254	13,969
SG	0.8994	0.8664

Well-to-Wheels Life Cycle Assessment



WTW Life Cycle Emissions = WTT + TTW

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