Presenting:

Selecting a Preferred Alternative To Meet Tier 3 Gasoline Requirements

by Rob Lazenby

DAAG Conference 2017

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Selecting a Preferred Alternative To Meet Tier 3 Gasoline Requirements

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Executive Summary

Discussion Topics

- Tier 3 gasoline specs
- Gasoline refining overview
- Focus on two alternatives to reduce sulfur at a specific refinery

Key Messages

Risk assessment takes place continually throughout the DA process

Proper assessment of risk can drive towards a better outcome, and can simplify the analysis required

The “obvious” solution is not always the optimal solution

Desired Outcomes / Decisions

Demonstration of how assessment of risk and development of risk mitigation is a natural component of selecting a preferred alternative.

New Rules Present a Challenge

30 ↘ 10

The Canadian Sulphur in Gasoline Regulations (SiGR), as amended in 2015, lowers the allowable annual average sulphur content of gasoline to 10 parts per million (ppm or mg/kg) from the previous limit of 30 parts per million, beginning in 2017.

Canadian Tier 3 fuel standards are aligned with, but not identical to, those of the United States.

The Opportunity

January 2015 Situation:

The 2014 refinery pool average sulfur content was just under 16 ppm. While this was well below the current 30ppm requirement, it is well above the new 10 ppm standard.

Project Opportunity Statement

Reduce the sulfur content in the gasoline pool to allow the refinery to sustainably and profitably supply the domestic market once the amended SiGR comes into effect.

Profitably	→	resulting operating costs must provide reasonable margins

Sustainably	→	solution must work over extended time horizon, under a variety of circumstances; solution must be robust.

What Happens If Project Fails?

Consequence of Non-compliance

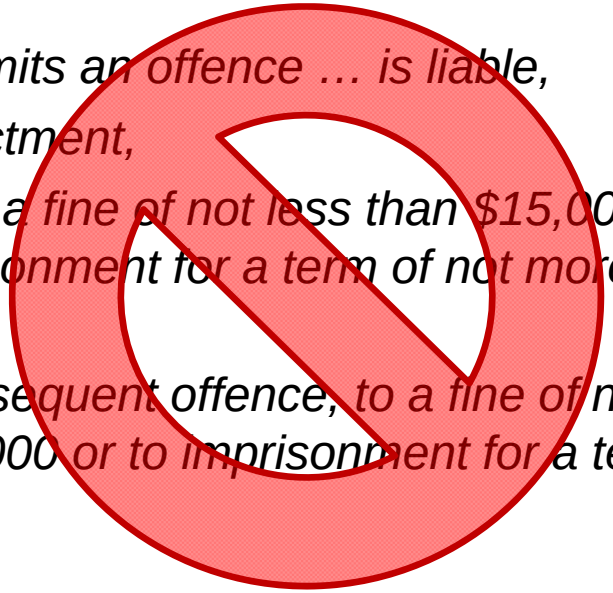
Tier 3 regulations are governed by the Canadian Environmental Protection Act, 1999 (CEPA 1999). Penalties are significant and applied under the criminal code. The Federal Government will act assertively on non-compliance, usually financially but prison is an option.

Every individual who commits an offence … is liable,

(a) on conviction on indictment,

(i) for a first offence, to a fine of not less than $15,000 and not more than $1,000,000 or to imprisonment for a term of not more than three years, or to both…

(ii) for a second or subsequent offence, to a fine of not less than $30,000 and not more than $2,000,000 or to imprisonment for a term of not more than three years, or to both….



Gasoline Refining

Gasoline is a complex mixture of hundreds of chemical compounds, primarily composed of hydrogen and carbon (hydrocarbons).

Gasoline Production

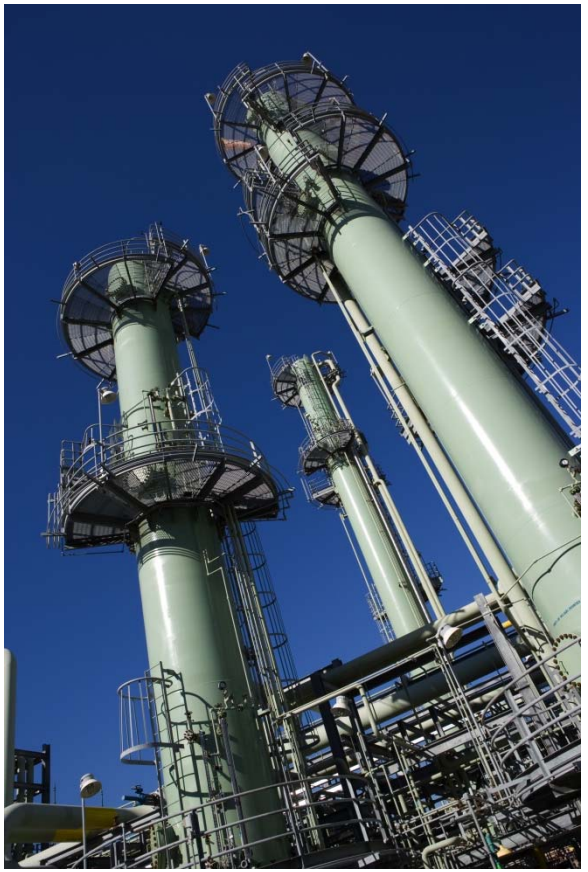
Step 1: isolate gasoline components naturally present within crude oil.

Step 2: convert non-gasoline components into gasoline.

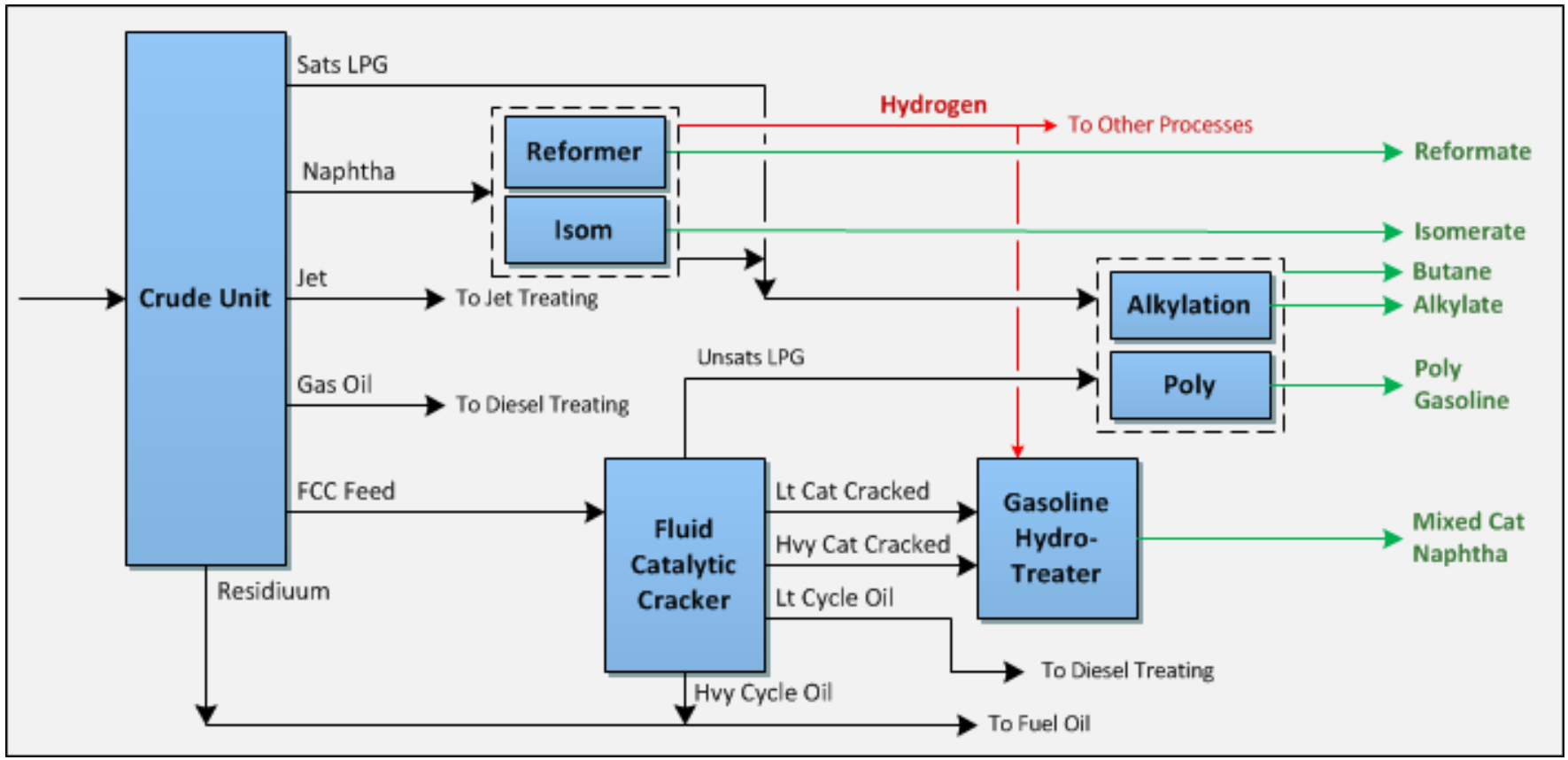
Step 3: alter the gasoline molecules to improve their fuel characteristics.

Step 4: blend the various component streams together to create saleable gasoline products.

Products must meet a myriad of specifications to address performance and environmental concerns.



Gasoline Production Within the Refinery



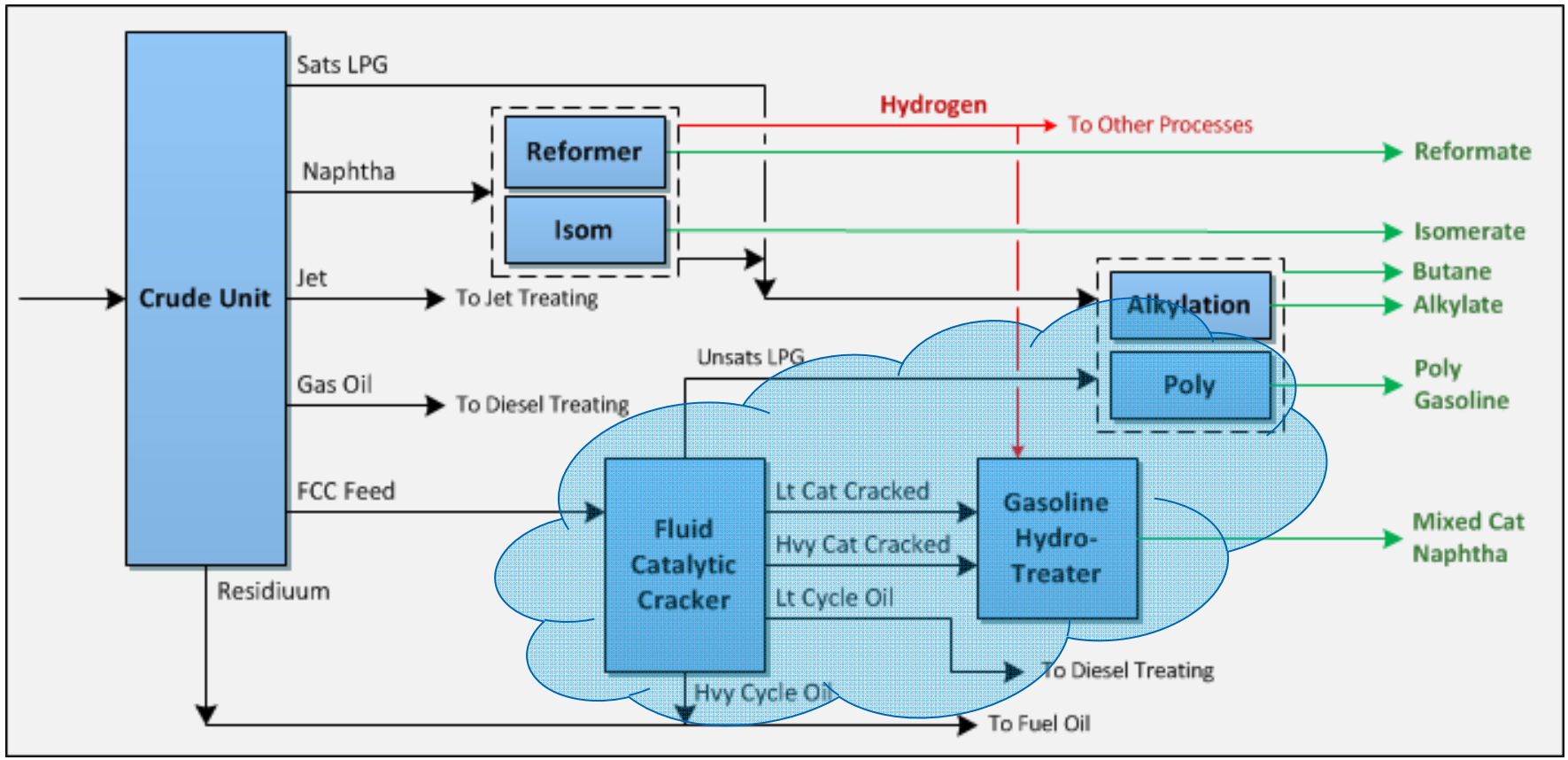
Starting Point: Where Is the Sulfur?

Blend Stream	Portion of Pool (wt%)	S in Stream (ppm)	S Contribution to Pool (ppm)
Butane	4%	6	0.3
Isomerate	17%	0.5	0.1
Reformate	27%	0.5	0.1
Alkylate	8%	20	1.6
Poly Gasoline	2%	90	1.9
Mixed Cat Nap	36%	32	11.6
HOBS*	6%	4	0.2
Total	**100%**		**15.8**

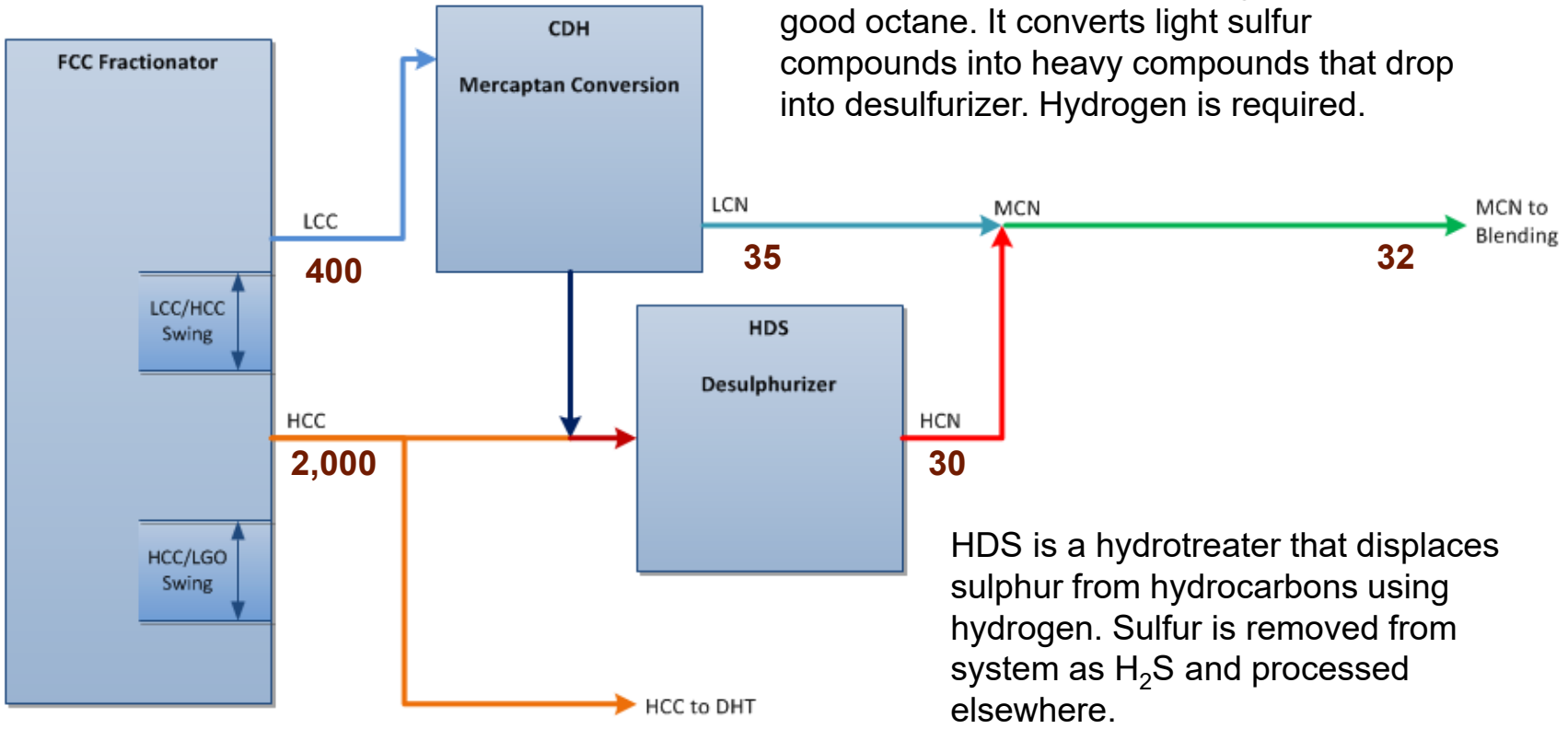
*HOBS = High Octane Blend Stock, a purchased blend component

Note: if MCN was at 10ppm, pool would be 7.8 ppm

Focus on the FCC and GHT System



GHT Operation



CDH is intended to preserve light olefins with good octane. It converts light sulfur compounds into heavy compounds that drop into desulfurizer. Hydrogen is required.

HDS is a hydrotreater that displaces sulphur from hydrocarbons using hydrogen. Sulfur is removed from system as H_2S and processed elsewhere.

Key Risks to be Assessed

- Project Timeline – lead time for large equipment
- Space Requirements (lack of real estate)
- Constructability (working within an operating facility)
- Initial Investment cost
- Continuing operating costs
- Hydrogen availability
- Operational responsiveness
- Sulfur removal guarantees
- Plan for when Reformer is off-line

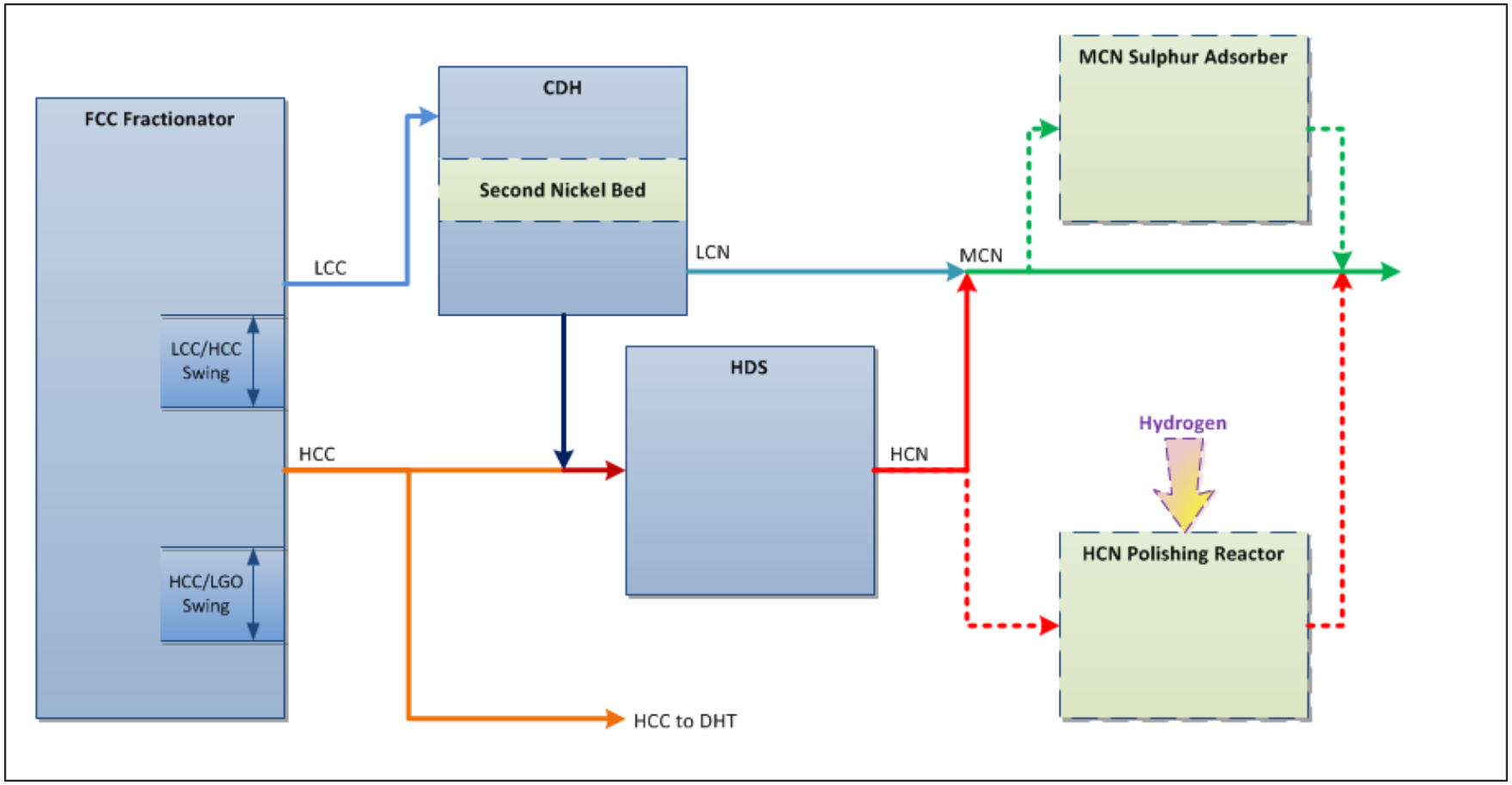
Alternatives Generation

A multi-discipline cross-functional team was assembled to brainstorm, vet and develop alternatives to reduce the total sulfur in the gasoline pool.

Alternatives considered included:

- FCC catalyst reformulation
- Multiple mercaptan (a particular type of sulfur compound) extraction technologies
- LPG Treating upgrades
- Alkylate “polishing”
- **GHT upgrades**
- **Sulfur adsorption on MCN stream**

Tier 3 GHT Finalists



Both alternatives have new catalyst bed in CDH as common element to lower LCN sulphur to 10 ppm.

Initial Concept: “Polishing” Reactor for HCN

- The GHT facility was originally designed (in 2000) with provision to include a “polishing” reactor to reduce HCN sulfur from 30 ppm to 10 ppm.
  - This was the presumed solution when Tier 3 work commenced.
- Additional hydrogen is required.
  - Does not vary significantly with sulfur removal.
- Discussions with vendor revealed additional scope required to guaranteeing 10ppm:
  - 13 new pieces of equipment, some with a long lead time requirement.
  - Resulting facility is quite large, requiring significant plant space created by demolishing existing out of use equipment.
  - HCN is only portion treated.
- Recent operational challenges within the CDH system has reduced confidence in the ability to sustain low sulfur LCN.

The Contender: MCN Adsorber

adsorption
the adhesion in an extremely thin layer of molecules (as of gases, solutes, or liquids) to the surfaces of solid bodies or liquids with which they are in contact
- Merriam-Webster dictionary

- Re-purpose some existing treaters (currently out of service) to treat MCN using an adsorbent to remove mercaptans, sulfides, and desulphides.
  - Bench tests in Chevron research lab generated excellent results.
- Sulfur content of the processed stream is effectively zero until saturation.
  - Adsorbent life depends upon the amount of sulfur in feed stream.
- Treaters may be bypassed if sulfur levels are acceptable.
- Adsorbent is removed and trucked off-site for reprocessing when spent.
- Re-use of existing plant equipment results in small capital investment, small plot space, and short implementation cycle requirements.

DA Model

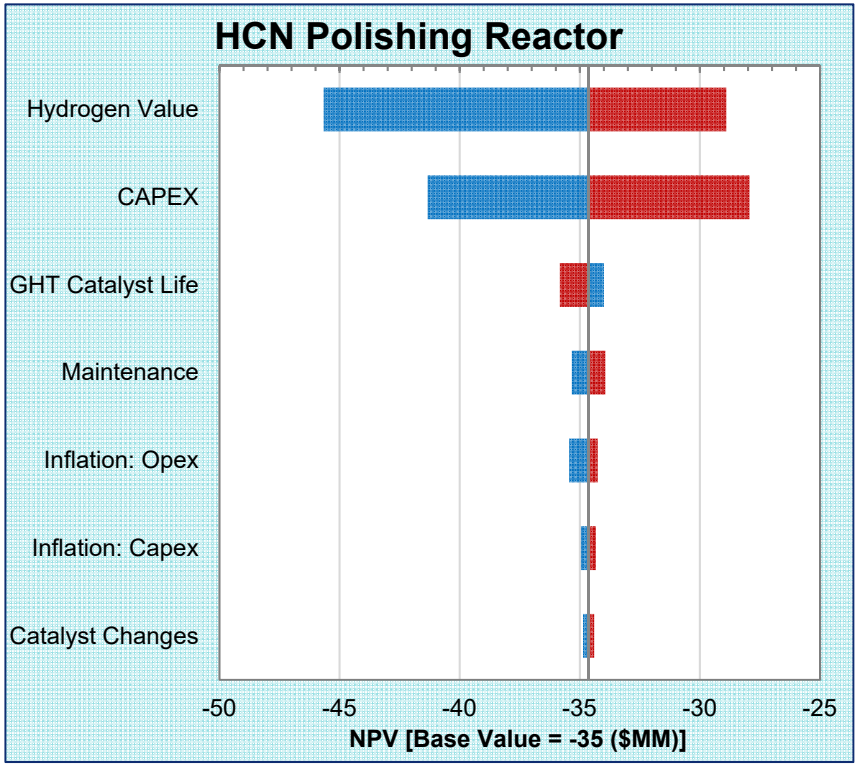
Original Intent

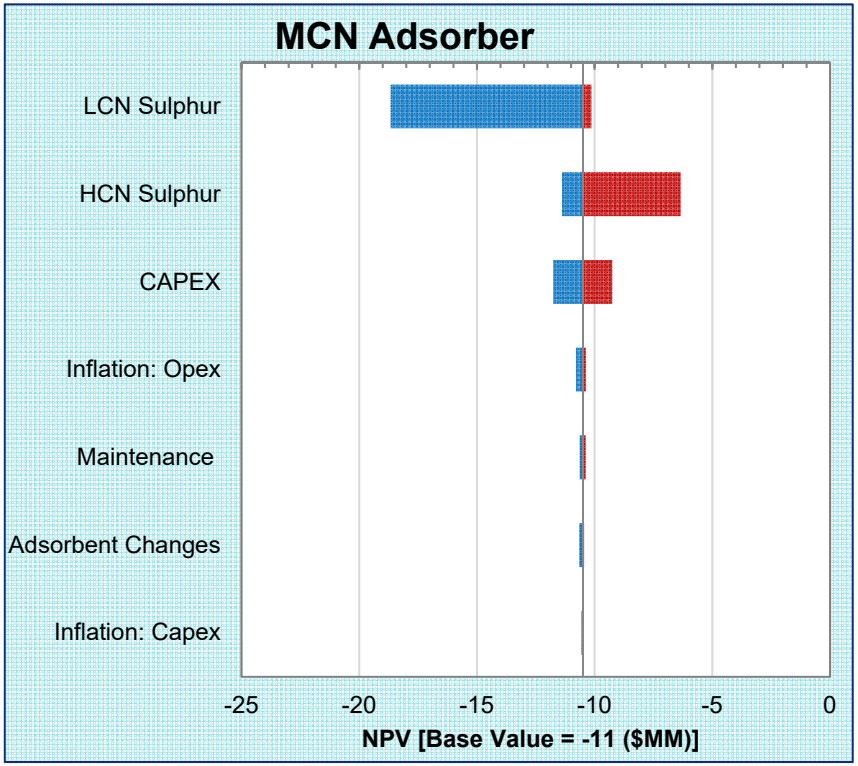
- Use Refinery LP (linear program) to generate detailed refinery stock shifts to value impact of alternatives:
  - changes in hydrogen use
  - changes in product yield (gasoline vs. diesel)
  - changes in properties (octane)
  - etc.
- Prior to generating LP, model will be validated against plant data within new operating regime.
- DA model would also include key parameters to test assumptions for their impact on economics.

Developments

- Validation work led to insights and improved LP for routine use.
- Adsorbent alternative has zero impact of refinery stock balance, so need to incorporate detailed stock shifts from model was eliminated, dramatically simplifying modelling and analysis.

DA Modelling - Results





Potential variability in MCN Adsorber costs pale compared to those associated with HCN Polishing Reactor.

Risk Assessment

Measure	HCN Reactor	MCN Adsorber
Timeline		
Plant Space		
Initial Investment		
Continual Opex		
Hydrogen		
Responsiveness		
Constructability		
Sulfur Removal		

The MCN Adsorber alternative scores better on all risk dimensions, subjective and quantified.

Recommended Solution: MCN Adsorber

MCN Adsorber Solution Has Many Compelling Facets

- Lower initial investment.
- No incremental hydrogen required.
- Re-use of existing facilities.
- Simple operation.
- Treats entire MCN, not just HCN.
- Biggest uncertainty is operational stability of GHT; GHT solution place all eggs in that basket.
- Focus on existing refinery operation may lead to minimal need to run adsorber.

Benefits From Application of DA Practices

- Structured brainstorming of alternatives led to unanticipated recommendation.
- Quest for meaningful data improved understanding of plant operation and simplified analysis requirements.
- Understanding risks in project provides focus and improves ultimate alignment.

Questions?