Bitumen Upgrader Residue Conversion to Incremental Synthetic Fuels Products

Technical Paper

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Introduction

During recent years there has been a significant change in market conditions affecting the oil and gas industry in North America. The introduction to the marketplace of natural gas from new sources has decreased the price of gas relative to crude oil and this is expected to continue well into the future. This change in marketplace conditions creates exciting new opportunities to maximize the benefit of "cheap" gas to produce value-enhanced liquid products using gas to liquids technology. One area where this can be of great importance is in bitumen upgrading and refining and, in particular, the effective utilization of the hydrogen-deficient asphaltenes produced in the upgrading process.

This paper discusses the use of a new process, FTCrude®, to convert the asphaltenes to synthetic fuel products using existing, commercially proven, technology. The process utilizes a combination of gasification, reforming and Fischer-Tropsch synthesis to produce high value naphtha, diesel and gas oil products. The economics of FTCrude® over a range of natural gas and crude oil price scenarios is also discussed.

Current Bitumen Upgrader Concepts

As is well known, bitumen is the heaviest, thickest form of petroleum: it is highly deficient in hydrogen and it does not flow at normal pipeline temperatures. In most instances it has to be mixed with lighter hydrocarbons (diluents) before it can be transported by pipeline for upgrading into synthetic crude oil and refined products. Bitumen upgraders can generally be defined in two categories:

- Carbon rejection types
- Hydrogen addition types

In both instances the hydrogen deficiency, in addition to sulphur, nitrogen and heavy metals removal, is corrected through the upgrading process and synthetic crude oil typically consisting of naphtha, diesel and gas oil can be produced.

Upgraders can either be located in relatively close proximity to the bitumen source (mine or an in situ reservoir) or be remote from the source and connected by a pipeline supplying diluted bitumen.

Carbon rejection is inherently inefficient and wasteful in most cases (significant volumes of petcoke are produced). Hydrocracking processes, which add hydrogen, offer higher liquid yields, better distillate qualities and low sulphur emissions, but at higher expense. Remote upgraders generally, with practically no exception, are of the hydrogen addition type.

The two latest bitumen upgraders in Alberta (Nexen Long Lake and North West Upgrader) use the hydrogen addition process. Using this approach, regardless of the ultimate hydroprocessing process configuration, there is always an unconverted residue. There are two basic options to utilize the unconverted residue:

- Gasification and syngas conversion to hydrogen to satisfy upgrader requirements.
- Gasification and syngas conversion to additional synthetic fuels.

The choice between these two options is primarily dependent on the natural gas/crude oil price relationship. During the planning stage for the above mentioned upgraders commodity prices were in the range of $8/mmbtu for natural gas and $40/bbl for crude. Under this pricing scenario the hydrogen generation option can be economically justified.

Block diagrams Figure 1 and Figure 2 illustrate the Nexen and Northwest concepts.

Upgrader configuration reflecting current natural gas/crude oil pricing

Would the hydrogen addition upgrader configuration change today? Today's commodity price environment is significantly different and prices are in the range of $3/mmbtu for natural gas and >$90/bbl for crude. Under this pricing scenario the residue conversion to additional synthetic fuels makes compelling economic sense and should therefore be considered.

In this concept, an unconverted residue can be gasified to syngas and additional synthetic fuels can be produced through Fischer-Tropsch (F-T) syngas synthesis. The F-T process produces primarily paraffinic naphtha and highly valuable sulphur and aromatics free diesel fuel with typical Cetane Numbers in excess of 70. Hydrogen required for the upgrader is produced through standard Steam-Methane Reforming (SMR) using "cheap" natural gas as feedstock.

Along these lines, Expander Energy, with the assistance of WorleyParsons, developed the FTCrude® concept. This concept is based on incremental synthetic fuels production utilizing gasification of upgrader residue and reforming of natural gas, followed by F-T synthesis.

Syngas originating from gasification of a high carbon-content feedstock, e.g. bitumen residue, is by definition hydrogen deficient and is not directly suited for F-T synthesis because it does not have the required stoichiometric H2/CO ratio. Therefore, in addition to the standard gasification/syngas/F-T synthesis configuration, FTCrude® also includes hydrogen enrichment of syngas. Hydrogen rich syngas is produced through a standard Steam-Methane-Reforming (SMR) process using natural gas, LPG, RFG, naphtha etc., as feedstock. The referenced SMR in addition to enriching the syngas provides sufficient amount of hydrogen for the bitumen upgrader as well as for the F-T products upgrade. A common SMR is typically used and provides high reliability of syngas and pure hydrogen for the Upgrader needs.

In addition to the economic advantages, there are other inherent benefits to this concept:

- Upgrader operation is critically dependent on a reliable source of hydrogen. In this concept hydrogen is produced from a highly dependable source (SMR) as opposed to a relatively low reliability gasification operation.
- There are major reductions in CO_2 emissions. In this concept no full Gas-Water-Shift (GWS) is required and this is a major source of CO_2 emissions in the hydrogen through gasification case

The FTCrude® concept has been patented and the intellectual property is exclusively owned by Expander Energy. The FTCrude® employs for all processing steps, proven and commercially viable technologies. As a result there is very limited technical risk. A simplified block diagram illustrating the FTCrude® concept is presented in Figure 3.

FTCrude® Case Study

Contracted by Expander Energy, WorleyParsons has developed a process design for an integrated bitumen upgrader/FTCrude® system with an upgrader capacity of 50,000 bpd of neat bitumen feed. In one, preferred configuration, the upgrader process is based on hydrocracking of deasphalted oil and vacuum gas oil and hydrotreating of straight run and hydrocracked naphtha, diesel and gas oil. The FTCrude® section takes asphaltenes from the upgrader as feed to a gasifier to generate syngas. A SMR provides additional hydrogen rich syngas for the F-T synthesis. The SMR is a combined service to provide sufficient hydrogen for the bitumen upgrader and F-T product upgrading. Based on 50,000 bpd of neat bitumen feed to the upgrader, 47,300 bpd of 30 API SCO, 1,700 bpd F-T naphtha and 11,400 bpd F-T diesel is produced. To achieve this production 98 mmscfd of natural gas is used for the combined SMR.

About 60,400 bpd of 35 API SCO is produced when the F-T products are included. This represents approximately 121% volumetric yield on bitumen. The table below summarizes the overall material balance for the study case:

Feed Streams	mmcfd	bpd	kg/hr
Bitumen (excluding Diluent)		50,000	334,560
Natural Gas	98		78,090
Steam (SMR)			179,722
Oxygen (POX)			45,526
Steam (POX)			25,292
Total Feed Streams			**663,190**

Product Streams & Effluents	mmcfd	bpd	kg/hr
Upgrader			
Naphtha		2,625	13,234
Diesel		22,014	125,421
Gas Oil		22,653	136,301
FTCrude			
Offgas	41.1		52,033
LPG		542	2,392
Naphtha		1,715	7,798
Diesel		11,412	57,899
Process Water		13,023	87,519
SMR Condensate		17,310	116,352
CO_2	11.1		24,306
Other Effluents by Difference			39,935
Total Product Streams & Effluents			**663,190**

Rough Order of Magnitude (ROM) capital costs for this integrated case installed in Northern Alberta were estimated to be in the range of $4.5 to $5.5 billion or about $75,000/bpd to $90,000/bpd of total SCO blend subject to level of contingency.

It should be noted that the capital costs include the Upgrader and FTCrude process areas as well as Utilities & Offsites as a full Total Installed Cost (TIC). Oxygen supply for the gasifier is considered to be over the fence and as such the Oxygen Plant capital costs are not included.

FTCrude® Economics

WorleyParsons used its EcoNomics® Comparative Assessment tool to assess the economic robustness of the FTCrude® concept. The first chart, Figure 4, presented below indicates IRRs for the Base Case for three natural gas prices, namely $3, $6 and $12 per million btu as a function of crude oil prices. It can be seen that negative NPVs can only be observed at very low crude oil prices. The probability for these very low crude oil prices, based on numerous long term forecasts is equally very low. Consequently, assuming longer term crude oil prices being in the range of $90 to $110/bbl, the FTCrude® concept can be considered economically robust and be able to tolerate significant increases in natural gas prices in the $6 to $10/mmbtu range.

Using the same tool an analysis was made to identify a balancing "sweet spot" between the upgrader hydroprocessing and FTCrude® section conversion capacities. As the economics are very sensitive to diesel prices, a range of diesel price assumptions are analysed along with a range of natural gas and SCO prices.

The interface between the bitumen upgrader and the FTCrude® unit is downstream of the solvent de-asphalting (SDA) unit. The SDA produces de-asphalted oil (DAO) and asphaltenes and the asphaltenes are sent (via intermediate storage) to a partial oxidation (POX) unit (gasifier). The operation of the SDA controls the volume and properties of the feed to the gasifier and subsequently controls the balance point between the bitumen upgrader and the FTCrude® unit. Two main cases were compared. One case, Case 2, represents a minimum throughput and highest DAO quality feed for the hydrocracker with a majority of the asphaltenes being fed to the gasifier in the FTCrude® section. The minimum FTCrude® case, Case 1, is the opposite with a low percentage of asphaltenes being fed to the gasifier, maximizing DAO feed to hydrocracker.

The following are the basic parameters for the two cases, based on vacuum residue feed to SDA unit:

		Case 1	Case 2
DAO yield	%	73	58
DAO flow to HDCR	bpd	20,126	16,296
Asphaltenes to POX	bpd	6,286	10,116

Both cases are compared on the same project return as a function of natural gas and crude prices. The results are presented in the Figure 5. At the current crude oil price range of $90 to $95/bbl natural gas prices below $14/mmbtu favour the maximum F-T route (Case 2).

FTCrude® Opportunities

The FTCrude® concept can be applied in a wide variety of facilities such as an existing upgrader that produces asphaltenes, unconverted hydrocracked residue or petcoke or in any heavy crude refinery producing asphalt or heavy fuel oil as unconverted residue. In the North American context of low natural gas and high crude oil prices the opportunities are numerous. Because of the demonstrated tolerance of the FTCrude® concept to relatively high natural gas prices, this concept can be applied in many places in Europe and Asia as well.

Immediate opportunities, in Alberta, include retrofitting the existing Nexen Long Lake Upgrader or the NorthWest Upgrader that is currently being designed and ready for construction. The design of both upgraders includes gasification of residues to generate hydrogen. There also will be opportunities in some European refineries which currently process heavy crudes and focus on diesel and seasonal asphalt production as primary products.

Because of the high carbon retention inherent to the FTCrude® concept there is obviously significant reduction in carbon dioxide emissions compared to other technologies as well. The reduction in greenhouse gas emissions is an additional driver for retrofitting existing facilities.

Last, but not necessarily least, the FTCrude® concept will increase the reliability of operation for hydrogen addition upgraders since hydrogen production is shifted from a less reliable operation (gasification) in the plant to highly reliable and industry proven SMR technology.

The FT Crude® Technology can be configured in three main process arrangements:

1. ***FTCrude® Partial Upgrader*** - used to convert bitumen to bottomless 20 to 24 API gravity Partially Upgraded Bitumen (PUB) with significant reduction in sulphur, heavy metals, naphthenic acid (TAN) and Conradson Carbon (CCR) , having preferred chemical and physical properties suitable for pipelining (without diluent) and refining, exceeding current WCS quality specification.
2. ***FTCrude® Full Upgrader -*** used to convert bitumen to Sweet Synthetic Crude Oil (SCO) with 35 to 40 API gravity and 50+ cetane diesel fraction, exceeding current Alberta SCO specification.
3. ***FTCrude® Refinery -*** used to convert bitumen to full specification refined products such as gasoline (ULSG), high cetane diesel (ULSD) and jet fuel (ULSJ).

In summary the FTCrude® concept offers the following advantages when employed in a hydrogen addition upgrader and compared to the residue gasification for hydrogen route only:

- Major economic advantage at current and future forecasted natural gas/ crude oil price relation
- Increased operational reliability
- High feedstock carbon retention thus lower CO_2 emissions
- Improved flexibility and marketability of products.

Summary and Conclusions

- Under current and medium term forecasts for natural gas and crude pricing, residues conversion to incremental synthetic fuels rather that to hydrogen production is economically attractive.
- The FTCrude® concept is economically very robust for a wide range of natural gas and crude oil prices.
- FTCrude® concept can be used for partial and full bitumen upgrading as well as for a complex bitumen refinery producing high quality transportation fuels (gasoline, jet fuel and diesel).
- FTCrude® employs, for all processing steps, proven and commercially viable technologies. As a result there is very limited technical risk.
- The FTCrude® concept provides significant improvements in SCO yields, operational reliability, and carbon conversion efficiency (> 90% conversion) resulting in sizeable reduction of CO_2 emissions.

List of Figures

Nexen Long Lake Upgrader

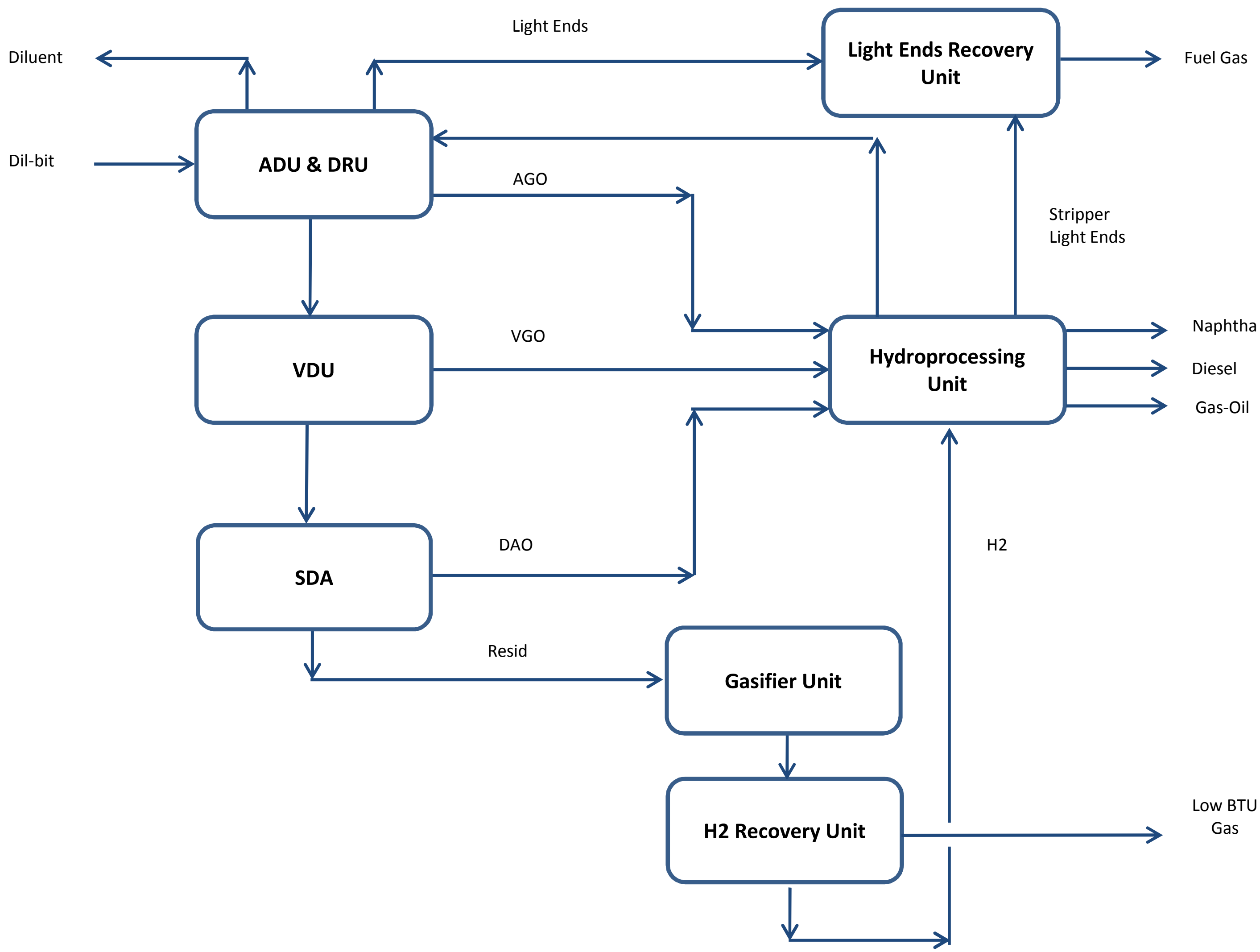


Figure 1

NorthWest Upgrader

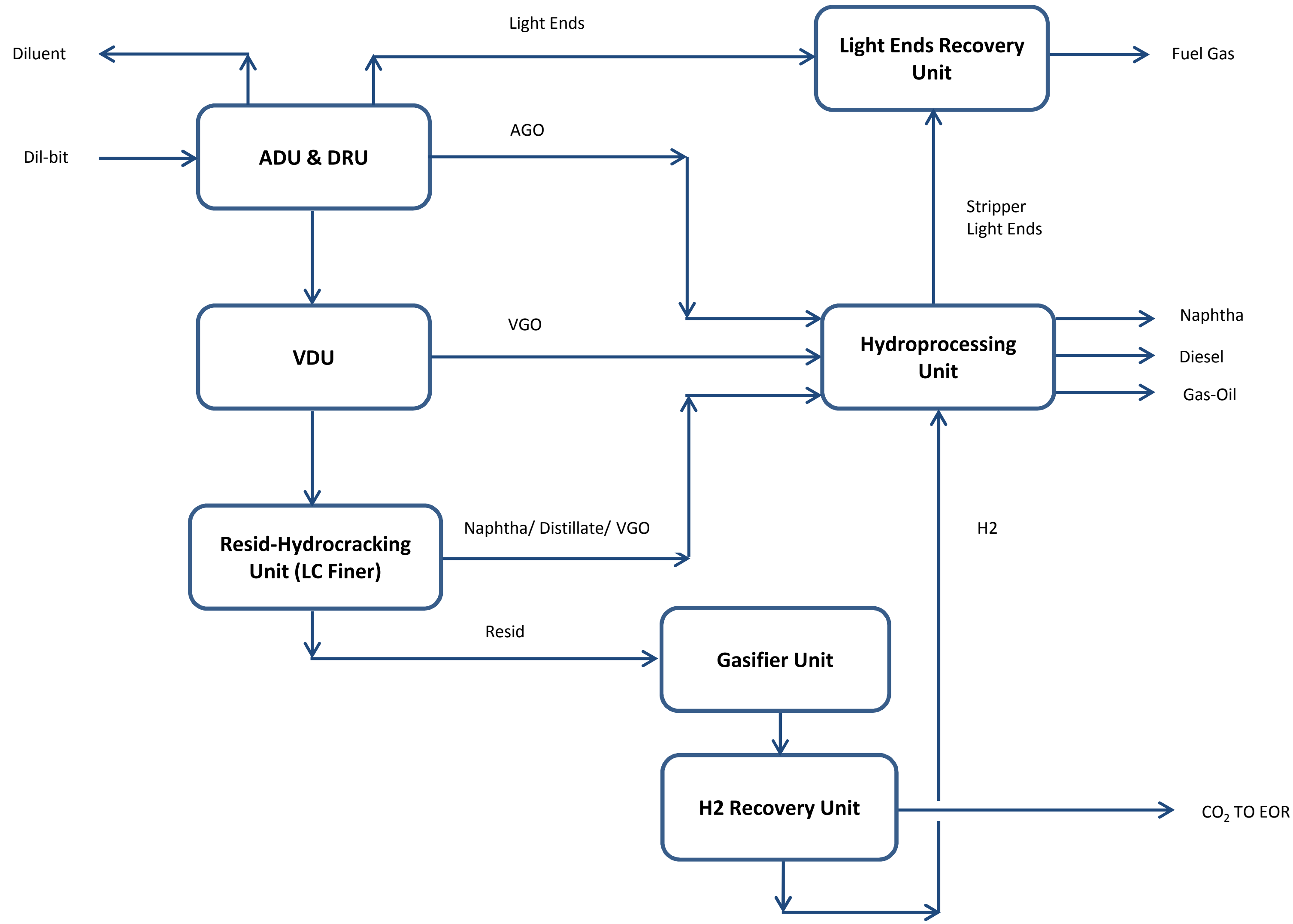
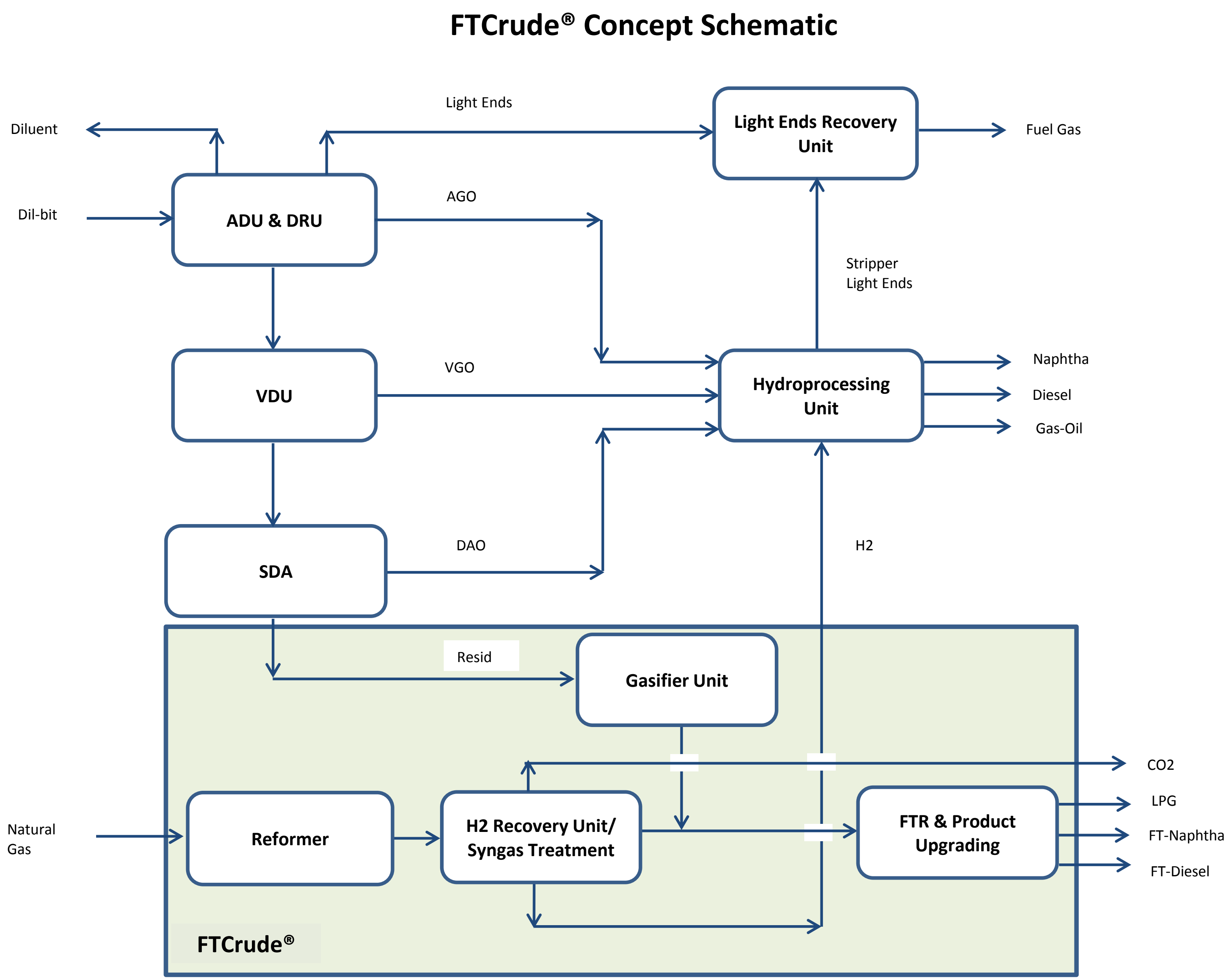


Figure 2



FTCrude® Concept Schematic
Diluent
Dil-bit
Light Ends
AGO
VGO
DAO
Light Ends Recovery Unit
Fuel Gas
Stripper Light Ends
ADU & DRU
VDU
SDA
Hydroprocessing Unit
Naphtha
Diesel
Gas-Oil
H2
Resid
Gasifier Unit
CO2
LPG
FT-Naphtha
FT-Diesel
Natural Gas
Reformer
H2 Recovery Unit/ Syngas Treatment
FTR & Product Upgrading
FTCrude®

Figure 3

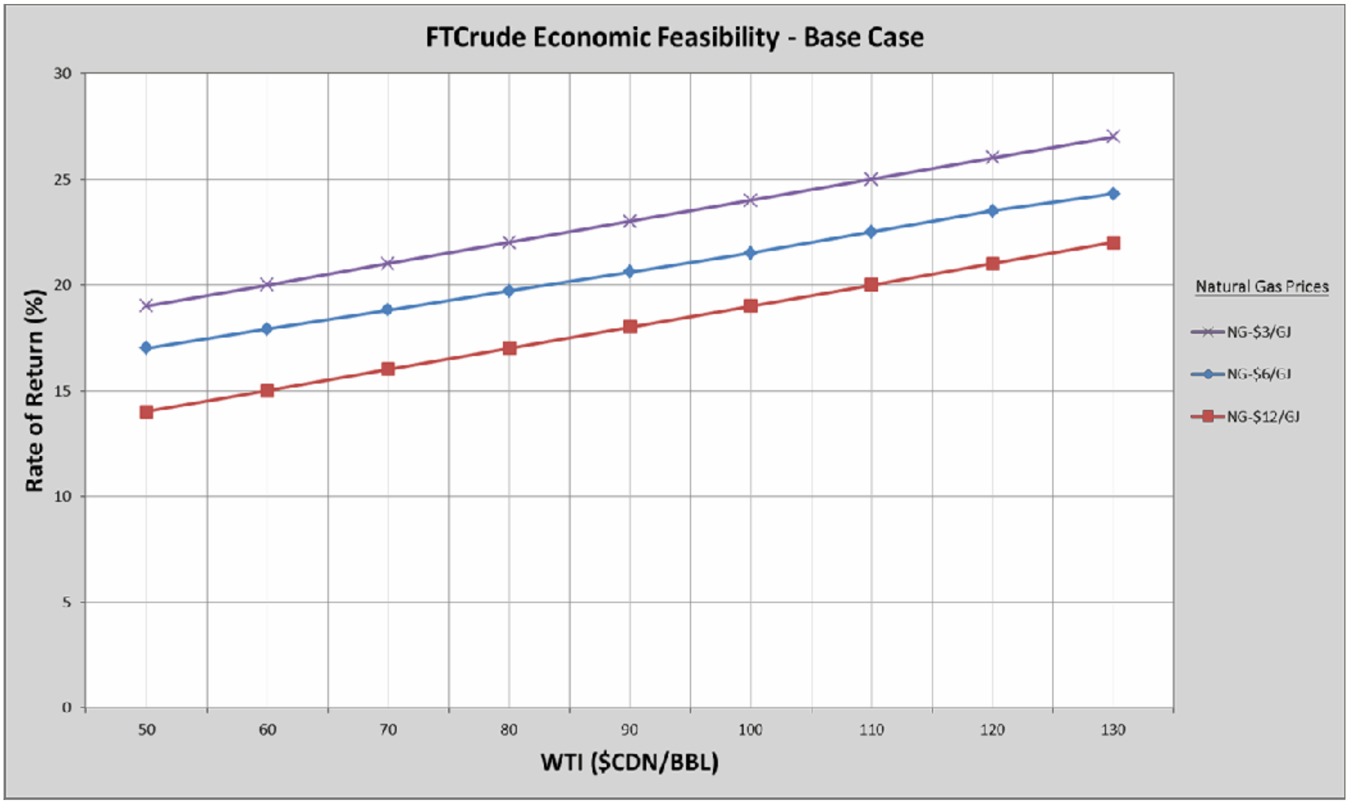


Figure 4

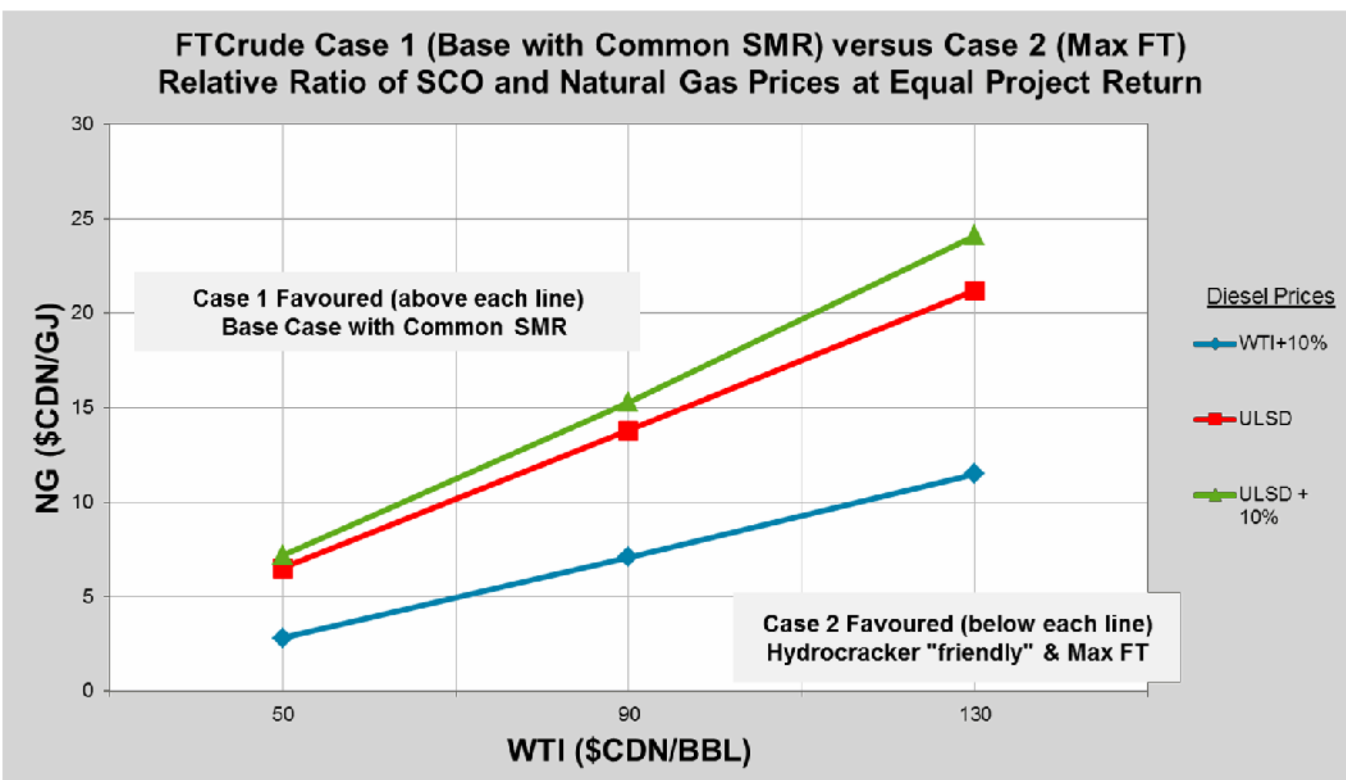


Figure 5