

# Gas to Liquids Explained

02 GTL series



This information sheet provides a technical description of the Gas to Liquids (GTL) process and details of the end products expected to be generated from a commercial scale plant.

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## Introduction

Gas to Liquids (GTL) is the term used to describe the chemical conversion of a gas containing hydrogen and carbon monoxide into synthetic crude (syncrude) by the Fischer-Tropsch (FT) synthesis process. The syncrude is then refined by traditional methods to produce liquid transport fuels.

As a feedstock, the process uses synthesis gas (syngas) generated from the gasification of solid, liquid or gaseous carbon rich materials, such as coal, natural gas or biomass. Linc Energy is planning to use syngas from Underground Coal Gasification (UCG) to commercially produce liquids by GTL.

The Linc Energy GTL process comprises three main steps:

1. Gas treatment: To remove impurities from the syngas and, where necessary, correct the hydrogen to carbon ratio ( $H_2/CO$ ) to within the acceptable range for FT synthesis.
2. FT synthesis: To produce syncrude by catalytic conversion.
3. Product work-up and refining: Separation of gases, hydrocarbon liquids and waxes and refining these into final products.

## Gas treatment

Coal derived syngas (such as UCG syngas) contains various impurities that need to be removed in order to meet the specifications to run an efficient GTL plant.

Some impurities act as a poison to downstream catalytic reactions in the GTL process or act to reduce the efficiency of the process.

These impurities include condensed oils, solid particles, arsenic, mercury, oxygen, compounds of sulphur and carbon dioxide, all of which originate from the coal itself or through its gasification. Removal of contaminants from the gas can be by catalytic conversion or by adsorption or absorption.

On completion of gas treatment, the syngas is free of impurities and is rich in  $H_2$  and  $CO$ , which are the basic elements needed to manufacture syncrude. Gas treatment in commercial scale plants is undertaken using proprietary processes that are readily available and have a long history of operation and development.

A significant advantage of the gas treatment processes considered by Linc Energy is that a clean  $CO_2$  stream

is obtained. In that regard, the plant is designed to capture  $CO_2$ , ready for further sequestration options.

## Fischer-Tropsch synthesis

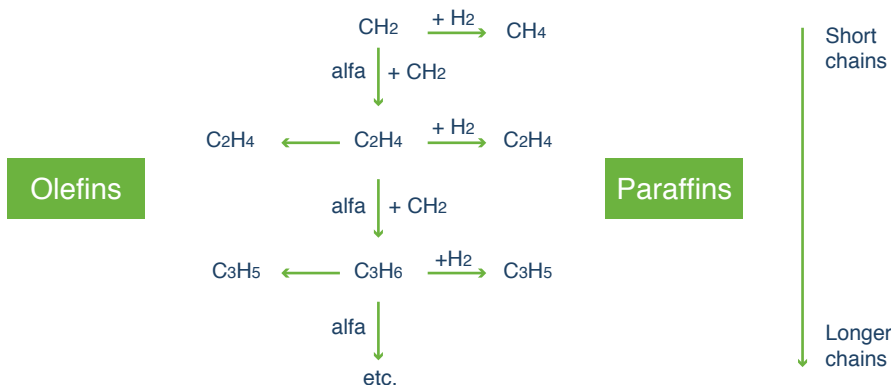
The purpose of FT synthesis is to combine  $CO$  and  $H_2$  into carbon chains by reacting carbon monoxide and  $H_2$  in the presence of a catalyst, heat and pressure.

For Linc Energy's business model of focusing on diesel fuel production, the preferable carbon chains are long, saturated and paraffinic in nature (linear, single bonded carbon chains).

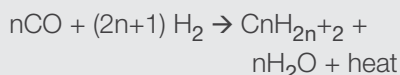
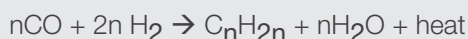
In FT synthesis, hydrocarbons are 'grown' on the active surface of the catalyst by addition of  $CH_2$  groups, formed by the hydrogenation (addition of hydrogen) of  $CO$  to an existing carbon chain.

The length of this carbon chain can increase further by undergoing additional  $CH_2$  insertions.  $CH_2$  and this intermediate chain can also be hydrogenated, which results in termination of the chain growth. Both olefins and paraffins will adsorb and desorb from the catalyst surface, causing the products to consist of a mixture of paraffins.





The overall reaction creates an olefin or paraffin with a chain length or carbon number 'n' and is chemically described as:



Additional products reacted during FT synthesis are reaction water containing oxygenates, such as alcohols, acids and ketones. CO<sub>2</sub> is formed by a side-reaction in which CO reacts with water to form CO<sub>2</sub> and H<sub>2</sub>. This is called the water-gas-shift reaction (WGS):



The FT reactions are exothermic (generating heat). To provide higher energy efficiency, this heat is removed by generating steam that is used to drive power generators.

The focus of Linc Energy's FT development is in low temperature, fixed bed, cobalt catalyst technology. This results in predominantly saturated straight chain hydrocarbons which are ideal for diesel refining.

This technology has specific advantages over other FT technologies because:

- There is increased production of straight chain hydrocarbons
- There is increased paraffinic wax production

- Reprocessing of gas to the FT reactor is lower
- Cobalt based catalysts exhibit little WGS activity, resulting in a relatively low yield of CO<sub>2</sub>
- Reaction water contains less acidic chemicals, requiring less treatment.

## Product upgrading

The product streams of the FT synthesis process contain hydrocarbons ranging from fuel gases and LPG to naphtha, middle distillates, heavy distillates and long chained paraffinic waxes.

Further upgrading of this synthetic oil into higher value end products generally involves fractionation, catalytic reforming, hydro treating, hydro cracking and isomerisation. These processes are widely used in the oil refining industry.

The product distributions vary according to the FT technology, process conditions and subsequent upgrading. Large new generation GTL plants are aimed primarily at producing middle distillates for transportation fuels, e.g. diesel, kerosene and naphtha. Smaller plants may be focused on specialty markets, e.g. chemicals, base oils and waxes.

## Feed materials

### UCG syngas as feedstock

Using coal derived syngas for liquids production is a demonstrated technology that has been utilised for many decades. By using UCG syngas, there are clear capital advantages (there is no need to build a surface gasification plant, which can represent a significant proportion of the capital cost of a coal to liquids facility).

The H<sub>2</sub>/CO ratio of UCG derived syngas will depend on the level of water ingress into the UCG cavity, and the level of inerts (i.e. nitrogen) in the syngas will depend on the purity of oxygen in the oxidant used. Specific coal properties will have a significant impact on the contaminants and level of undesirable by-products, such as heavy tars and phenols. In this way, UCG syngas can be managed to meet the specifications of the GTL process.

### Electricity

Power used in the GTL process is generally associated with refrigeration, gas compression, heating and cooling. GTL plants are generally significant users of electricity, but also have many waste heat and steam recovery options for power generation.

### Water

As in any other refining process, water is used for plant cooling and

steam generation. In addition, the FT process produces significant quantities of reaction water with associated chemicals which needs to be upgraded and incorporated into the water management system.

## By-products

### Coal tar and coal tar oil

Gasification produces liquid hydrocarbons during the pyrolysis reactions. These liquids are tar oils (heavy and light) which condense in the gas treatment section of a GTL plant. Once considered to be waste products requiring disposal, modern refining techniques allows for reprocessing of these tars into more usable liquid hydrocarbons.

### Water

Various sections of a GTL plant produce waste water contaminated with organics associated with

hydrocarbons. As for any refining operation, waste water treatment plants would be included in a commercial scale operation.

### Gas treatment by-products

Sulphur removed from raw syngas is generally converted into elemental sulphur, a by-product that can be sold into the fertiliser market.

The CO<sub>2</sub> produced during the gas treatment stage means that GTL plants can naturally facilitate carbon capture opportunities. The potential to sequester upstream CO<sub>2</sub> emissions is a significant advantage in the combined UCG and GTL processes.

Effluents or solid waste containing the remaining materials like ash and heavy metals can be disposed of according to established methods.

### Tail gas and steam

Waste gas, heat and steam from the plant will be used for power generation.

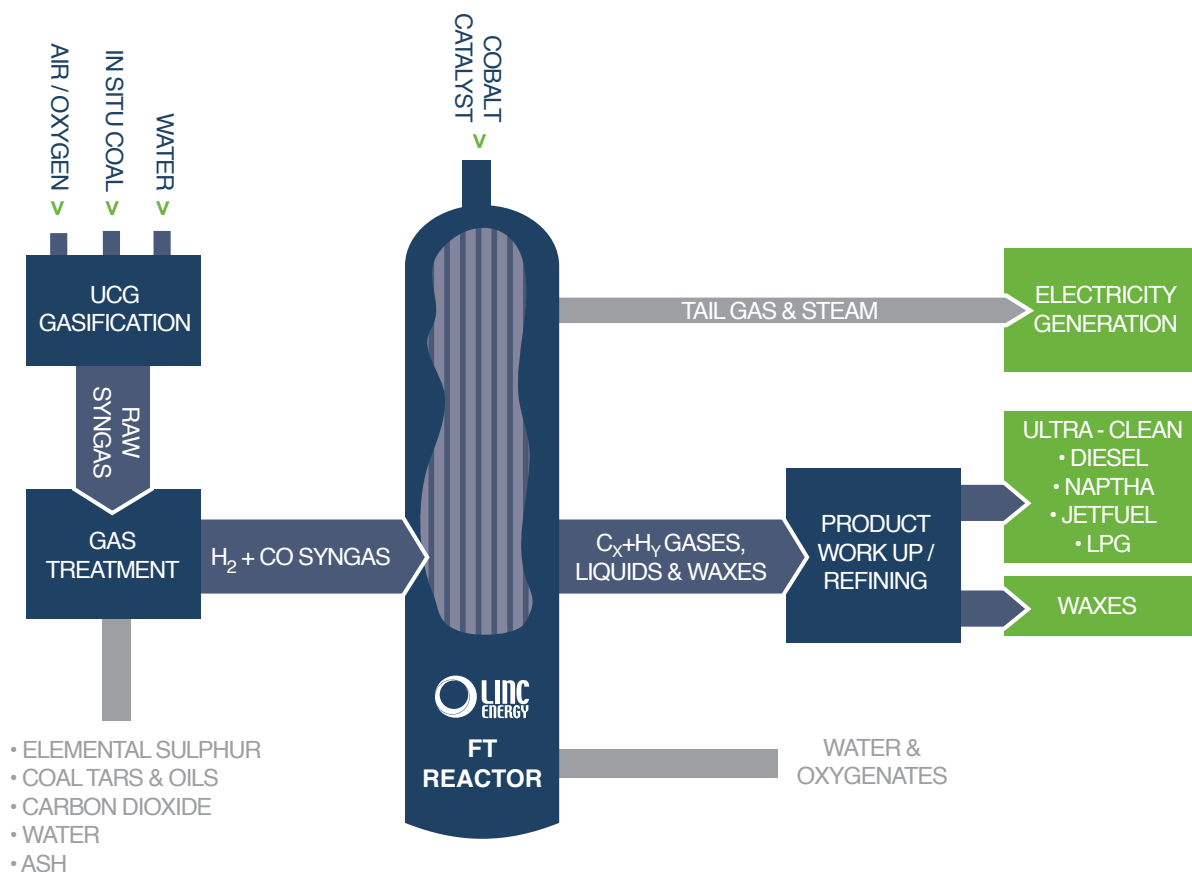
## Products

### Naphtha

GTL naphtha is used primarily in the refining process as blend stock for lighter fuel, such as petrol, as well as for ethylene and propylene manufacturing. The highly paraffinic naphtha from the GTL process is an excellent cracker feedstock that provides a higher ethylene and propylene yield than naphtha from petroleum refining.

### Kerosene

Kerosene can be used as jet fuel to power jet engine aircrafts. Special International Air Transport Association test and certification is required to achieve this and will be issued only for



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the specific manufacturing facility for which the certification was obtained.

## Diesel

FT diesel has a cetane value above 70, compared to refinery diesel which is below 50. The cetane value measures the combustion characteristics of the fuel in the engine. The higher the cetane value, the better the combustion.

As such, FT diesel can be used either

as a pure product, or as a blend to increase the cetane value of conventional refinery diesel.

Additionally, FT diesel is sulphur-free and low in aromatics. With Australian and international specifications for transportation fuels continuing to be tightened, FT diesel is expected to attract premium market value.

## Base oils and waxes

Base oils are the starting material for lubricant production. GTL products can be developed into lubricants and refined paraffinic waxes that are of very high quality, fitting into niche markets with high standard specifications.

## FT diesel properties and emissions profile

GTL products are environmentally friendly because they have no sulphur content, near zero aromatics and provide excellent combustion properties. In particular, GTL transportation fuels have superior environmental performance (as measured at the tailpipe) compared to conventional crude oil refinery diesel, providing a higher cetane number and a significant reduction in emissions of particulates, NOx, carbon monoxide and light hydrocarbons.

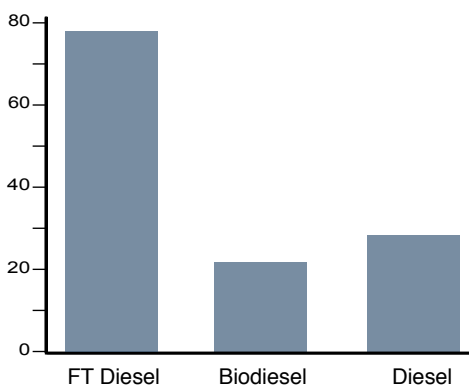


Figure 1: Cetane number of diesel fuels

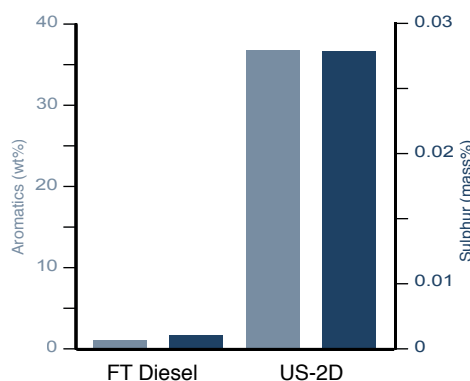


Figure 2: Aromatics and Sulphur Content of FT fuel relative to US diesel <sup>2</sup>

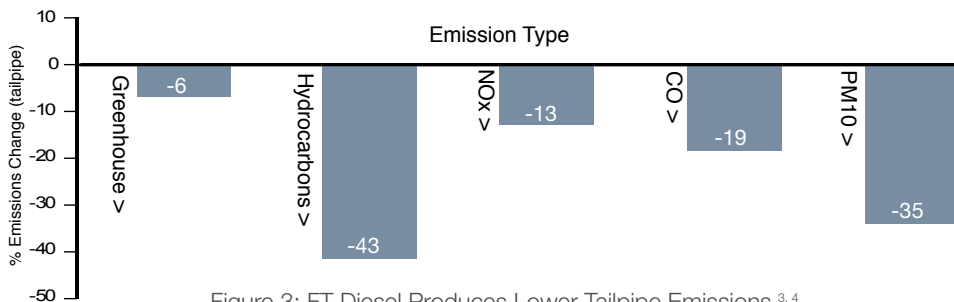


Figure 3: FT Diesel Produces Lower Tailpipe Emissions <sup>3, 4</sup>

1. Lurgi GmbH, 2007. Product Brochure - The Rectisol® Process. Lurgi's Leading Technology for Purification and Conditioning of Synthesis Gas. Lurgi GmbH, Frankfurt, Germany.
2. Steynberg, A. and Dry, M. (eds), 2004. Fischer Tropsch Technology. Studies in Surface Science and Catalysis. Vol 152. Elsevier B.V. Amsterdam, The Netherlands.
3. Beer et al, undated. Comparison of Transport Fuels. CSIRO Final Report to the Australian Greenhouse Office on the Stage 2 Study of Life Cycle Analysis of Alternative Fuels for Heavy Vehicles.
4. In the absence of any published works on the life cycle emissions of FT fuels where UCG syngas is the feedstock, tailpipe emissions only have been presented.

## About Linc Energy

Linc Energy is an Australian energy company which listed on the Australian Securities Exchange (ASX) in May 2006 and the OTCQX in December 2007. Through the unique combination of Underground Coal Gasification (UCG) and conventional Fischer-Tropsch technology to produce Gas to Liquids (GTL), Linc Energy is developing a significant energy business based on the production of cleaner energy solutions for the future.

## Related information sheets

Overview of Gas to Liquids

UCG, GTL and the Environment

### AUSTRALIAN HEAD OFFICE

32 Edward Street  
GPO Box 1315  
Brisbane QLD 4000  
AUSTRALIA

**p** +61 7 3229 0800  
**f** +61 7 3229 6800

### UNITED STATES HEAD OFFICE

1200 17th Street  
Suite 2100  
Denver CO 80202  
UNITED STATES

**p** +11 303 623 0510  
**f** +11 303 623 0547



[linc@lincenergy.com.au](mailto:linc@lincenergy.com.au) [www.lincenergy.com.au](http://www.lincenergy.com.au)