Recent Advances in Direct Coal Liquefaction Technology

By

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HEADWATERS CTL

Forward Looking Statement

Management may make forward-looking statements during this presentation. Actual results could differ from those projected in such forward-looking statements, which involve a number of risks and uncertainties and should be considered in conjunction with the information contained in the Company's SEC filings.

Presentation Outline

- Description of Direct Coal Liquefaction
- Commercial Development
- Product Quality
- Feedstock Flexibility
- CO_2 Footprint
- Summary of DCL Technology Advantages

CTL Technology Options

Lignite
Sub-Bituminous
Bituminous
Anthracite

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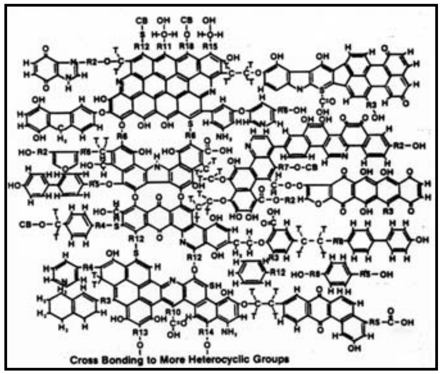


Typical Coal Molecular Structure

Direct Coal Liquefaction (DCL)

Coal + Hydrogen (H_2) $\xrightarrow{\text{Catalyst}}$ Linear + Ring Type Hydrocarbons (C_xH_y)

Indirect Coal Liquefaction (ICL)

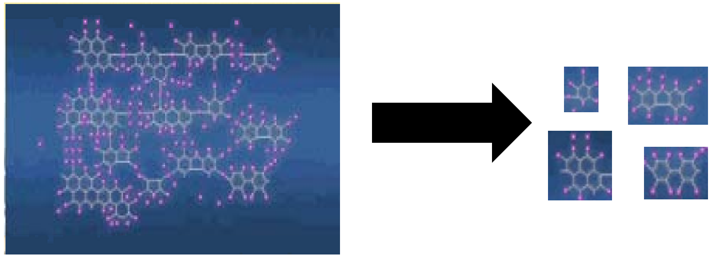
1. Gasification: Coal + Oxygen + Steam → Syngas (H_2 + CO)
2. Syngas Conversion: H_2 + CO $\xrightarrow{\text{Catalyst}}$ Linear Hydrocarbons (C_xH_y) or Chemicals

Hybrid Coal Liquefaction

Combination of Direct and Indirect Coal Liquefaction

Objectives of Direct Coal Liquefaction

- Break down large coal molecules into smaller component molecules.



- Add hydrogen

Coal H/C ratio: 0.6 to 0.8

↓

Oil H/C ratio: 1.6 to 2.0

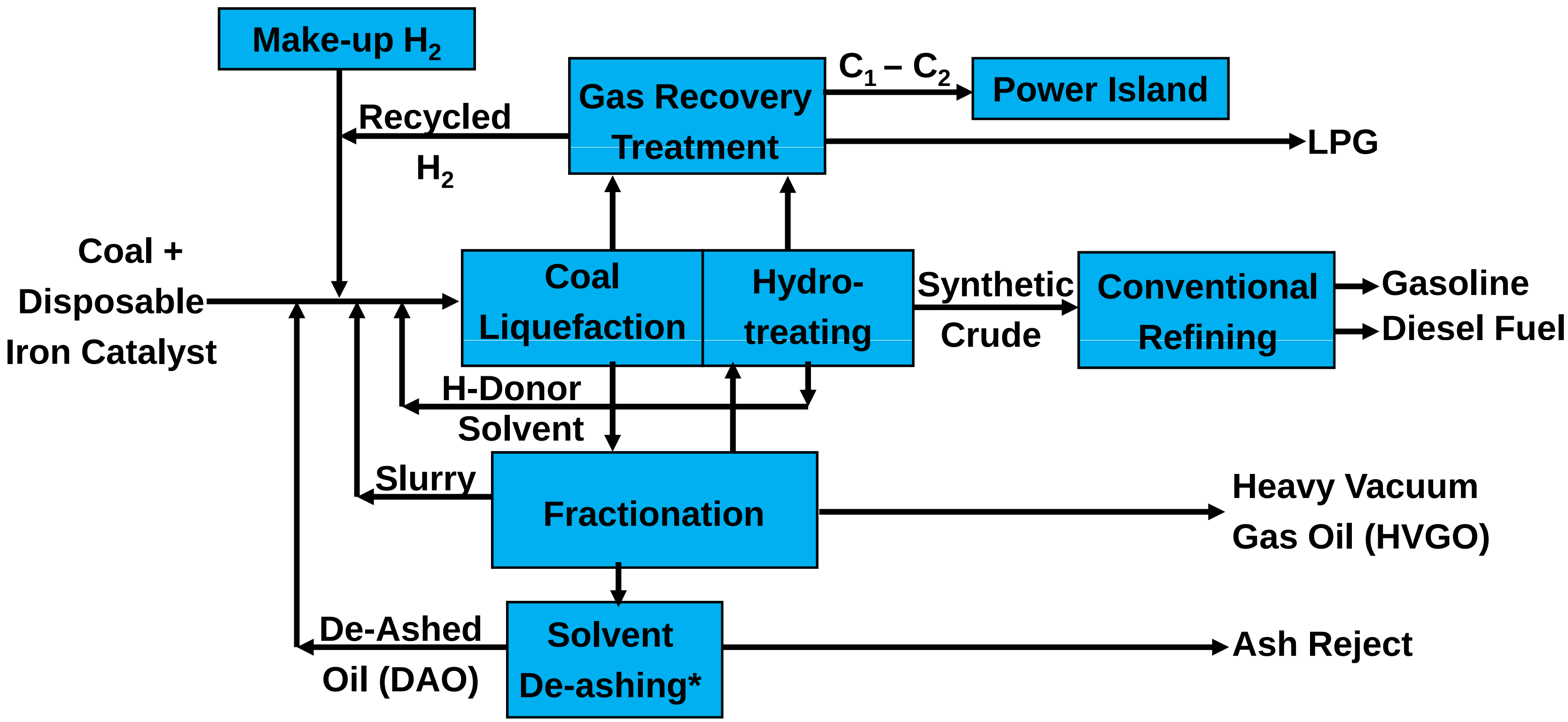
- Remove oxygen, sulfur and nitrogen impurities

$H_2 + O \rightarrow H_2O$

$H_2 + S \rightarrow H_2S$

$1.5H_2 + N \rightarrow NH_3$

Direct Coal Liquefaction Process



** Omitted for low-ash and/or high-reactivity coal*

DCL Commercialization Road Map

20,000 BPD Pioneer Plant

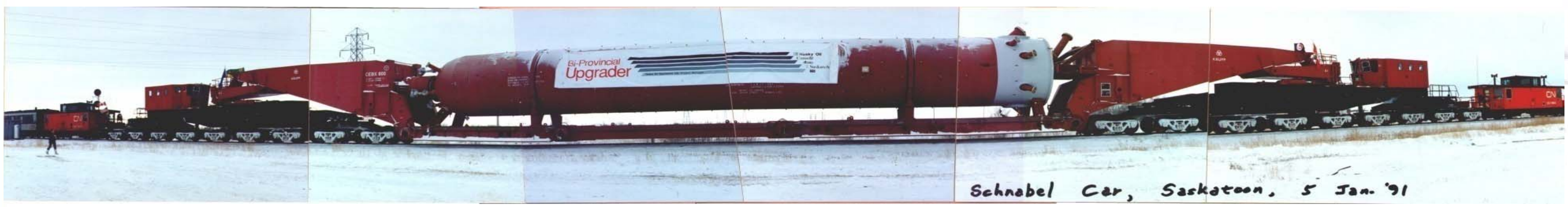
1,800 BPD Demo Plant

15 BPD Pilot Plant

DCL Technology Development History

- HRI, Inc. started development in early 1970's.
- Supported by US Bureau of Mines and US DOE
  - US Government spent $3.6 billion from 1975-2000 to develop DCL Technology
- Single-stage fluidized bed reactor technology (H-Coal Process)
  - Demonstrated in 250 and 600 tpd demo plant at Catlettsburg, KY (1978-1982)
  - Commercial-scale equipment demonstrated in petroleum resid hydrocrackers
  - Breckinridge Conceptual Design completed by Bechtel Corp.
- Two-stage fluidized bed reactor technology (CTSL Process)
- Supported catalyst replaced by low-cost, Fe-based, disposable catalyst (Headwaters DCL Process)
- First commercial license to Shenhua Group of China

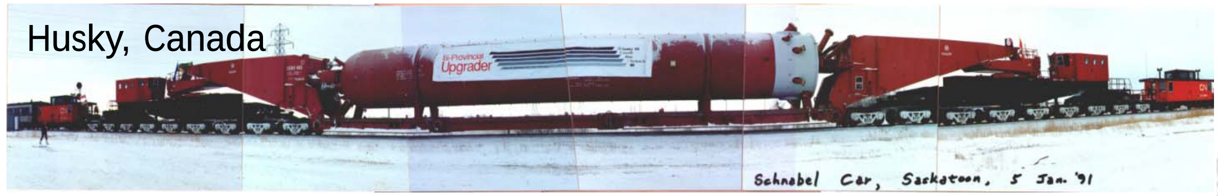
Proven Reactor Technology



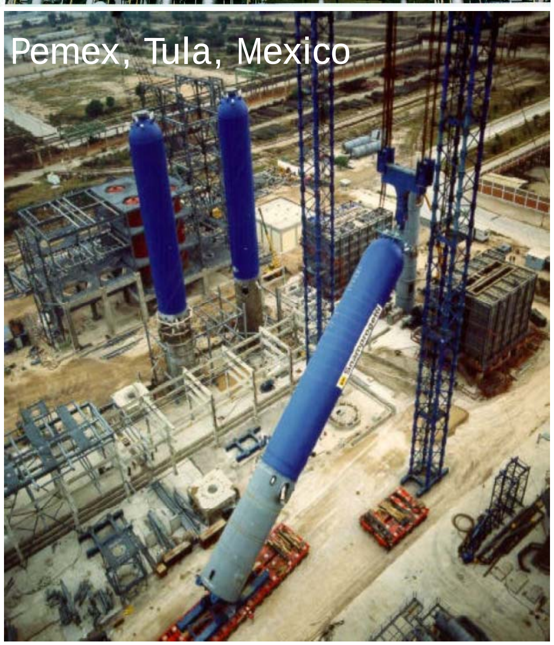
- Direct coal liquefaction and petroleum resid hydrocracking use similar back mixed reactors.
- The commercially proven back mixed reactor is used in over 13 hydrocracking plants around the world.

Petroleum Resid Hydrocracking Reactors

Tonen
Japan



Husky, Canada



Pemex, Tula, Mexico

PKN, Poland

Pemex, Salamanca, Mexico

Shenhua DCL Project
Inner Mongolia, China

- 1996: US DOE recommended HTI DCL Process to Shenhua Group
- 1997-2001: Shenhua project development & competition
  - Several coal pilot plant tests conducted by HTI
  - Feasibility study and expert review meetings held
  - Competition against German and Japanese technologies
- August 2001: HTI acquired by Headwaters
- June 18, 2002: Process license signed for first DCL reactor train
- December 2002: Delivery of process design package and reactor block mechanical and system design
- December 30, 2008: Plant start up

Shenhua DCL Plant, Inner Mongolia, China

Typical Refined DCL Liquids

Properties	Naphtha	Diesel
Boiling Point (^oC)		
5%	99	195
50%	112	234
90%	159	277
Density, g/cm^3 (20^{o}C)	0.7641	0.8648
Viscosity, mm^2/s (20^{o}C)	-	3.69
S, ppm	<0.5	<5
N, ppm	<0.5	<1
Cetane No.		46.7
Acidity mg KOH/100 ml		0.4
Oxidation Sludge, mg/100ml		<0.3
Flash Point, ^{o}C		76
Cold Filter Plugging Point, ^{o}C		-9
Solidification Point, ^{o}C		-26
Compound Class Type Analysis, wt%		
Paraffins	26.7	13.3
Naphthenes (Cyclo-paraffins)	68.3	81.9
Aromatics	5.0	4.8

Shi, Yuhua (RIPP, OCT04)

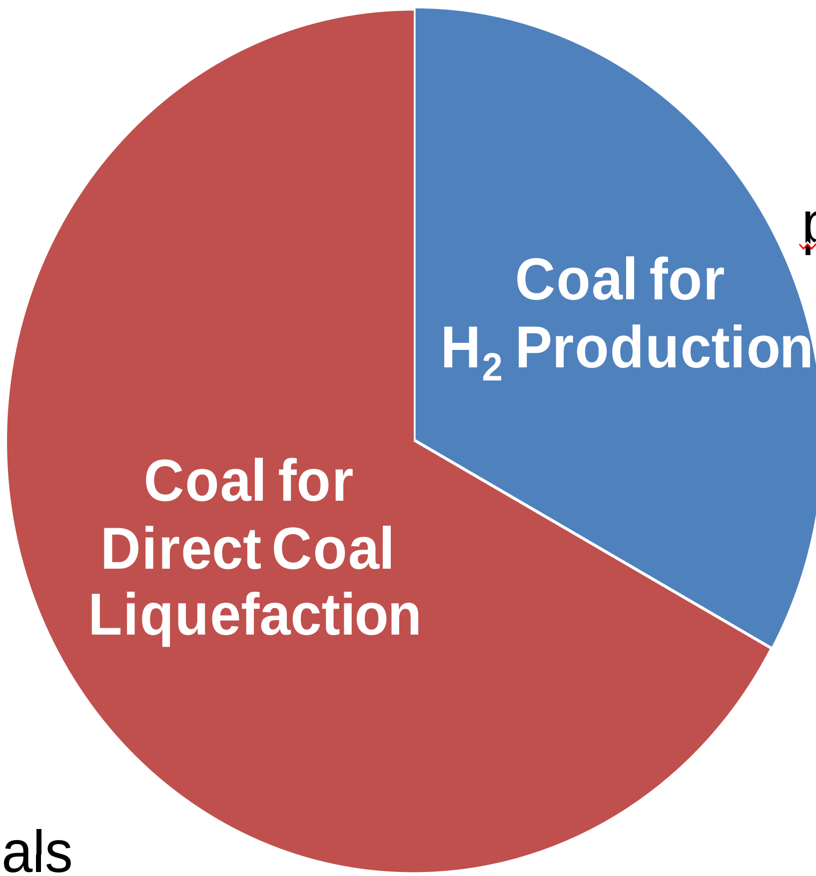
Comparison of DCL & ICL Final Products

	Direct Liquefaction	Indirect Liquefaction	EPA 2006 Diesel Spec
Distillable product mix	65% diesel 35% naphtha	65-80% diesel 20-35% naphtha	
Diesel cetane	42-47	70-75	>40
Diesel sulfur	<5 ppm	<1 ppm	<15 ppm
Diesel aromatics	4.8%	<4%	<35%
Diesel specific gravity	0.865	0.780	
Naphtha octane (RON)	>100	45-75	
Naphtha sulfur	<0.5 ppm	Nil	
Naphtha aromatics	5%	2%	
Naphtha specific gravity	0.764	0.673	

Summary of Product Quality

- DCL can produce high-octane naphtha and on-spec diesel
- ICL can produce low-octane naphtha and high-cetane diesel
- Hybrid DCL/ICL can produce premium gasoline and diesel fuel with minimal refining.

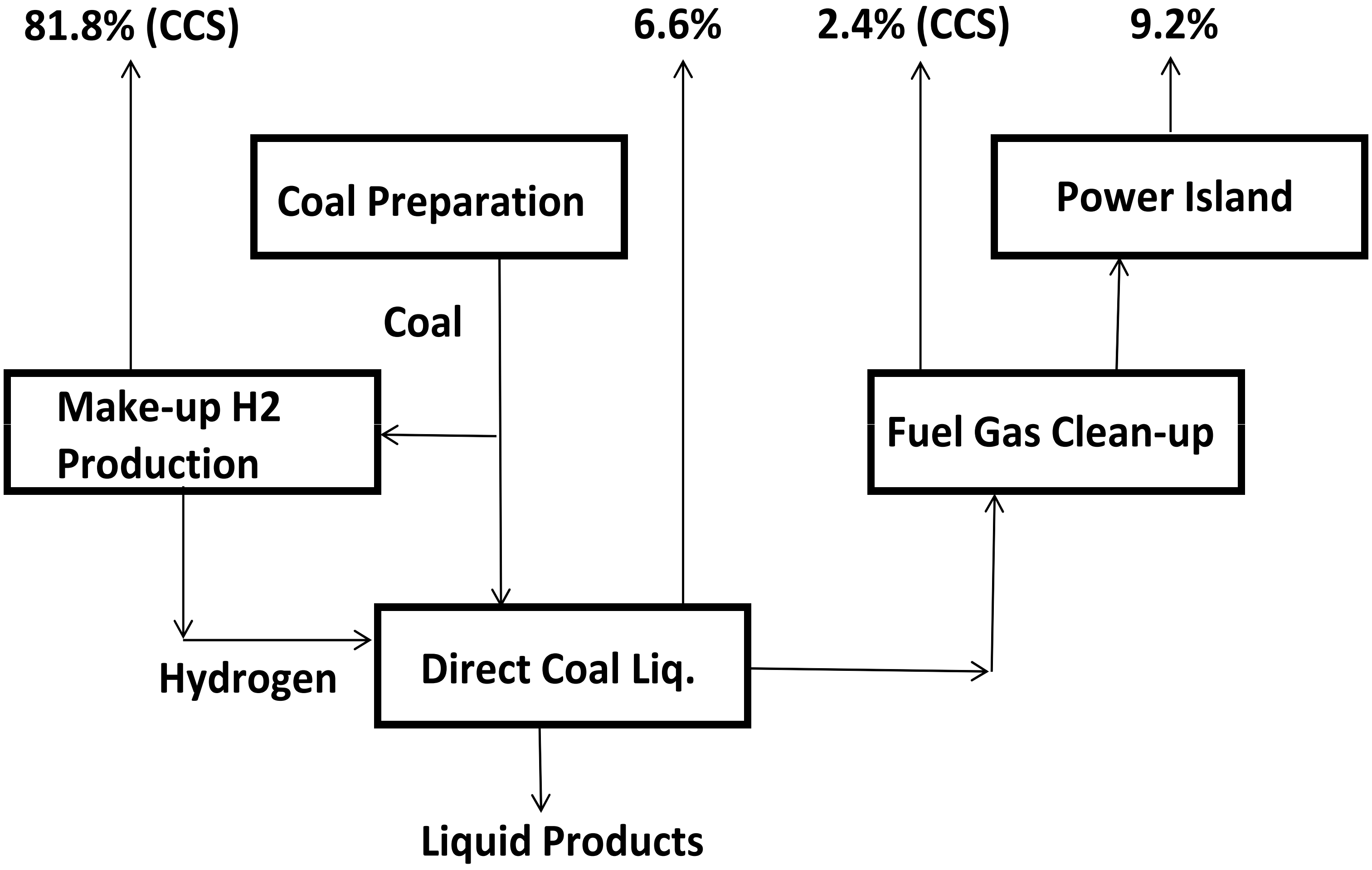
Feedstock Flexibility



Gasification of any rank of coal, petcoke or biomass depending on gasifier design
or
steam reforming of natural gas
or
off-peak power and electrolysis

Prefer low-ash, high-reactivity bituminous or sub-bituminous coals

DCL Carbon Footprint



Comparison of Various CTL Configurations

	DCL	ICL Recycle	ICL Once Through	Hybrid DCL/ICL
Coal consumption (tonnes per day, dry basis)	23,027	29,307	34,450	23,146
Product Mix Diesel (bpd) Naphtha (bpd) LPG (bpd) Total (bpd)	 45,812 18,863 5,325 70,000	 47,687 22,313 0 70,000	 47,687 22,313 0 70,000	 46,750 20,591 2,660 70,000
Net Export Power (MW)	0	399	1139	45
Thermal efficiency (%)	60.1	48.4	47.4	58.7
Product yield (bbl/t dry coal)	3.04	2.39	2.03	3.02
Plant CO_2 generation (kg CO_2 /bbl product)*	434	706	894	458

*Approximately 80% of the CO_2 is in concentrated form ready for sequestration.

Summary of DCL Advantages versus ICL Technology

- **30% lower capital cost for a comparable sized plant**
- **Up to 50% more liquid product per ton of coal**
- **Up to 50% less CO_2 generated***
- **50% less water consumption**
- **25% higher thermal efficiency**
- **Balanced power – no need to produce excess power**
- **DCL syncrude can be refined to meet existing specifications for gasoline, jet fuel and diesel**

*** Over 80% of this CO_2 is in concentrated form ready for sequestration**

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