Status of Coal-to-Liquids Project Technology

McIlvaine Hot Topic Hour – Nov 4/10

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Coal Liquefaction Pathway

Direct Route (High Thermal Efficiency)

H_2 + Catalyst

Recycle Solvent

LPG, water Fuel Gas, **+ Syncrude**

Conventional Refining

Ultra Clean Liquid Fuels
(mixture of straight chain & ring structure)

Indirect Route (Lower Thermal Efficiency)

O_2 + Steam

(Gasification)

H_2S & NH_3 + **CO + H_2,** (Syngas)

Gas Treatment + Cleaning

Synthesis + Refining

Ultra Clean Liquid Fuels
(mostly straight chain compounds)

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DCL Liquid (better gasoline, on spec kerosene & diesel)

FT Liquid (good diesel)

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Shenhua Group Study

- **Shenhua Group is operating DCL and planning ICL plants in China**
- **2005 Study performed by Shenhua on a Chinese coal to compare DCL and ICL**
- **Study conclusions**

	DCL	ICL (High Temp.)	ICL (Low Temp.)
Thermal Efficiency, %	60	41	41
Liquid Product Rate, % MAF Coal	55	38	43
Water Usage, T/T Coal	7	11	12
CO_2 Production, Kg Carbon/GJ Product	20	35	36
Investment, per MT of Liquid Product	Base	1.25xBase	1.16 x Base
Production Cost, per MT of Liquid Product	Base	1.24xBase	1.04 x Base

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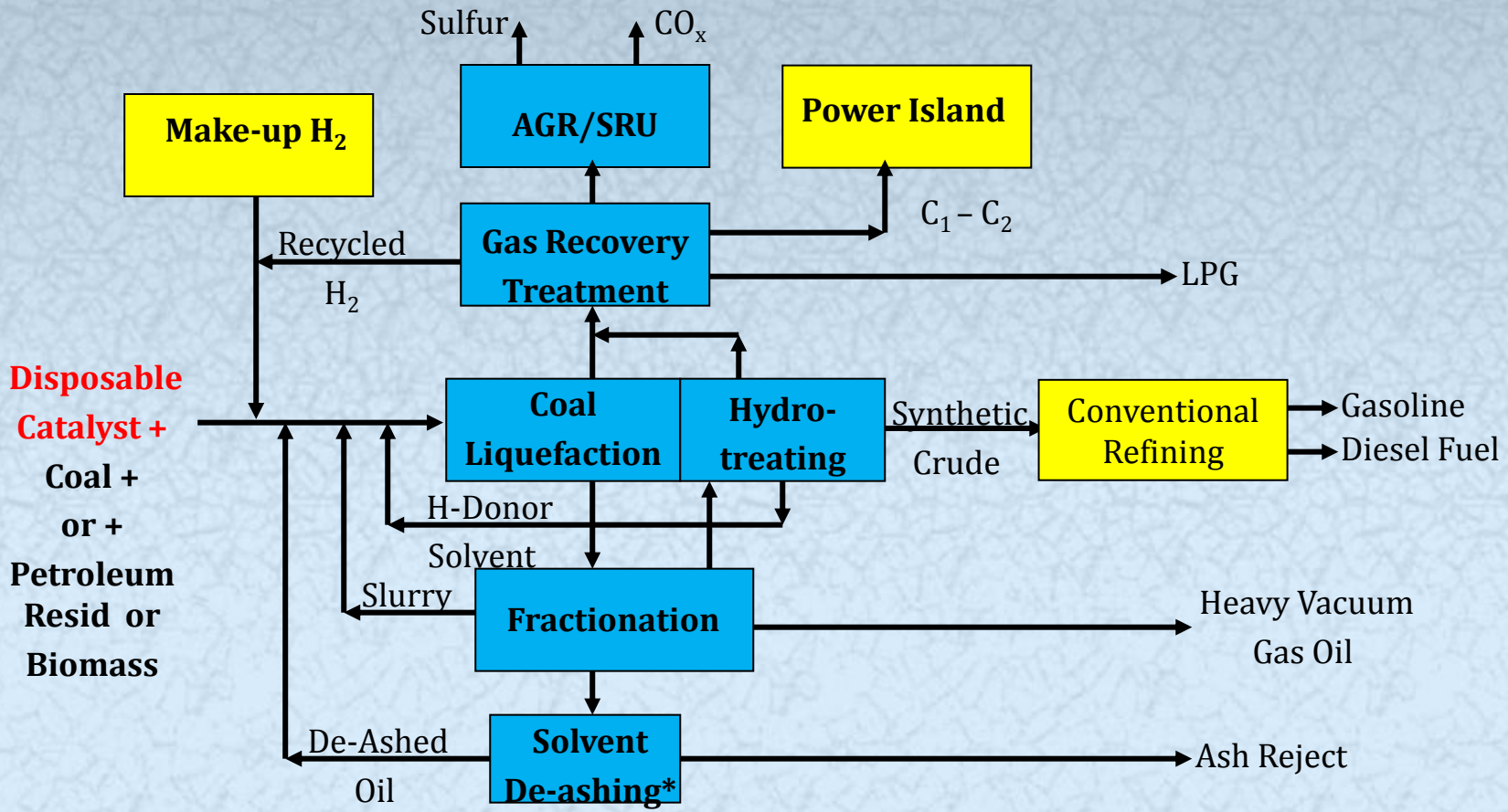
Direct Coal Liquefaction Process

Dispersed Catalyst



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

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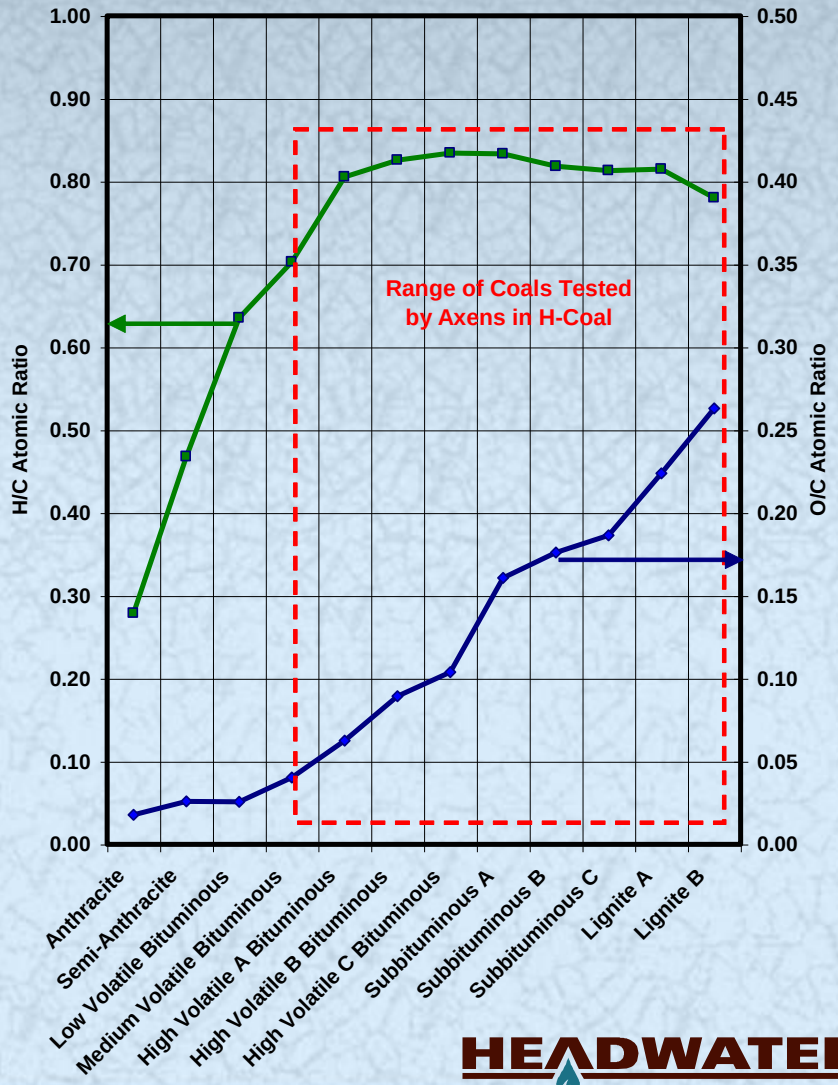
Feedstock Flexibility

Over 150,000 hours of pilot & demo plants operation

United States Coals	Foreign Coals
Bituminous Coals	**Bituminous Coals**
Illinoise No. 6	Yanzhou Beisu (China)
Kentucky No. 9, 11, & 14	Shangwan (China)
Pittsburgh	Shaanxi (China)
Ohio No. 5 & 6	Westerholt (Germany)
Utah D Seam	Steinkohle (Germany)
Coloardo	United Kingdom
New Mexico - McKinley	Taiheiyo (Japan)
Indiana V	South African
	Nova Scotia (Canada)
	Assam (India)
Sub-bituminous Coals	Sub-bituminous Coals
Wyodak (Wyoming)	Foeestburg (Canada)
Black Thunder (wyoming)	
Black Mesa (Wyoming)	
Lignites/Brown Coal	Lignites/Brown Coal
Texas	Australian Brown
Big Horn (Montana)	
North Dakota	



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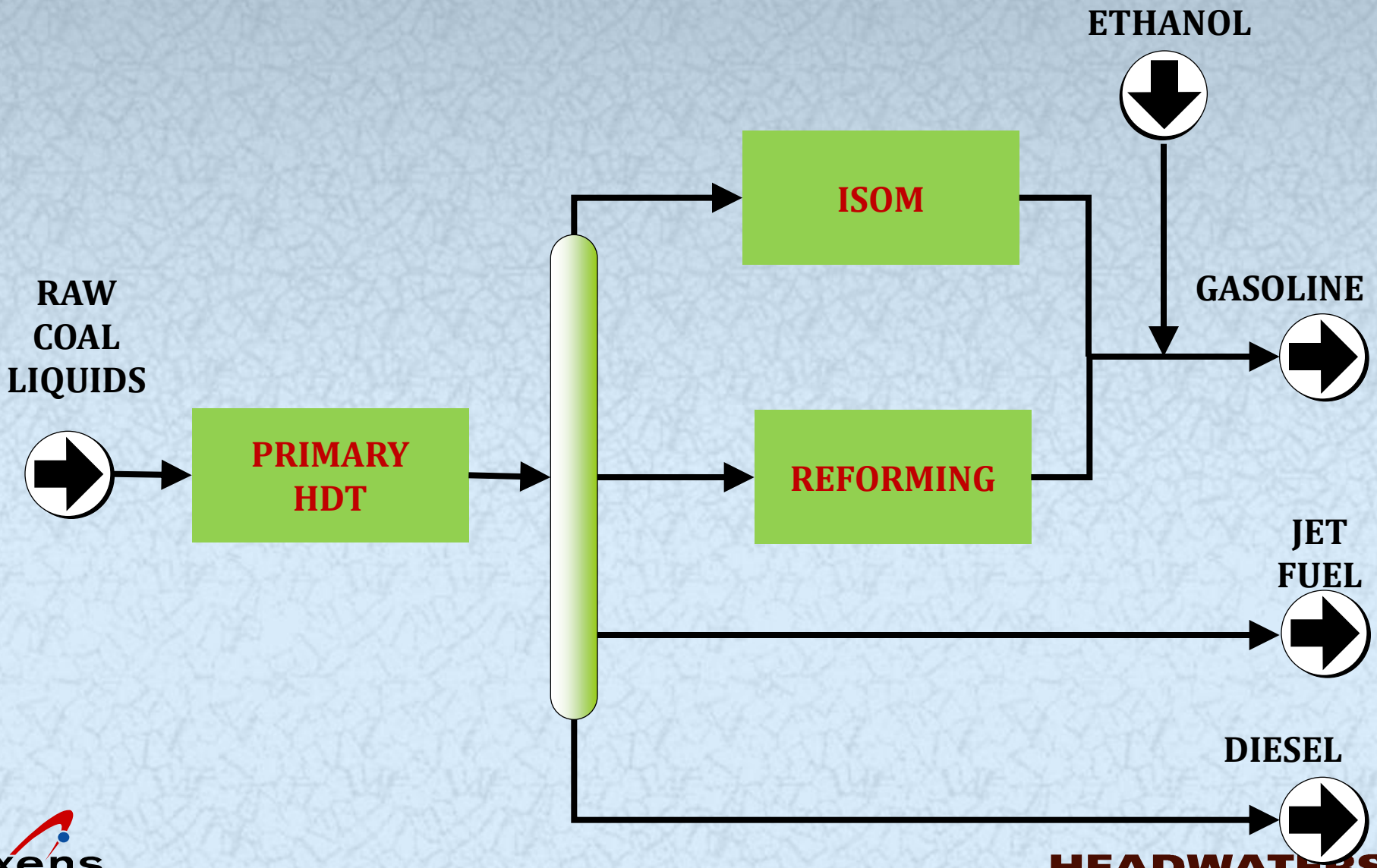
First Commercial Reference Plant

- Shenhua Group Shangwan Coal
- 20,000 BPD two-stage back-mixed reactors
- Headwaters' slurry catalyst DCL Process licensed for this site in 2002
- Headwaters provided process design package for DCL
- Axens' H-Oil®$_{DC}$ Technology licensed in 2003
- Axens provided extended basic engineering design of DCL and integrated H-Oil-$_{DC}$
- Axens provided engineering services during EPC and on-site technical services for Shenhua during startup and initial operations

Shenhua Direct Coal Liquefaction Plant at Start-Up

Refining of Coal Derived Liquid



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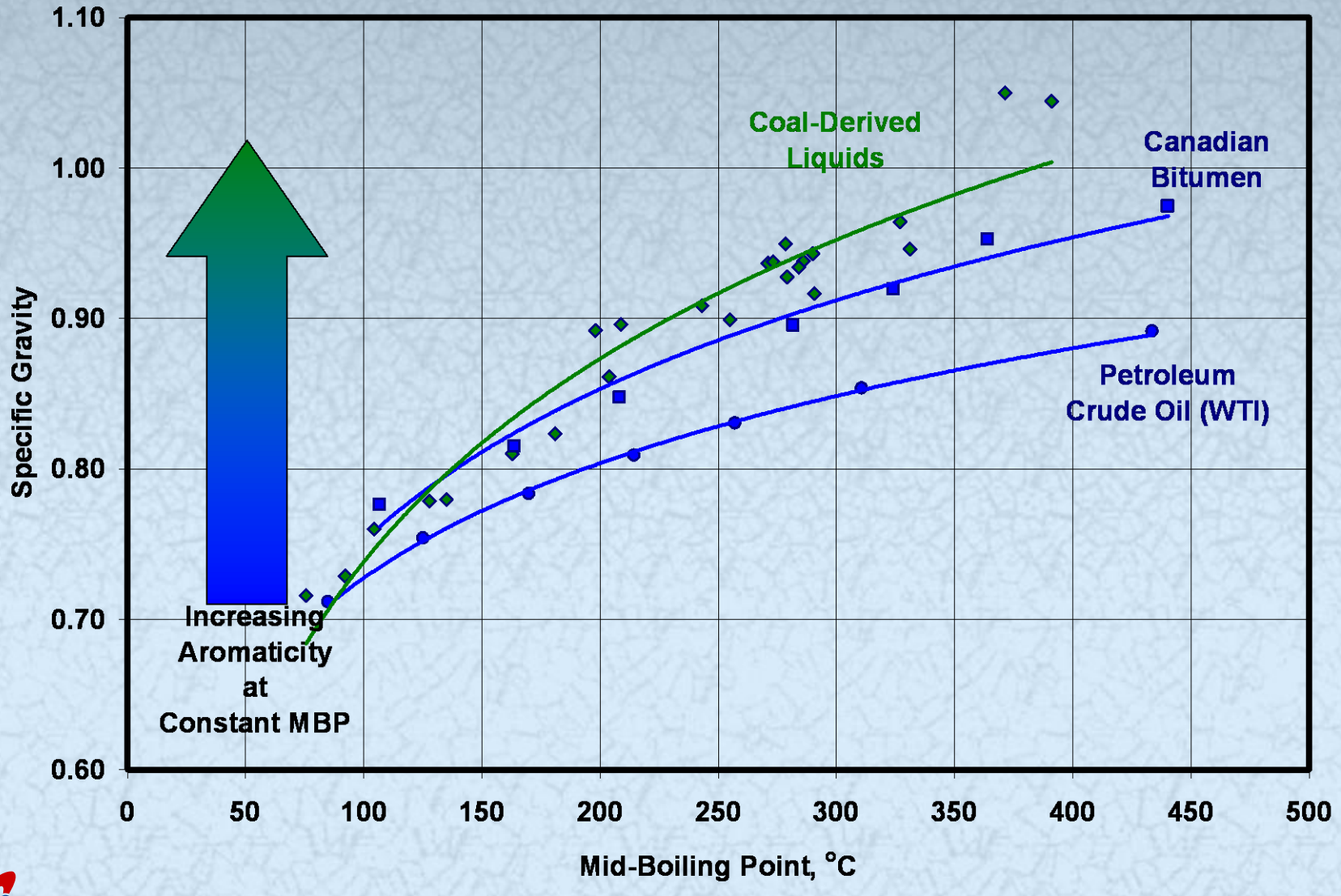
Specific Gravity of CDL



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Comparison of CDL Gasoline with Gasoline Specifications

		US RFG	Euro V	Coal Liquid	Coal Liquid
RON	min	-	95	96	92
MON	min	-	85	85	82
(R+M)/2	min	87/89/91	90	90	87
Aromatics, vol%	max	-	35	43	33
Olefins , vol%	max	-	18	< 1	< 1
Benzene, vol%	max	1.0	1.0	0.5	0.5
Oxygen, wt%	max	3.5	2.7	2.7	2.7
Sulfur, ppm	max	30	10	< 1	< 1
RVP, kPa	max	69	60	47	47

- US Specification
  - Meets (or exceeds) current US gasoline specification
- Euro V Gasoline
  - At 95 RON aromatics are above specification – need to blend with low aromatics gasoline

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DCL Alliance Jet Fuel Testing

- Alliance DCL Jet Fuel has high density, low freeze point, and high volumetric heat of combustion while meeting all JP-8 Specs.

	DCL Diesel	Typical JP-8	JP-8 Spec.
Density (kg/m3)	0.837	0.804	775 - 840
Sulfur (ppm)	<3	383	<3000
Aromatics (w%)	1.6	18.8	<25
Freeze Point (°C)	-77	-51	<-47
Hydrogen (w%)	13.7	13.8	>13.4
Heat of Combustion (MJ/kg) - calc.	43.1	43.2	>42.8
Heat of Combustion (MJ/liter) - calc.	36.1	34.7	+3.9% vs JP-8
Smoke Point (°C)	23	22	>19

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DCL Diesel Compared to Specifications

- **Alliance DCL Diesel meets or exceeds current US Specifications (ASTM D975)**

	DCL Diesel	U.S. Spec. (No.1)	EU Spec.
Density (kg/m3)	855-885		>820, <845
Sulfur (ppm)	<5	<15	<10
Aromatics (w%)	2 - 10	<35	
Di-Aromatics (w%)	0 - 2		<11
Pour Point (°C)	< -48		CFPP < -15
Cetane Number	45 - 54	>40	>51

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ALE North Dakota DCL Project 1/2

Feed & Power	
Lignite (37.5 % H_2O)	17,970 mTPD
Power Export	19.5 MW
CO_2 Capture	3.85 MMTPY

Refined Products (24,921 BPSD)	
Gasoline	7,477 BPSD
Kerosene/Jet Fuel	6,070 BPSD
Diesel Fuel	4,095 BPSD
Fuel Oil	2,935 BPSD
LPG	4,334 BPSD

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ALE North Dakota DCL Project 2/2

Financial Analysis		
H_2 Plant Feed	Lignite	Natural Gas*
Relative Total Installed Cost	1.43xBase	Base
Breakeven Cost ($/bbl)	47	50
IRR (70 debt/30 Equity)		
WTI @$75/bbl	17.4	20.1
WTI @$100/bbl	24.9	29.3

* Natural gas @ $4/MMBTU

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Conclusion

- DCL results higher energy efficient and low investment cost then ICL for transportation fuel production
- ICL offers flexibility to co-produce clean power and chemicals/petrochemical feedstock
- DCL produces ultra clean, on spec transportation fuels
- The first DCL commercial plant is in operation and technical viability is no long an issue.
- Reasonable IRR for single reactor train DCL plant
- Hurdles for CTL plant in US include project financing and unclean legal rule on CO_2 emission.

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