Lignite Conversion Technologies and Product Value Streams

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Coal Gasification – an affordable alternative when petroleum in short supply

- Used during World War II to convert coal into transport fuels
- Used extensively in the last 50+ years to convert coal and heavy oil into hydrogen – for the production of ammonia/urea fertilizer
- Refinery industry – for production of hydrogen (1980's) resulting in development of modern "entrained flow" gasifier
- A growing part of global fuels industry today – (South Africa, China, USA)

Factors driving options for fuels today

- Continuing rapid economic growth…. China / India / Middle East…+ all regions of the world
- Rising capital costs and rising cost structure of energy supply
- Petroleum production costs remain high…growing interest in alternatives
- Energy security concern rise… infrastructure investment in all areas
- Climate change concerns force action on carbon mitigation… including technology incentives

Coal-To-Liquids: Current Status

- Costs – Many systems analyses ongoing – for 50,000 bpd plant:
  - Capital costs estimated at $4.5–5.0 billion
  - Product cost at US$60–65 /bbl (based on US$1.0/GJ coal)

- Technology is considered commercial
  - Sasol producing 150,000 bpd of F-T products
  - Shenhua China Coal Liquefaction Corp. constructing 20,000 bpd plant additional 180,000 bpd planned
  - Shenhua support feasibility studies for two 80,000 bpd coal-to-liquid plants

- A number of US CTL developments announced … several are at design stage

Announced US CTL Development Projects

Project Name	Location	Project Status	Feedstock	Gasifier	Synfuels Technology	Estimated Synfuel Production (bpd)
DKRW-WY	Medicine Bow, WY	Design	Sub-bituminous	GE	ExxonMobil MTG	15,000 Gasoline
WMPI, Inc.	Gilberton, PA	Design	Anthracite culm	Shell	Sasol	5,000
Rentech Strategic Fuels and Chemicals Complex	Natchez, MS	Design	Bit-coal Petcoke / Bio-mass co-feed	N/A	Rentech	1,600 (Stg1) 28,000 (Stg2)
Ohio River Clean Fuels, (Baard Energy)	Wellsville, OH	FEED Design	Bituminous/Bio-mass co-feed	Shell	N/A	50,000
Alaskan Industrial Devel. and Export Authority	Cook Inlet, AK	Feasibility	Sub-Bituminous	Shell or Sasol	Shell or Sasol	80,000
Rentech	Mingo County, WV	Feasibility	Bituminous/Bio-mass co-feed	N/A	Rentech	20,000
Peabody/ Rentech	IL/KY	Feasibility	Bituminous/Bio-mass co-feed	N/A	Rentech	30,000
Headwaters, Inc Consul Energy	Multiple	Concept	Bituminous	N/A	Headwaters	N/A
American Lignite Energy	Beulah, ND	Concept	Lignite	N/A	Headwaters	32,000
Illinois Clean Fuels	Oakland, IL	Concept	Bituminous Biomass	N/A	N/A	25,000
Peabody/ Rentech	MT	Concept	Sub-bituminous	N/A	Rentech	10,000
Southeast Idaho Energy LLC	American Falls ID	FEED/ Design	Sub-bituminous / Petcoke	ConocoPhillips E-Gas	N/A	4000 tpd Fertiliser 8300 bpd diesel
Synfuels, Inc.	Ascension Parish, LA	Concept	Lignite	GE (?)	N/A	N/A

In this table, the project status of the plants is identified as either design (front-end engineering design [FEED] initiated), feasibility (siting, economic and/or engineering studies underway); concept (partnership and/or announcement of plant), or pilot (constructed for testing and production of small quantities of product only).

Challenges for coal based projects

- Recent enormous change in public concern about "Climate Change" effects associated with fossil fuel usage.
- In one of the most important decisions in environmental law, the US Supreme Court has ruled that carbon dioxide (CO2) is a pollutant to be regulated by the EPA
- During 2007, fifty-nine of the 150-odd coal previously announced power projects were either cancelled or shelved.
- Financial sector is reportedly increasingly cautious of coal-based projects
- Several US utilities have abandoned their coal power projects in favour of less commercially risky gas combined cycle

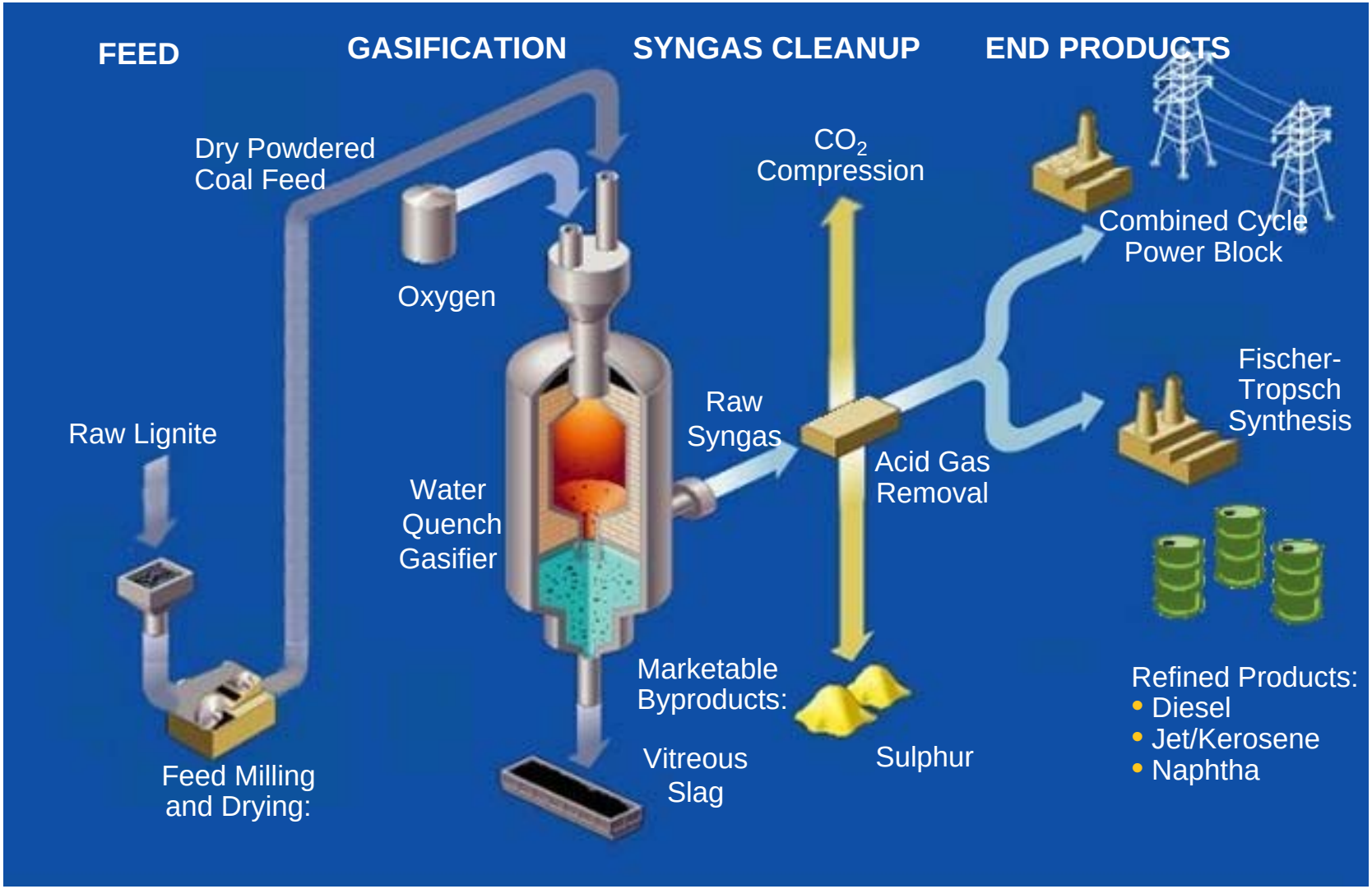
Inherent advantage of CTL projects

- little impediment for financing projects that can demonstrate a sound carbon management plan
- capture of up to 80% of carbon dioxide co-produced is an integral part of the CTL process
- Four US projects have progressed to design stage; each has sound carbon management plan

Lignite Gasification CTL Process

- First, the lignite feedstock is dried and ground to a powder so that it can be fed pneumatically into the gasifier
- In the gasifier, the powdered coal, oxygen and steam are reacted together under pressure to produce a synthesis gas (“syngas”) consisting mainly of hydrogen and carbon monoxide.
- In the gas clean-up stage, sulphur compounds and carbon dioxide are removed from the syngas stream
- The hydrogen, carbon monoxide and steam can then be catalytically reacted to form a wide variety of hydrocarbons, fuels and chemicals depending on what type of catalyst is used and the temperature pressure conditions.
- Steam produced in the process and tail gas from synthesis are used to generate electricity in a combined cycle power block

Lignite Gasification Process



Characteristics of Gasification Process

- extremely clean process compared with conventional coal burning
- all the reaction products remain contained
- CO2 is extracted as a captured product stream
- H2S is reduced to elemental sulphur for sale as by-product
- slag discharged from bottom of gasifier is in form of an unleachable vitreous frit that is usable as building aggregate or road base material
- main source of “polluting material” is small and comes from clean-up of the waste water streams

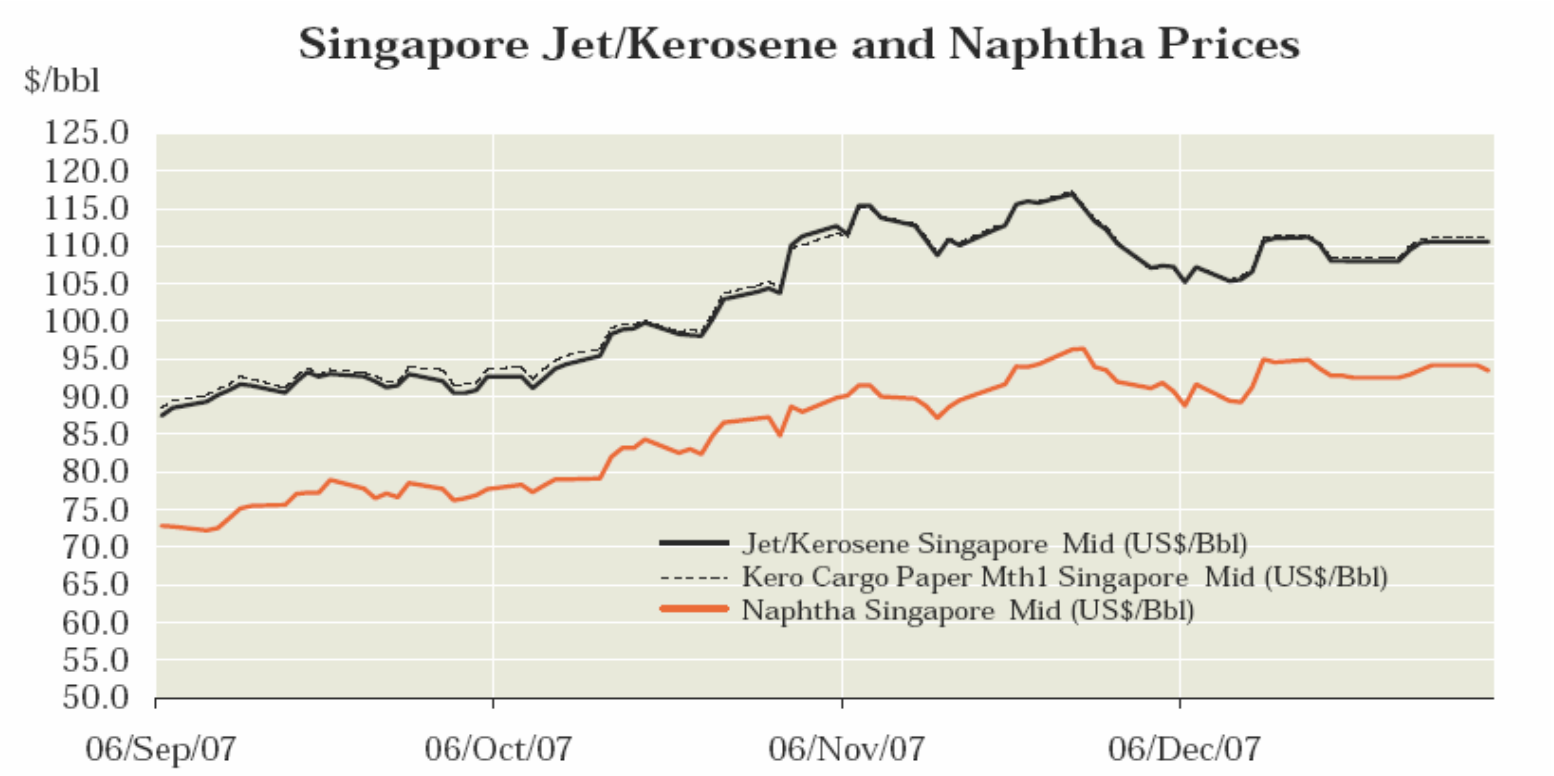
Characteristics of Fischer-Tropsch Synfuels

Property	Current ASTM D975 Diesel	October 2006 EPA Diesel	Current EU EN590 Diesel	Fischer-Tropsch Diesel
Sulfur, ppm	500	15	50	*0*
Aromatics (%)	35	35	N/A	*0*
Cetane Number	40	40	51	*74+*
Biodegradable	NO	NO	NO	*YES*

- Performs better than petroleum diesel and other alternative fuels
- Valuable blending stock to meet new guidelines with for lower emissions
- Compatible with existing engines and infrastructure (pipelines, storage terminals, pumps)
- Non-toxic and biodegradable, very stable for long shelf life
- Produced from many raw materials
- **Long shelf life (~8years compared with 4-6 mths for petroleum diesel) makes this a high demand strategic fuel for emergency services**
- **Large demand for FT middle distillate as a single spec military fuel for US Defence Department**

Market Value of Synfuels

- Expected to have market value as substitute petroleum-derived products meeting same specifications.
- Singapore refined product pricing expected to benchmark market price for Asia-Pacific region



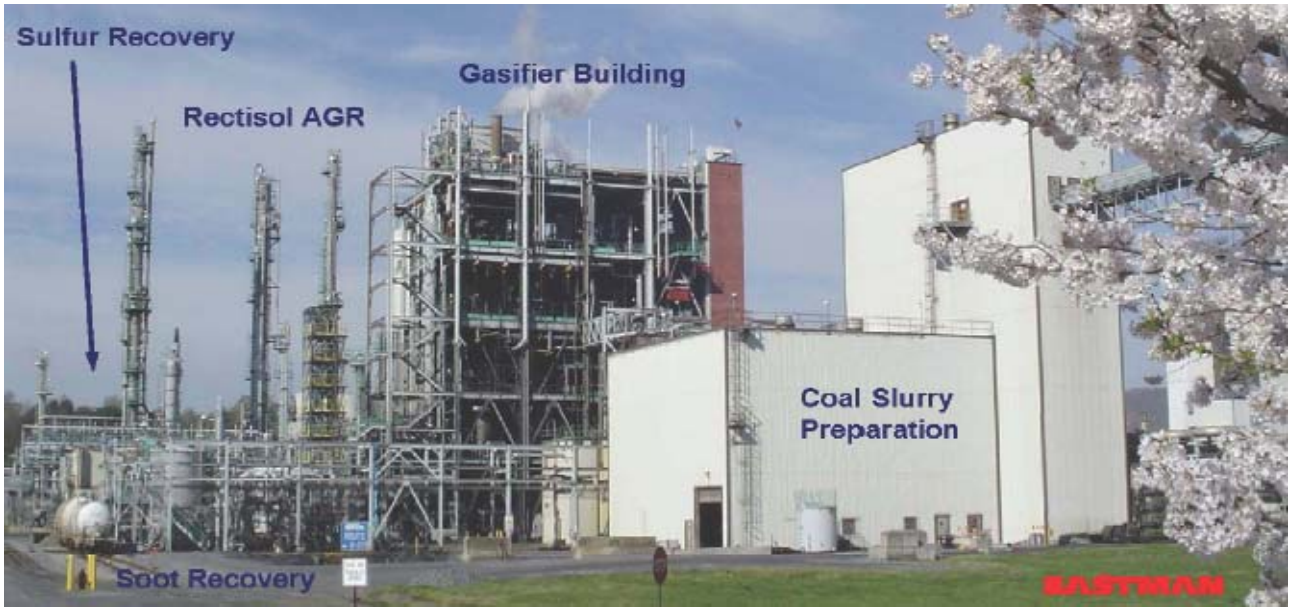
Coal Gasification Plants from Last Era

- **Sasol Secunda (South Africa) - Lurgi Dry Ash**
- **Eastman Chemical Complex (USA) - Texaco**
- **Great Plains Synfuels (USA) – Lurgi Dry Ash**
- **Many others in China making Fertilisers and Chemicals**

Also, numerous gasifiers in refineries around the world making hydrogen from refinery wastes – petroleum coke, refinery bottoms

[Note: This is the origin of the modern entrained flow gasifiers - developed by Texaco, Shell, Uhde, Dow (Conoco-Phillips) and now being adapted to coal feedstocks]

Success Story – Eastman Chemical Complex – TN



- Switched to coal gasification for chemicals feedstock following 1979 energy crisis
- Now one of world's top chemical producers - ~US$ 6 bn annually 15,000 employees
- Secure coal supplies have enabled business to grow while many others have closed down
- Worlds best-performing coal gasification plant ~ over 99% availability. Many advancements made in operating technology

Success Story – Great Plains Synfuels Plant – ND

- Built to produce synthetic natural gas (SNG) from lignite
- Developed with Government assistance in response to 70's energy shortages and began operating in 1984.
- Six million tonnes lignite annually
- Produces 170 mmscfd SNG, 1150 tpd ammonia, 575 tpd ammonium sulphate, plus solvents, phenol, and other chemicals.
- 160 mmscfd carbon dioxide piped 330 km and sold to Canadian oil fields for enhanced oil recovery.

Present Era CTL Projects

For the North American CTL projects that are moving ahead, it seems that addressing carbon mitigation up front has removed a major obstacle

- **Waste Management Processors Inc**
- **DKRW Medicine Bow**
- **Rentech Natchez Strategic Fuels & Chemicals Complex**
- **Baard Energy's Ohio River Clean Fuels (ORCF) Project**

CTL Projects in progress……..

Rentech Strategic Fuels & Chemicals Complex Natchez, MS

- Land optioned and due diligence in progress
- Feasibility study underway
- Inducement for up to $2.75 billion in tax-exempt and taxable bonds approved
- Signed CO_2 off-take agreement with Denbury Resources, Inc. for all captured CO_2 at facility
- Produce FT fuels on a large commercial scale through co-feed of biomass with coal or petroleum coke
- 25,000 bpd plant (with potential to expand to 50,000 bpd) expected to be completed in 2012

DKRW Medicine Bow CTL Project

Medicine Bow Fuel & Power LLC (MBFP) is developing a greenfield, mine-mouth coal-to-liquids facility near Medicine Bow, Wyoming.

The main features of this project are:

- GE (Texaco) gasification of PRB coal and conversion of syngas to gasoline using ExxonMobil methanol-to-gasoline process
- 15,000 - 20,000 barrels per day of refined hydrocarbon liquids (primarily gasoline), which will be sold into the regional market.
- Carbon dioxide will be extracted and sold via pipeline to the enhanced oil recovery market in Wyoming
- Progress: FEED well advanced (SNC Lavelin is the EPC contractor) construction is expected to start in 2008 with operation scheduled for 2013
- Capital investment of approximately US$2 billion

Ohio River Clean Fuels CTL Project

Baard Energy LLC is developing a 50,000 bbl/day coal-to-liquids facility incorporating “very-low–carbon-emissions” technology.

The main features of this project are:

- $5 billion coal-to-liquid fuel (CTL) project located near Wellsville, Ohio.
- technology license to use the Shell Coal Gasification Process to produce syngas from coal with up to 30% biomass (wood chips)
- At least 80 percent of the carbon dioxide produced in the process will be captured.
- Much of the CO2 is expected to be sold for enhanced oil recovery in nearby oil fields, while the remainder will be sequestered.
- A major year-long study by Idaho National Laboratory found that the ORCF plant would have a significantly smaller carbon “footprint” than conventional refining.
- FEED commenced in Oct 2007 with AMEC as engineer/contractor

Co-Gasification of Coal and Biomass: An Alternative Approach to Carbon Mitigation

	GJs/Tonne:
Bituminous coal (Pgh seam dry)	31
Biomass (over-dried)	16

1 GJ Input

0.05 GJ Biomass +
0.95 GJ Coal

0.48 GJ Output

0.15 GJ Electricity +
0.33 GJ F-T Liquids

Net Carbon Emissions

1. **All Coal plant:** **28.3 kg C per GJ of F-T liquids**
2. **Coal + Biomass Plant:** **25.0 kg C per GJ of F-T liquids**

Therefore, by co-feeding 5% biomass on an energy input basis, carbon emissions are reduced by about 12%

F-T Liquids Production from Coal and Coal + Biomass with CO_2 Capture and Alternative Storage Options; R.H. Williams, et al; review draft 13 Jan 2006

Idaho National Laboratory (INL) Study

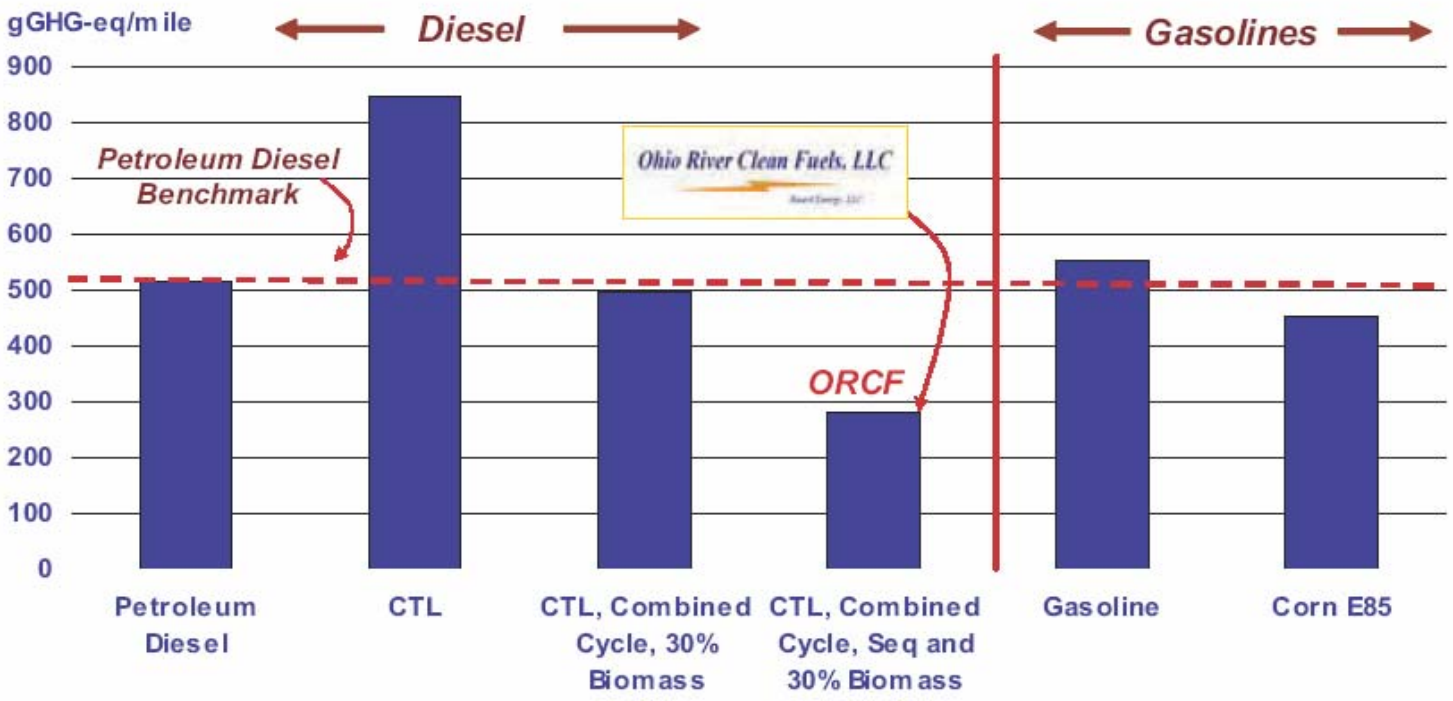
- 12 month environmental study of ORCF Project
- Well-to-wheels / Mine-to-wheels comparisons with Argonne GREET model
- 46 percent less emissions of carbon dioxide and other greenhouse gases than conventional diesel transport fuels
- Dramatically reduced emissions of regulated pollutants compared with low-sulfur diesel fuel. (SO2 reduced 86%, NOx reduced 25%, particulates reduced 18%)

Findings of INL's CTL Environmental Study

Life-Cycle GHG Emissions for Various Fuel Types

GREET Model Comparative Analysis

Idaho National Laboratory



Potential for Carbon Mitigation (NZ project)

Carbon dioxide produced

- On a "Life Cycle Analysis" (LCA) basis, combustion of a barrel of CTL fuel made from Southland lignite would contribute about 1.1 tonne of CO2 to the environment.
- This is made up of:
  - 0.4 tonne of CO2 from combustion of fuel in an engine: and
  - 0.7 tonne of CO2 extracted from the CTL process and also emitted from gas turbines
- By comparison, combustion of a barrel of petroleum fuel from a refinery would contribute about 0.55 tonne of CO2, made of 0.4 tonne of CO2 from combustion of fuel plus 0.15 tonnes CO2 from production, transport and refining of crude.

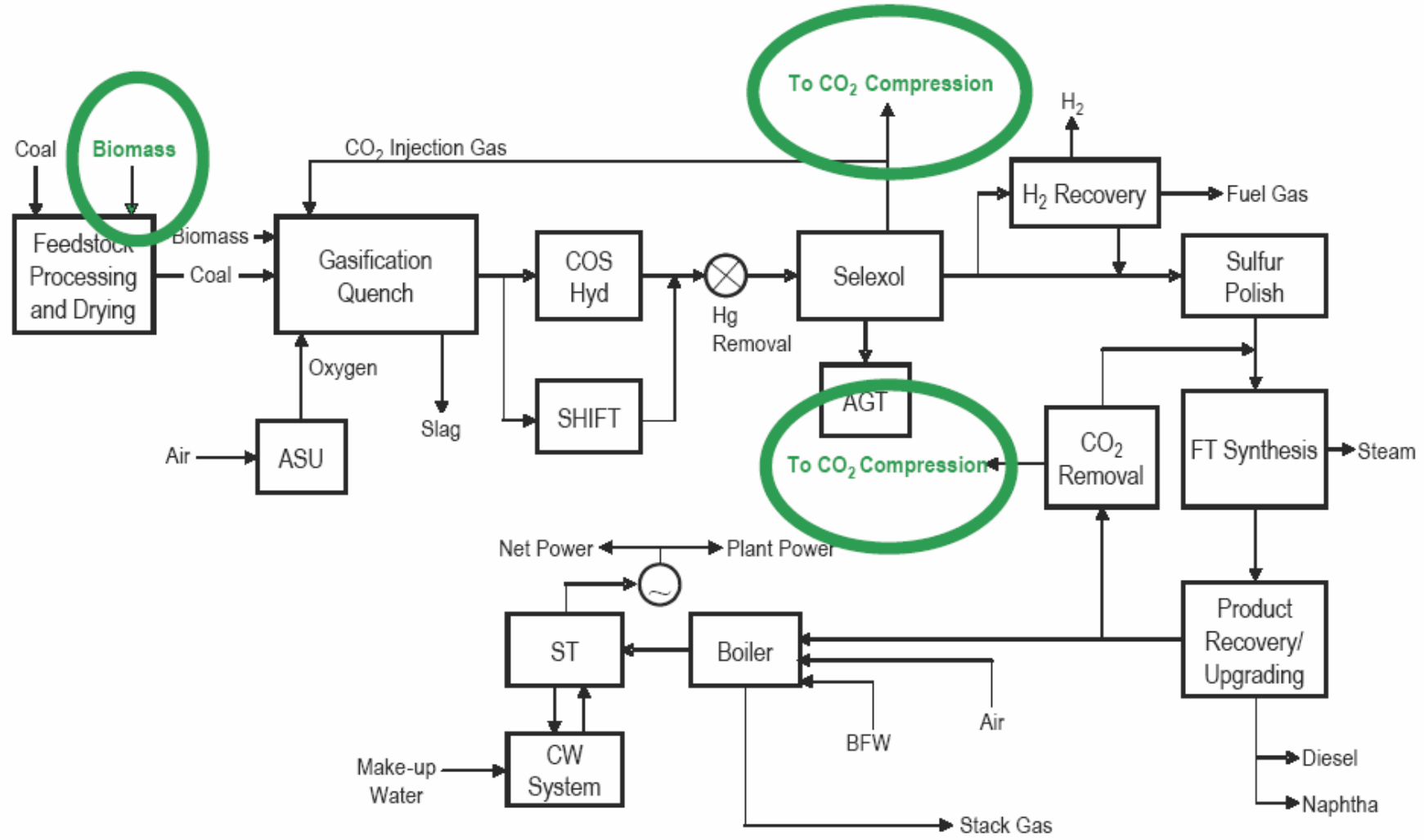
Potential for Carbon Mitigation

Carbon mitigation options

- Before considering geosequestration, there are several options that could be considered for reducing the amount of CO2 discharged to the environment.

CO2 Contribution	**tonne CO2/bbl**
FT Liquids Combustion	0.4
Base Process case	0.7
Power export credit	-0.12
10% CSM addition (50 mmscfd)	-0.11
10% Biomass blend (energy basis)	-0.11
Net Emissions with mitigation options	**0.36**

Process Flow Diagram of CBTL w/CCS



Potential for Carbon Mitigation

Geosequestration options

- We have looked at the potential for geosequestration of CO2 in the Western Southland onshore basin. This was mostly done by Richard Self who was one of the first to implement CO2 injection for enhanced oil recovery in the United States in the 1970's
- A review of available public data for the five sub-basins comprising the onshore and offshore of the Western Southland region of New Zealand indicates a significant potential storage capacity for long term sequestration of carbon dioxide.
- In the Waiau basin alone, there would appear to be capacity to hold of the order of up to nine billion tonnes of super-critical CO2 in the Beaumont formation.

Potential for Carbon Mitigation

Geosequestration options cont'd.

- These basins also indicate potential leaks along faults, both from onshore surface indications and geological interpretation of subsurface migration failures. Neither of these observations nor explanations are considered to negate the potential to safely store over 100 years of CO2 production from a 50,000 bpd CTL plant; more data and study are required to substantiate the potential.
- Even if only 10 percent of the potential 9 billion tonnes storage capacity were to be available, it would still offer sufficient storage for the CO2 output from a large CTL industry producing a total of 100,000 bpd over 50 years

In Summary

- By converting lignite to ultra-clean fuels and sequestering the captured CO2, GHG emissions from NZ road transport could be reduced significantly below present levels in a cost effective way not achievable by any other means.
- A plant including just 10% biomass and sequestration of 85% of the captured carbon dioxide would have about 20% lower GHG's than for conventional petrol.
- The outcome is an inherently environmentally cleaner fuels "cycle" than for any other fuels
- Estimated production cost of 65 – 70 US$/bbl is to be compared with ex-Singapore diesel cargo price, currently about US$110/barrel.

The Future