GTL in the XTL Mix

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GTL, CTL, BTL Interactions
Topics

- Current interest in CTL & BTL
- Difference between GTL, CTL, BTL product quality
- Effect of CTL & BTL product volumes on GTL commercial space
- Critical issues that might affect GTL:
  - Biomass as BTL feedstock
  - XTL Economics and resource availability
  - CTL CO_2 emissions

About E-MetaVenture, Inc.

- Consulting, Design, Training firm established in 2000
- XTL, petroleum refining & gas processing, novel technologies
- Feasibility studies, technology evaluation, process design, energy optimization, project development, litigation support, customized training, strategy development
- Active in the Middle East, East Asia, North & South America, Europe

CTL in Crossroads

- Significant coal reserves worldwide:
  - To last ~150 years at current usage
  - More evenly distributed with significant reserves in USA, China, Russia, India, Australia

- Existing CTL: approx. 150 KBD
  - South Africa Sasolburg converted to GTL
  - Inner Mongolia DCL (shakedown/startup)
  - Large number of projects in development
    - China, India, Australia,…

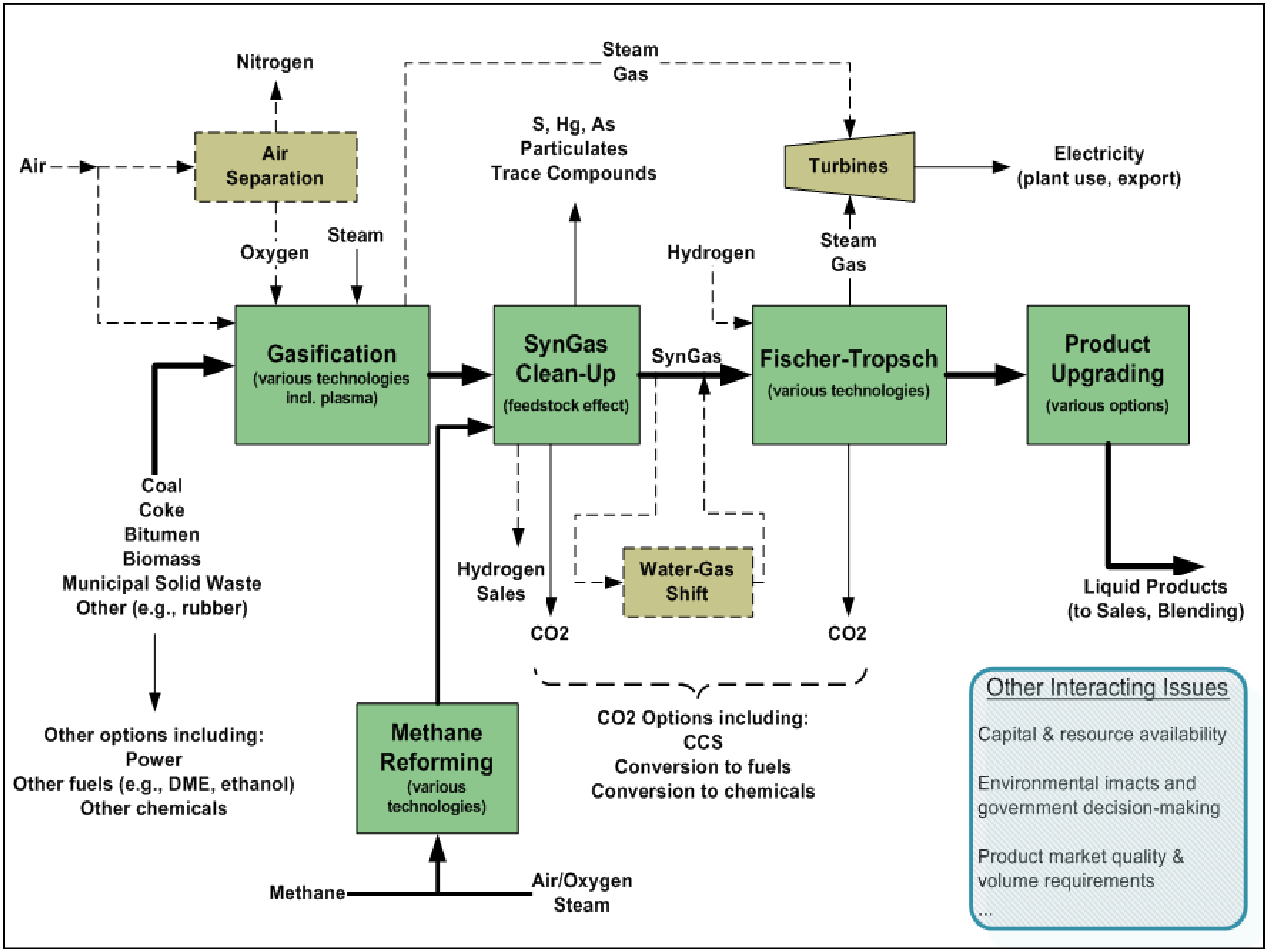
- Technology improvements:
  - FT, gasification, and post-processing
  - Other options including co-generation
  - Critical issue: CO_2 emissions and fate

BTL of Great Interest

- Crowded technology space; much in development
- Great political and policy interest in BTL and other biomass-to-fuels
  - Example: US DOE Biorefinery Assistance Program included $100s of million on BTL-related R&D in 2009

- 1st, 2nd, 3rd generation biomass-to-fuel technology and commercialization using a variety of feeds
- Feedstock can be used to make products through non-FT routes:
  - Ethanol, Bio-diesel, Pyrolysis oils, Bio-DME,…
- Testing many different and unique biomass feeds. Example: Kentucky Horse Park to build a biomass gasification plant at the park to process 3,450 tons/yr of horse muck to generated 1.6 MWh of electricity!

KENTUCKY HORSE PARK



Nitrogen
Steam
Gas
Air
Air
Separation
S, Hg, As
Particulates
Trace Compounds
Turbines
Electricity
(plant use, export)
Oxygen
Steam
Hydrogen
Steam
Gas
Gasification
(various technologies
incl. plasma)
SynGas
Clean-Up
(feedstock effect)
SynGas
Fischer-Tropsch
(various technologies)
Product
Upgrading
(various options)
Coal
Coke
Bitumen
Biomass
Municipal Solid Waste
Other (e.g., rubber)
Hydrogen
Sales
CO2
Water-Gas
Shift
CO2
Liquid Products
(to Sales, Blending)
Other options including:
Power
Other fuels (e.g., DME, ethanol)
Other chemicals
Methane
Reforming
(various
technologies)
CO2 Options including:
CCS
Conversion to fuels
Conversion to chemicals
Other Interacting Issues
Capital & resource availability
Environmental imacts and
government decision-making
Product market quality &
volume requirements
...
Methane
Air/Oxygen
Steam

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Major XTL Products

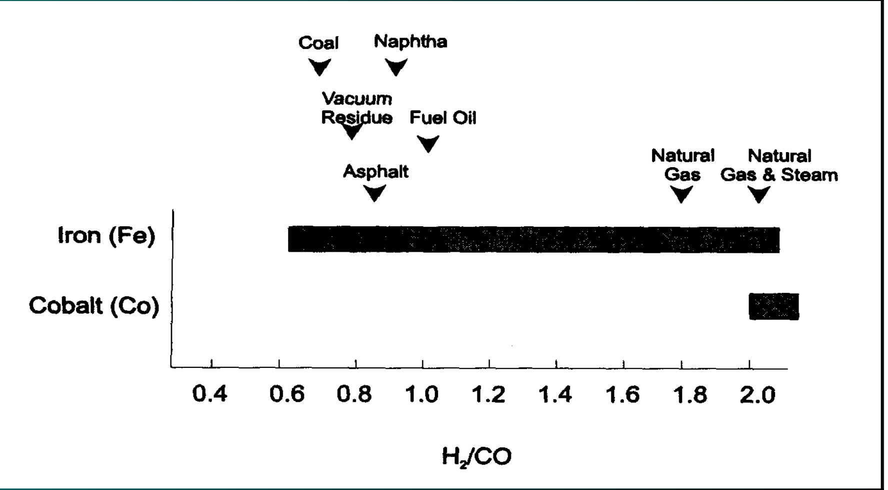
Sample product slate for 100 KBD facility

	No HC	With HC	Comments	
LPG	2	4	• Similar to other plant (LNG, refinery) LPG	• Can be co-processed and marketed with them
Naphtha	18	26	• Straight chain paraffinic • Near zero sulfur	• Preferred use: steam cracker feed
Jet-Kero /Diesel	50	70	• High cetane • Near zero sulfur	• Low density • Low aromatics
Lubes	30	<1	• High grade • Low volatility • Low pour point	• Low viscosity • Low sulfur
Wax	10	<1	• High quality	
Specialty	α-Olefins, Solvents, Detergents, Drilling Fluids,…			

Difference between GTL v. CTL/BTL Product Quality?

Classic CTL

- H2/CO ratio in syngas
  << 2.1 (ideal value)
- Iron-based FT catalyst to allow for water-gas shift chemistry
  $CO + H_2O \leftrightarrows CO_2 + H_2$
- Lower productivity with Fe-based catalyst
- Different product distribution, branching structure, saturation



Sample FT Reactor Product Distribution		
	Iron-Based	Cobalt-Based
Naphtha	10%	15%
Jet & Diesel	20%	30%
Wax (C20+)	60%	40%
	Olefinic	Paraffinic

After Peter Tijm (2007)

More on Classic CTL v. GTL

- Downstream processing differences (hydrotreating, mild hydrocracking, isomerization) to meet product specifications
- Significant impurities in CTL/BTL feedstock when compared with GTL feeds
  - (Side note: Co-based FT catalyst highly sulfur-sensitive)
  - Impurities (sulfur, nitrogen, metals) removed via various processes in order to meet product specifications
- Implication: higher capital and operating cost for CTL

Work continues On improving FT using novel reactors and catalyst

Velocys microchannel FT reactor

Syntroleum cobalt-based catalyst for use in CTL/BTL

New Jet Fuel Specifications

ASTM D-7566 approved for 50/50 blend in October 2009

- "Drop-in" as alternatives to petroleum-based jet (D-1655)
  - Completely interchangeable and compatible
  - No requirement for modification/adaptation of fuel distribution network or engine fuel system
- No differentiation made between CTL, GTL, or BTL source

	GTL Jet (Syntroleum)	CTL Jet (Sasol)	JP-8 Average	JP-8 Specs
Paraffins (vol%)	100	100	60-80	
Aromatics (vol%)	0	0	17.9	< 25
Specific Gravity	0.756	0.760-0.775	0.803	0.775-0.84
Flash Point (°C)	45	42-57	49	> 38
Freeze Point (°C)	-51	<-60	-51.5	< -47
H2 Content (mass%)	15.4	15.06	13.84	> 13.4
Heat of Combustion (MJ/Kg)	44.1	43.2-44.0	43.25	> 42.8
Sulfur (wt%)	0	0	0.05	< 0.3

After R. L. Altman (2009)

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Will BTL/CTL Volumes Affect the GTL Product Market Space?

- EIA and others' XTL volume projections
- Consider the cases of diesel and lubricants

- Issues include:
  - Significant flux due to policy zigzags, economic conditions, environmental concerns
  - Technology developments and their impacts
  - Feedstock availability and price
  - Other potential uses for BTL/CTL feedstocks
  - Other (parallel) technologies for diesel augmentation/replacement

GTL Diesel Supply Projections

- Approx. 50 KBD 2009 total liquid production capacity
  - South Africa mix of CTL and some GTL
  - Includes nameplate 33,000 BPD for QP/Sasol Oryx I

- Qatar Shell Pearl (140,000 BPD, start-up 2011-2012)
- Nigeria Escravos Sasol/Chevron (34,000 BPD, startup 2013?)
- Trinidad World GTL stopped & in receivership (2,250 BPD)

- A large number of potential projects; a small fraction likely to be built
- Many ups & downs. Example: PRC rule changes regarding NG use in the last 2-3 years

- California Energy Commission estimate:
  - 2015: 388 KBD global GTL diesel
  - 2020: 800 KBD

- Sasol Chevron estimate: 600 KBD by 2016-2019

- EIA 2009: 200-700 KBD by 2030 (range due to investment scenarios)
  - (0 KBD projected for US)

CTL Diesel Supply Projections

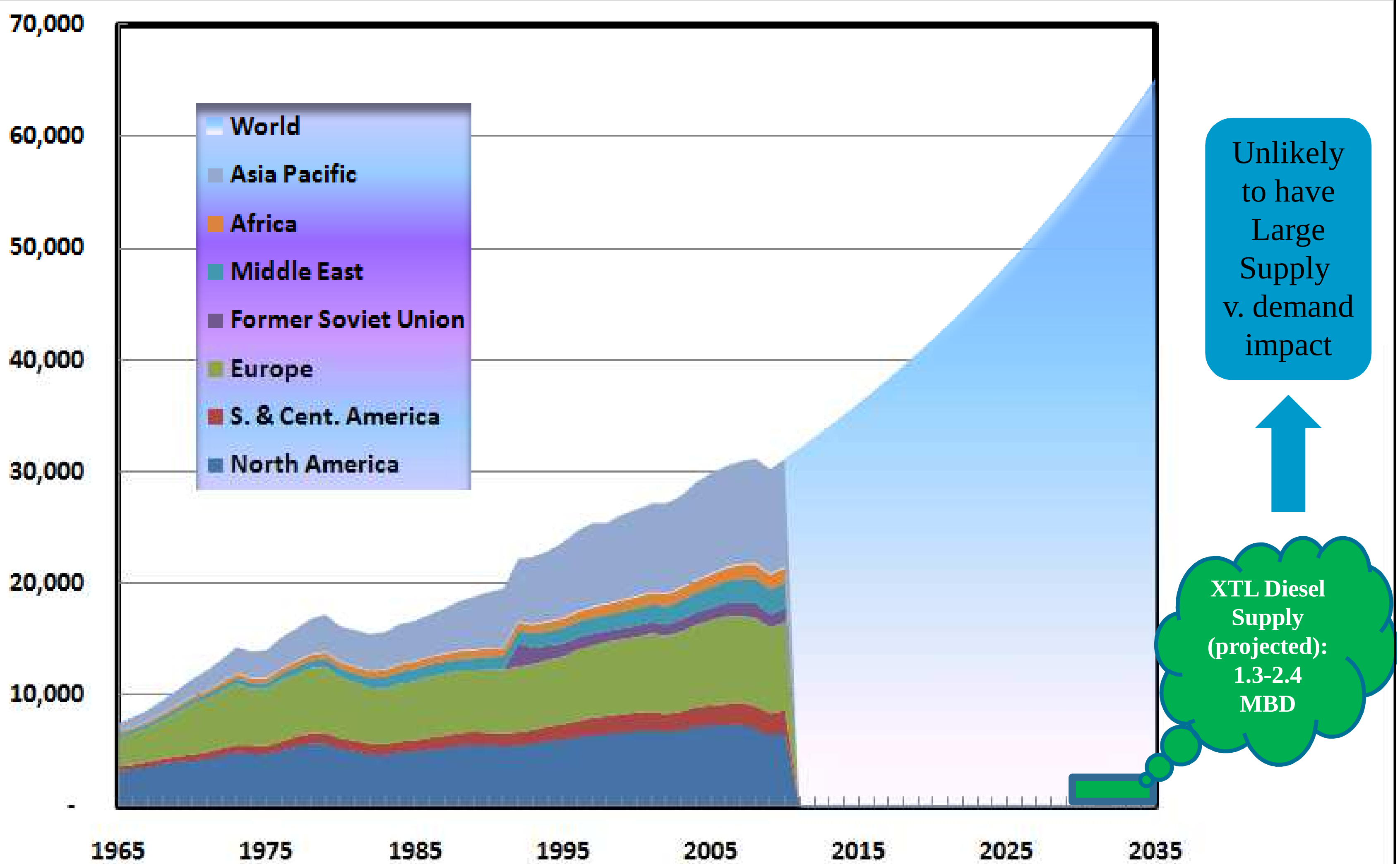
- Key potential locations: US, Peoples Republic of China, Russia, Australia, …
- PRC projections & activity:
  - 2007 study: as much as 160 KBD liquid fuels projected
  - Another (IEA, 2007): 180 KBD by 2015, 750 KBD by 2030
  - Environmental concerns—all but two projects cancelled (20008-09)
  - 20 KBD Inner Mongolia DCL: trial operation (Oct. 2009)
- USA projections (EIA 2010):
  - 110 KBD for US by 2020!
  - 230-250 KBD for US by 2035
- Worldwide projections 300-2,000 KBD by 2030 (range due to investment scenarios; EIA 2009)
- Technological improvements critical including in-situ gasification, CO_2 sequestration and re-conversion, *etc*.—many at early stages
- Internal analysis based on technology, environmental, political, policy factors:
  - 300-500 KBD by 2020
  - 600-1,000 KBD by 2035

BTL Diesel Supply Projections

- US EIA 2010 for all "biofuels" including ethanol, biodiesel, FT-based, *etc*.
  - From a current/actual of close to 1 million BPD
  - 1.25 million BPD by 2020
  - 2.56 million BPD by 2035
- Our analysis based on feedstock availability, economics, capital concerns, technology development rates:
  - 200-400 KBD BTL diesel by 2020
  - 500-700 KBD by 2035

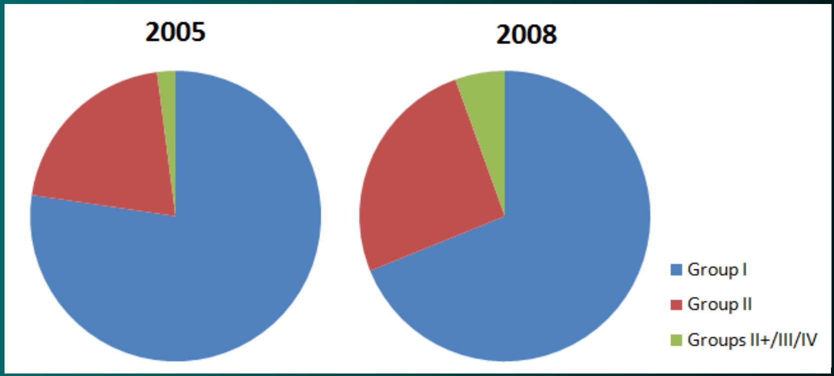
FT Diesel v. Global Middle Distillates

MDist (incl. Jet/Kero) projections at 3% annual growth



Lubes Markets

- Basestock global market size ~ 962 KBD in 2008 (800 KBD in 2005)



- Slow overall growth
  - Rapid demand growth in developing regions (*e.g.*, China, Brazil)
  - Decline in US, WE, Japan, Australia, New Zealand
  - Overall in 2008: 1.4% growth (1.8% in 2005)
- Assuming 1.6% growth rate:
  - 1,160 KBD market size in 2020
  - 1,480 KBD in 2035

Potential XTL Lubes Impact

- Consider previous 2035 XTL projections
- Without hydrocracking, potential lubes manufacture approx. 50-60% of diesel
  - 2035: 650-1,200 KBD
  - Market overwhelmed

- Hydrocracking will continue to be a key component of most or all new XTL facilities

- Likely scenario in terms of impact of XTL on lubes markets:
  - XTL lubes will trigger shutdown of less efficient lube capacity
    - Group I plants highest manufacturing cost—have been shutting down

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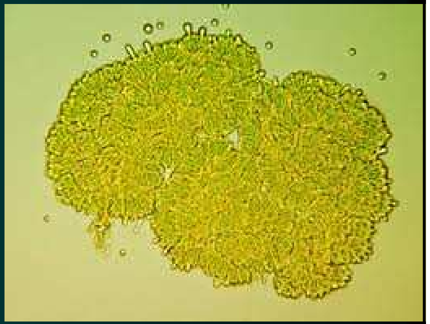
Critical Issue: Biomass as BTL Feedstock

- Feed availability and impact on food supply/environment
- Issues of "green-ness" and true sustainability
- Types of feed and yields



- 1st, 2nd, 3rd generation biomass to fuel technology and commercialization
  - 1st generation: biofuels from sugar cane or corn (commercial in small & large scales)
  - 2nd generation: biofuels from waste vegetable elements such as corn stover, cane bagasse, wheat straw, hay, soft wood, stems, leaves, wood chips, pulp, grass and other cellulosic matter (in R&D, pilot testing stages)
  - 3rd generation (aka "holy grail"): biofuels from algae (in R&D)

Some Potential BTL Feedstocks

	Liquid Yield (Gallons/Year/Acre)	Fuel Type	Land Needed to Produce 1 million BPD (Km^2)
Corn	15-18	Alcohol	3,716,364
Sugar cane	20-25	Alcohol	2,725,333
Soybean oil	40-50	Diesel	1,362,667
Sunflower oil	100-105	Diesel	598,244
Palm oil	600-650	Diesel	98,112
Coconut oil	280-300	Diesel	211,448
Caster oil	150-155	Diesel	402,098
Olive oil	120-130	Diesel	490,560
Rapeseed oil	125-130	Diesel	480,941
Micro-algae	1850-5000	Alcohol/Diesel	17,904

UK crop area: 171,000 Km^2

UK total arable land: 744,000 Km^2 (includes woodland, grasses, barefallow, rough grazing, Set-aside)

Based on D. P. Lal (2010).
Note: micro-algae Km^2 is for pond surface area.

Critical Issue: Economics and Resources

- Economics of XTL and impact on speed and degree of commercialization

- GTL: have several examples by now, ranging from $30 K/BBL capacity and up
- CTL: $85-100 K/BBL and up
- BTL: likely in the CTL range

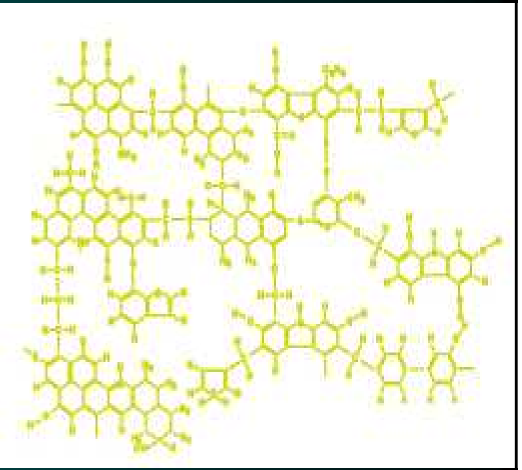
- Consider projected worldwide capacities and potential total capital cost

	Projected Capacity by 2030-2035 (KBD)	Projected Capital (Bil. 2010 dollars)
GTL	200-700	6-21
CTL	600-1,000	60-100
BTL	500-700	50-70

- Each project will be multi-billions requiring several partners and conservative due-diligence
- Other biofuels, alternative-resource projects will compete for same capital, feedstocks, skills/resources
- Other resources to consider: manpower and skills, E&C and construction material availability

Critical Issue: Environmental Impacts, Politics, Policy

- Issue of CO_2, water usage, environmental impact
  - CO_2 fate and options
  - Impact of all above on the economics, direction, speed of development
  - Example: China 2008 decision on CTL



- CO_2 from CTL: ~0.65 ton CO_2 per Bbl of liq. Prod.
  - 50,000 BPD plant: 11.3 million tons CO_2/year
  - One million BPD: 226 million tons CO_2/year

  - Is this significant?
  - How important is it to carbon capture and sequester (CCS)?
  - Are there other mitigation options?

CTL CO_2 Emission Projections

- CTL with no mitigation: emissions better than coal-fired power plants
- CTL with mitigation: emissions on par with refineries
  - Typical CCS in CTL: 80-90% CO_2 emission reduction
- Large stationary source CO_2 in 2005: 13,466 million tons

Consider EIA (2007) US CTL projections

Projected Emissions from CTL (million tons CO_2/years)	**without CCS**	**with CCS**
2015	10-41	1-8
2020	28-61	3-12
2030	175-230	17-46
2030 CTL Emissions as % 2005 Global Large Stationary Sources	1.3-1.7	0.1-0.3

KEY NOTE

Nearly all responsible Western parties agree

CO_2 issue is critical

Plan to incorporate mitigation

No CTL without mitigation

Rough CTL+CCS Economics

50,000 BPD*

- Consider 50,000 BPD CTL
- Addition of CCS (incl. 50 km pipeline):
  - $300 MM extra to TIC
  - Or $230 MM/year to operating costs (including amortized TIC addition)

Case	CTL	CTL+CCS
ROI	16.8 %	11.3 %
Simple Payout	6 years	9 years

One scenario. For discussion purposes only. Results depend on a number of variables and parameters.

ISSUE
Mitigation Studies Proceeding at Slow Pace

Other Approach to CO_2 Issue?

- Significant R&D on conversion to useful products.
- Including catalytic and biocatalytic technologies. Examples:
  - Carbon Sciences Inc. (USA): to methanol, diesel/gasoline/jet
  - Agency for Marine-Earth Science & Technology (Japan): to methane
  - Mantra Venture Group (Canada): to formic acid, formate salts, oxalic acids, methanol
  - University of Oxford (UK): to methanol
  - Sandia National Laboratory & partners (USA): to diesel
- US DOE funding several projects including CO_2 mineralization to bicarbonate & carbonates (ultimately to construction materials), conversion to plastics polycarbonate products, biofuels and "biocrudes" using algae, *etc*.
- Additionally, significant work on improving CCS efficacy and economics

Summary

- Little difference in quality between GTL and other XTL products
  - In most cases and using the modern proper process design
- CTL/BTL volumes unlikely to adversely affect major fuel (*e.g.*, jet, diesel) markets
- CTL/BTL volumes could contribute to oversaturation of lubes and wax markets
  - New units will continue to include mild hydrocracking
- Biomass-as-feedstock is evolving rapidly with much R&D and room for improved productivity
- Commercialization to continue in a measured pace due to their high capital cost and resource requirements
- Issue of CO_2 emissions from CTL (and possibly BTL) is critical and could impede commercialization progress

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