GTL and CTL Commercialization: Status and Impact on Global and Regional Product Markets

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Introduction

- Significant interest in GTL/CTL technology and its products
- One new GTL unit on line late 2006; others slated for the next 5 years
- Examination of the likely impact of key GTL/CTL products in their respective markets
  - Diesel
  - Lubes
  - Waxes

Sample GTL/CTL Product Slate

50 MBD Plant

	No HC (MBD)	With HC (MBD)	Comments	
LPG	1	2	• Similar to other plant (LNG, refinery) LPG	• Can be co-processed and marketed with them
Naphtha	4	13	• Straight chain paraffinic • Near zero sulfur	• Preferred use: steam cracker feed
Diesel	25	35	• High cetane • Near zero sulfur	• Low density • Low aromatics
Lubes	15	<1	• High grade • Low volatility • Low pour point	• Low viscosity • Low sulfur
Wax	5	<1	• n-paraffins • High quality	

GTL/CTL Diesel Quality & Effect of Regulatory Environment

- GTL/CTL diesel virtually sulfur-free, low aromatic (<5% PNA), high cetane
- Regulations on
  - "Alternative" fuel content (*e.g.*, biofuels)
    - Congressional Act of 2005: $0.50/gallon incentive for US CTL fuels
    - Other incentives that would support US CTL might be in the works
  - Fuel composition
  - Emissions
- Fuel composition regulations:
  - Tightening standards for light and heavy-duty diesel vehicles
  - Expected to continue to tighten
  - Sulfur, aromatics, PNAs
  - US, WE, Japan: sulfur down to 10-50 ppm
  - Developing world: sulfur mandates down to 200-1000 ppm

Emissions

- A number of studies demonstrated tailpipe emission benefits
  - Neat or in blends
  - Compared to both conventional as well as reformulated
  - Some controversy about this data and its interpretation

- Typical examples of tailpipe emission results:

  - 40-50% reduction in HC, 9% in NOx, 30% in particulates when compared with low-sulfur refinery diesel

  - Benefits with current as well as new engine technologies (Euro-4 and Euro-5) using neat and blend GTL diesel

- Well-to-Wheel: no great benefit for GTL diesel
  - Shifts CO_2 emissions from auto to plants (away from population centers; potential for sequestration)

Additional Comments on GTL/CTL Diesel Quality

- Highly paraffinic ➔ typical cetane numbers in 70-80
- Lower density than refinery diesel
  - 0.77-0.80 Kg/L v. 0.83-0.85 Kg/L
  - ➔ Density premium
  - ➔ Perceived lower fuel efficiency (in MPG)
- Relatively poor cold-start; low lubricity
- A number of studies (90s) show a premium of 5-10 ¢/gal
- More recent studies (Baker and O'Brien) expect CTL diesel to be half-way between ULSD (USGC) and LA CARB
  - ➔ 120-130% of WTI

GTL Diesel Supply Projections

- A large number of potential projects
- Only a small fraction are likely to be built short-term

- Qatar: self-described GTL capital
  - Oryx I: 2006 start up; March 2007 upgrader on line, May 2007 1st product lift
  - Shell Pearl: 2009 (cost issues: $18 billion)
  - ExxonMobil: 2011 (canceled Feb. 2007)
  - Marathon, ConcoPhillips on hold per Qatar government temporary moratorium—likely to hold at least until 2009

- Nigeria:
  - Escravos (Sasol/Chevron): under construction (delays and cost increase)

- California Energy Commission estimate:
  - 2010: 75 MBD global GTL diesel capacity (seems low)
  - 2015: 388 MBD
  - 2020: 800 MBD

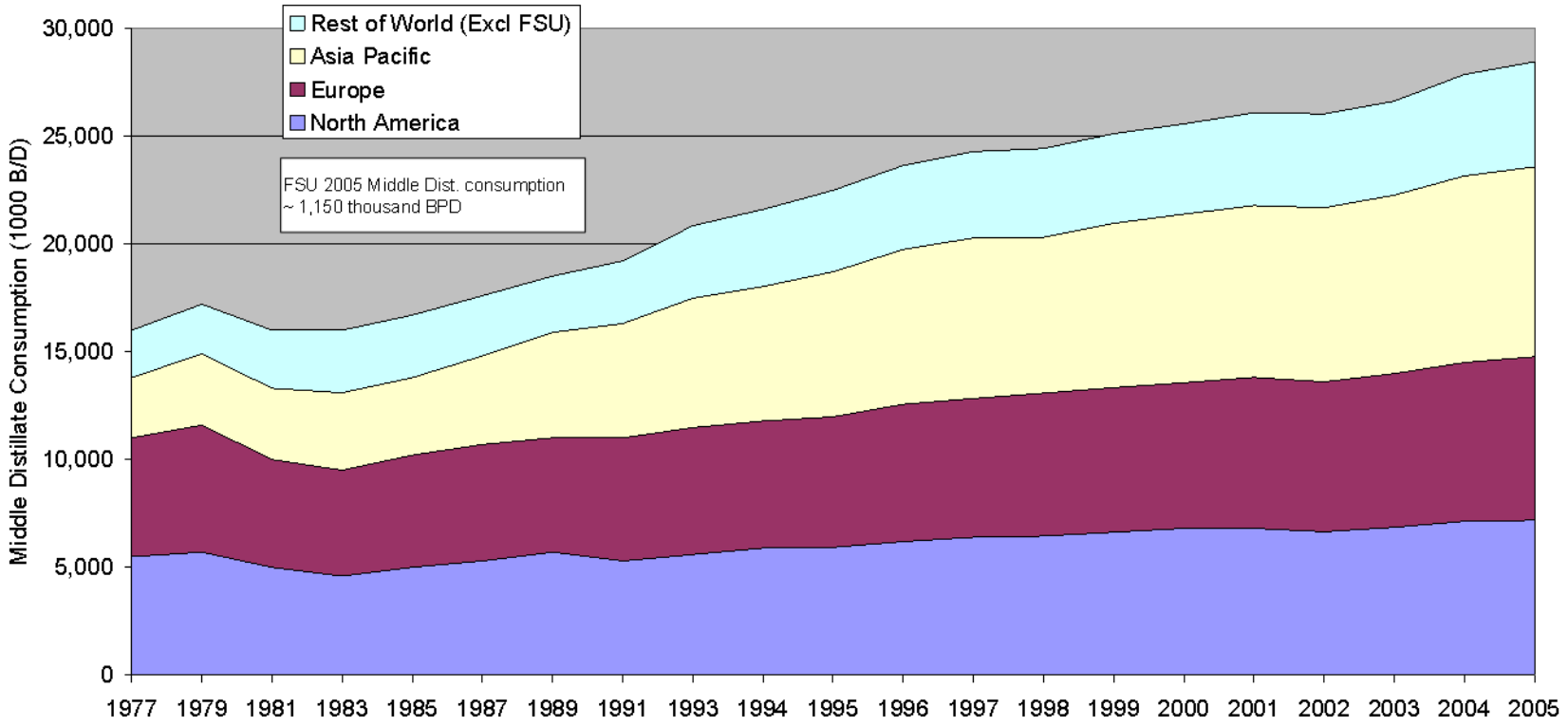
- Sasol Chevron estimate: 600 MBD by 2016-2019

CTL Diesel Supply Projections

- Much less well-defined
- Sasol plants in SA recently switched to NG from Mozambique rather than coal
- Key potential locations: US, Peoples Republic of China
- US CTL study (Baker and O'Brien):
  - 2017-2022: 4-6 large-scale (>40 MBD) CTL in Western US
  - Some smaller plants under consideration in the Eastern US
    - Potential: 250 MBD of middle distillates
- PRC CTL:
  - A number of projects under study; considered a key component of the PRCs overall, long-term energy strategy
    - Example: 20 MBD plant in Inner Mongolia
    - A "new" key issue: recent environmental awareness of the PRC government
  - Projected (Robinson and Tatterson, OGJ Feb 2007 study): as much as 160 MBD liquid fuels
- Hand-waving estimate: 300-500 MBD by 2020

Automotive Diesel/Mid. Dist. Market
Historical

- Global middle-distillate market: 28-29 MMBD
  - Approx. 3% annual growth
  - 14-15 MMBD automotive diesel



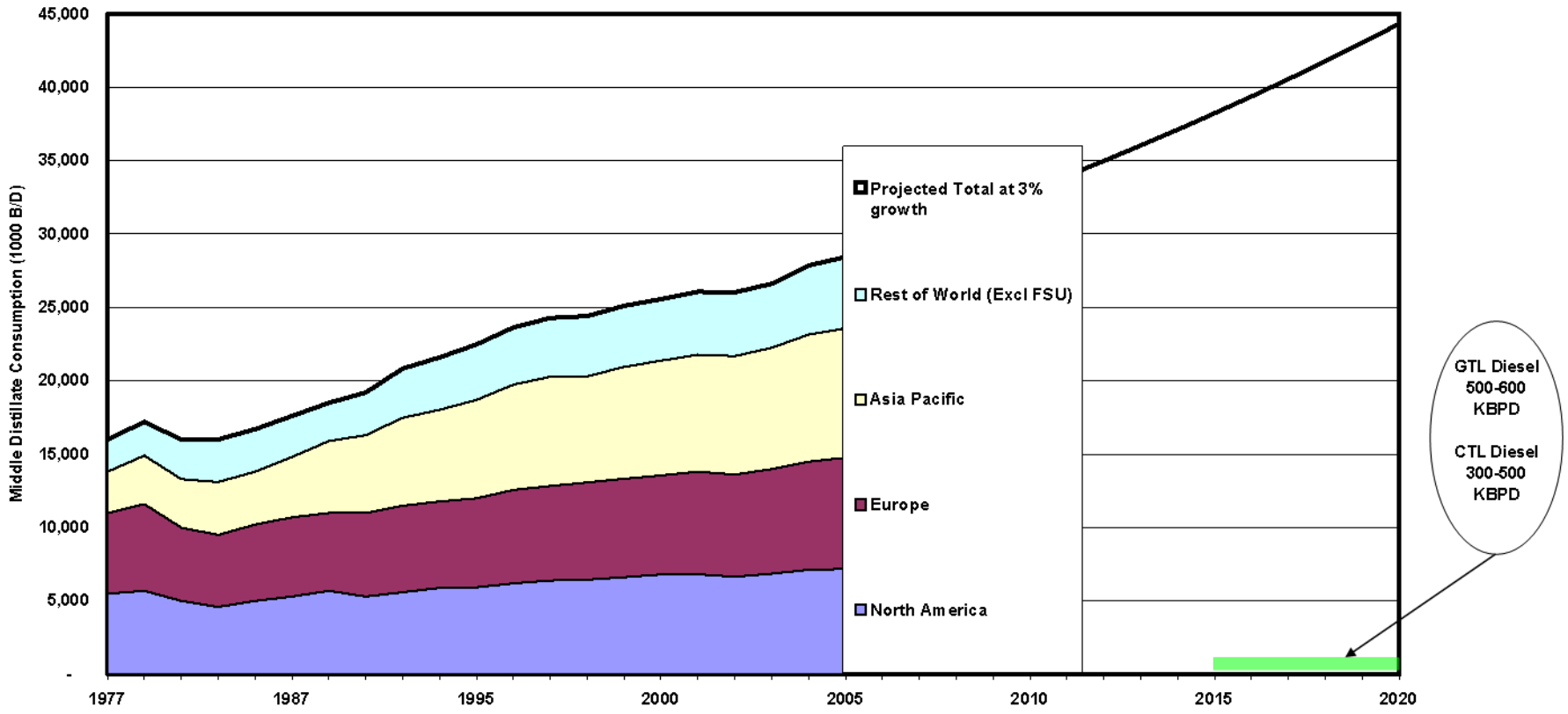
Growth Projections (1)

- Europe: increase in diesel-powered autos
  - Currently over 60% of auto sales in France and Austria
  - Emission mandates, jurisdictional tariff strategies, improved auto designs, increased low-emission fuel availability
- US: driven by commercial sector and tied to overall economy growth (average about 5% annual)
  - Light diesel vehicles 4% of total market
  - Regional and regulatory efforts are likely to increase diesel auto usage
- Asia-Pacific: rapid yet uncertain growth
  - China factor: 8-10% annual economic growth; loosely correlated to diesel fuel usage

Growth Projections (2)

- Globally: diesel powered autos at about 30%
  - Projected to grow to about 40% by middle of next decade
  - Followed by partial replacement with hybrids
- Overall:
  - Projected middle distillates demand to grow by 3% annual
  - To 44 MMBD in 2020
  - 22.5 MMBD automotive diesel
- Question: what is the potential impact of GTL on this market?

GTL/CTL Diesel v. Global Middle Distillates



- Small as fraction of total middle distillates or diesel supply (less than 4% of diesel by 2020)
- Unlikely to impact global market greatly

Potential Impact on Local Diesel Markets

- GTL supply could potentially form a significant portion of a region's diesel
  - Example: Shell estimates one large GTL plant would fully satisfy the city of London and 10 plants would satisfy PADD V
- Possible to develop a critical mass of GTL diesel as blendstock for a small market
  - Example: Shell Bintulu has offered 30% Pura throughout Thailand
  - Also sold as blendstock in Greece, Germany, and South Africa
- CTL supply could have significant impact in US regions
  - Baker and O'Brien 2007 study: as much as 20% of current PADD 2 and all of PADD 4 demand
- CTL in PRC could reduce some of the price, availability, and supply security pressure in the Dubai/Singapore crude and products region

Likely GTL/CTL Diesel Scenario

- Pure GTL/CTL diesel would require separate infrastructure and auto modifications
  - Would take away key GTL/CTL benefit compared to many alternatives: compatibility with current fuels and systems
- In jurisdictions with very tight specifications, volume of GTL/CTL required would be very high
- Most likely use: as a premium blendstock to bring slightly off-spec diesel into compliance
- Competition:
  - HT in refineries, improvement in FCCs and other units
  - Biofuels (*e.g.*, ethanol, methyl esters) are expected to grow in line with tax benefits and mandates
  - ➔ GTL/CTL diesel sulfur premium might erode
  - ➔ Some observers: GTL/CTL diesel premium will be primarily due to its high cetane and low aromatics (benefit for Europe, less so in US and Asia)

GTL/CTL Lubes Quality and Cost

- GTL/CTL lubes produced from isomerization of FT waxes
  - Virtually no sulfur, nitrogen, or aromatics
  - Narrow HC distribution
  - Excellent oxidation stability
  - Excellent volatility and pour point
  - Very high VI (140+)

- Studies suggest attractive economics for production
  - Manufacturing costs similar to Group I/II
  - Quality similar to other basestocks of 140+ VI

Lubes Markets (1)

- Basestock global market size ~ 800 MBD in 2005
  - Group I: 75%
  - Group II: 20%
  - Groups II+/III/IV: 5%
- Groups II+/III/IV expected to grow to >10% by 2015 (perhaps as much as 20% depending on automaker demands)
- Currently at "surplus quality" relative to technical demand
  - Complicated as basestock market is in great flux
  - Shifting quality and specifications likely to consume quality overhang
  - Group I capacity rationalizations continue in NA and WE
    - Triggered by Group II/III construction/expansions primarily in Asia and NA
    - Depends on efficiency and structure of plant

Lubes Markets (2)

- Slow overall growth
  - Rapid demand growth in developing regions (*e.g.*, China, Brazil)
  - Decline in US, WE, Japan, Australia, New Zealand
  - Overall in 2004: 1.8% growth
  - ➔ Basestock movement from NA/WE to other regions

- Increased demand for high quality (Group III/IV)
  - Evolving industry standards for passenger car motor oils (GF-4 in effect; moving towards GF-5)

GTL/CTL Lubes Capacity Impact

- One world-scale GTL/CTL could produce as much as 15-30 MBD lube basestocks (8-15% of current Group II/II+/III/IV supply)
- Example: ExxonMobil Qatar project would have produced 30 MBD lube basestocks
- Estimates and announcements: 50 MBD GTL lube basestock capacity by 2011
- Globally, possibility of at least 200 MBD of GTL lube basestocks by 2020
- CTL lubes: a number of factors including upgrader design and economics

Likely GTL Lubes Scenario

- GTL economics primarily based on gas monetization to produce high quality diesel
  - historical F-T plants (Sasolburg and Segunda) make no lubes
  - Max lubes yields of 20-30% from key GTL plants?

  - In reality: All major GTL plants will include some product cracking

- Likely scenario in terms of impact of GTL on lubes markets:
  - GTL lubes will trigger shutdown of less efficient lube capacity
  - Key: manufacturing cost
    - Typically highest cost today are many Group I plants
    - Some of the lowest cost plants are Group II in US and Asia and Group III in Asia

GTL/CTL Wax Quality

- Unlike petroleum wax (mix of iso- & n-paraffins), today's FT wax is primarily linear in the C_{20-100} range
  - Benefit in high melt applications
  - Require fractionation and blending to meet low and mid-melt applications
- Typically can produce only two wax grades (MPs) and blend to meet all other MPs
- Shell Bintulu and Sasol Secunda provide about 6% of worldwide waxes (low oil content, high MP)
- Oryx and other planned GTL projects
  - No plans announced to sell waxy F-T material or upgrade to finished wax
  - Tight wax markets may create opportunity
  - Possibility: softer wax than from current GTL units with oil content close to slack waxes

Global Wax Overview

- Total global wax capacity in 2005: approx. 10,900 MMlb (~103 MBD)
  - About 13% of the base oil market
  - Most produced from petroleum sources (lube refinery)
  - About 6% currently produced from Shell and Sasol GTL plants

Types of Wax	Wt %
Slack and Semi-Refined	29
Fully Refined	54
Microcrystalline	5
Petrolatum	4
Other	~2
From GTL	6

Sources: *C. Garrigou. First ICIS-LOR Pan American Base Oils & Lubes Conference 2005* and in-house

Wax Supply

- Slack/unrefined wax considered lube refinery by-product
- Production depends on rates of other key products especially Group I base oils
  - Rationalizations in NA, Europe, Asia
  - Wax isomerization to base oils
- Production concentrated
  - 75% in 10 countries
- Over 1/3 of total wax production in Asia (especially refined)
- Companies: CNPC, XOM, Shell, Sasol are largest (55% of production)
- Overall cap. util. ~ 85%
  - High in NA, WE, Asia (~95%)

Total Wax Production incl. GTL (2005)	%
North America	28
Latin America	5
Europe	18
Asia	35
FSU and Eastern Europe	11
ME/Africa	3
TOTAL (MMlb/yr)	~9,300

Sources: *Wax Data 2005 and 2006* and in-house

Wax Demand

- Refined waxes ~ 2/3 of market
- Approx ½ food grade
- Significant wax refining capacity in China
  - ➔ refined wax exported to North America

Approximate Wax Demand by Region (2005)	%
North America	30
Latin America	14
Western Europe	17
Asia	23
FSU and Eastern Europe	12
Middle East/Africa	4

Sources: *Wax Data 2005 and 2006* and in-house

Wax Trends—China

- Chinese crude production steady (3.4-3.6 MMBD) and projected to hold for ~15 years per upstream reserves estimate
  - Waxy/paraffinic
- Economic growth has led to 3-fold crude demand increase over the last 15 years
  - Import 40% of their crude (primarily ME, Russia)—less waxy
  - New refineries focus on transportation fuels
  - Some historical wax-producing refineries changing output and reducing/eliminating wax manufacture
  - Operational issues with imported crudes (?)
- Growth in wax demand (loosely correlated to economic growth of 8-10% annual) and end-use shift
- Result: less Chinese wax available for export
  - Trend expected to continue
  - Question: what would PRC CTL do to this picture?

Source: *Amy A. Claxton of My Energy*

Overall Wax Trends

- Relatively steady growth in global wax demand in the past 25 years
  - Expected to continue at approx. 3% annually
  - Regional and end-product shifts likely

- OVERALL:
  - Continued growth in demand
  - Reduction in supply of petroleum-derived waxes
  - Potential increased supply of natural waxes (*e.g.*, soy, palm)
  - Opportunity for GTL/CTL to impact these trends

GTL/CTL Wax Supply and Demand

- The wax market is easily overwhelmed
  - Example: typical GTL plant can produce 500-1,000 MMlb/yr of high grade wax (if not hydrocracked)
    - 6-12% of total projected market
- One analysis (Shell): potentially as much as 4,400 MMlb/yr new wax by 2015 from GTL
- Another analysis (Kline & Co.): 1,000-1,500 MMlb/yr of FT wax might be needed by 2014 to keep balance

Likely GTL/CTL Wax Scenario

- ➔ Most GTL/CTL plants will hydrocrack their wax-range products into diesel and other light products
- ~1/3 left for use/sale as slack wax or to isomerize into base oils
- Can fine-tune wax produced in light of market
  - Analysts expect GTL/CTL wax to fill high-end niche applications and possibly move into petroleum wax market space

In Summary

- GTL/CTL is capable of producing high quality diesel as well as lubes and waxes
- GTL/CTL is unlikely to have a major impact on the global diesel markets
  - Can be a positive component in meeting high quality blend-stock demands
  - Can have impact in local market supply-and-demand picture
- GTL/CTL lubes and waxes can have a significant effect on the worldwide pool

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