

Synthesis Gas Utilization

The Fischer-Tropsch Process

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Environment and Carbon Management

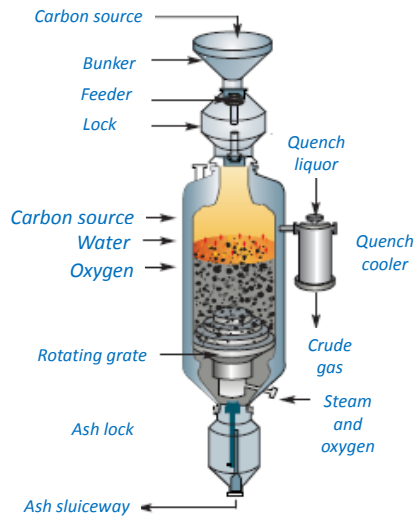
Alberta Innovates Technology Futures

Seminar & Tour - Edmonton Waste Management Centre October 5, 2011
Co-presented by the Edmonton Waste Management Centre of Excellence

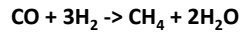
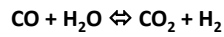
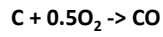
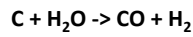
Outline

- **Syngas generation i.e. Gasification**
- **Syngas, a powerful reagent**
- **Syngas to Liquids**
- **Conclusions**
- **Questions**

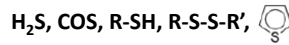
Gasification



Chemistry...

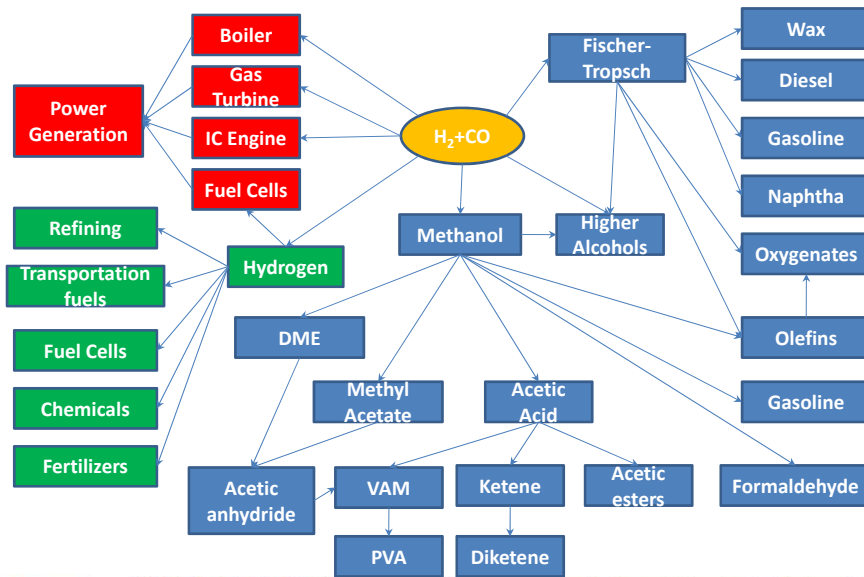


But also...



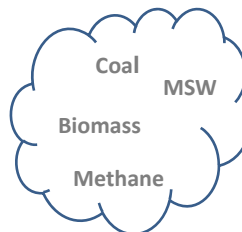
Tars, volatile metals

Syngas as building block



What is "Fischer-Tropsch"?

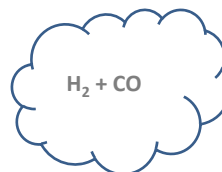
Catalytically mediated chemical process that...



...converts carbonaceous material



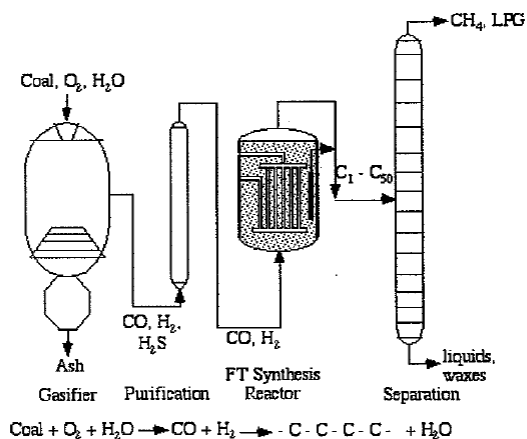
...into hydrocarbon products



...via "synthesis gas" (syngas)

Elements of "Fischer-Tropsch"

IB. Typical Simplified Coal to Liquids PFD (BTL nearly identical)



Conditions

H_2/CO

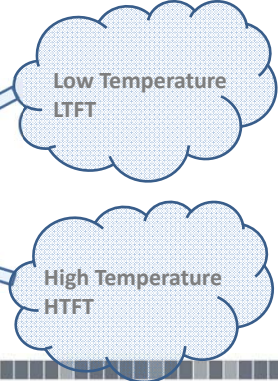
1.0 – 2.2

Pressure

20 – 40 bar (290 – 580 psi)

Temperature

1. 220°C – 240°C
2. 300°C – 350°C



Catalysts

THE PERIODIC TABLE

																		18 VIII A																																																					
1 H 1.008 Hydrogen																	2 He 4.00 Helium																																																						
2 Li 6.94 Lithium	2 Be 9.01 Beryllium											13 B 10.81 Boron	14 C 12.01 Carbon	15 N 14.01 Nitrogen	16 O 16.00 Oxygen	17 F 19.00 Fluorine	18 Ne 20.18 Neon																																																						
3 Na 22.99 Sodium	4 Mg 24.31 Magnesium	3 Al 26.98 Aluminum	4 Si 28.09 Silicon	5 P 30.97 Phosphorus	6 S 32.07 Sulfur	7 Cl 35.45 Chlorine	8 Ar 39.95 Argon											9 K 39.10 Potassium	10 Ca 40.08 Calcium	11 Sc 44.96 Scandium	12 Ti 47.88 Titanium	13 V 50.94 Vanadium	14 Cr 51.99 Chromium	15 Mn 54.94 Manganese	16 Fe 55.85 Iron	17 Co 58.93 Cobalt	18 Ni 58.69 Nickel	19 Cu 63.55 Copper	20 Zn 65.39 Zinc	21 Ga 69.72 Gallium	22 Ge 72.61 Germanium	23 As 74.92 Arsenic	24 Se 78.96 Selenium	25 Br 79.90 Bromine	26 Kr 83.80 Krypton																																				
4 K 39.10 Potassium	5 Ca 40.08 Calcium	6 Sc 44.96 Scandium	7 Ti 47.88 Titanium	8 V 50.94 Vanadium	9 Cr 51.99 Chromium	10 Mn 54.94 Manganese	11 Fe 55.85 Iron	12 Co 58.93 Cobalt	13 Ni 58.69 Nickel	14 Cu 63.55 Copper	15 Zn 65.39 Zinc	16 Ga 69.72 Gallium	17 Ge 72.61 Germanium	18 As 74.92 Arsenic	19 Se 78.96 Selenium	20 Br 79.90 Bromine	21 Kr 83.80 Krypton																																																						
5 Rb 85.47 Rubidium	6 Sr 87.62 Strontium	7 Y 88.91 Yttrium	8 Zr 91.22 Zirconium	9 Nb 92.91 Niobium	10 Mo 95.94 Molybdenum	11 Tc (97.9) Technetium	12 Ru 101.07 Ruthenium	13 Rh 101.07 Rhodium	14 Pd 106.42 Palladium	15 Ag 107.87 Silver	16 Cd 112.41 Cadmium	17 In 114.82 Indium	18 Sn 118.71 Tin	19 Sb 121.76 Antimony	20 Te 127.60 Tellurium	21 I 126.90 Iodine	22 Xe 131.29 Xenon																																																						
6 Cs 132.91 Cesium	7 Ba 137.33 Barium	8 La 138.91 Lanthanum	9 Hf 178.49 Hafnium	10 Ta 180.95 Tantalum	11 W 183.85 Tungsten	12 Re 186.21 Rhenium	13 Os 190.2 Osmium	14 Ir 192.22 Iridium	15 Pt 195.08 Platinum	16 Au 196.97 Gold	17 Hg 200.59 Mercury	18 Tl 204.38 Thallium	19 Pb 207.2 Lead	20 Bi 208.98 Bismuth	21 Po (210) Polonium	22 At (210) Astatine	23 Rn (222) Radon																																																						
7 Fr 87 Francium	8 Ra 223.02 Radium	9 Ac 227.03 Actinium	10 Rf (261) Rutherfordium	11 Db (262) Dubnium	12 Sg (263) Seaborgium	13 Bh (264) Bohrium	14 Hs (265) Hassium	15 Mt (266) Meitnerium	16 Unlabeled (267) Nov. 1994	17 Unlabeled (268) Nov. 1994	18 Unlabeled (269) Nov. 1994	19 Unlabeled (270) Nov. 1994	20 Unlabeled (271) Nov. 1994	21 Unlabeled (272) Nov. 1994	22 Unlabeled (273) Nov. 1994	23 Unlabeled (274) Nov. 1994	24 Unlabeled (275) Nov. 1994																																																						
ALKALI METALS																		ALKALI EARTH METALS																		HALOGENS																		NOBLE GASES																	
LANTHANIDES																		ACTINIDES																																																					
Ce 58 Cerium	Pr 59 Praseodymium	Nd 60 Neodymium	Pm 61 (145)	Sm 62 Samarium	Eu 63 Europium	Gd 64 Gadolinium	Tb 65 Terbium	Dy 66 Dysprosium	Ho 67 Holmium	Er 68 Erbium	Tm 69 Thulium	Yb 70 Ytterbium	Lu 71 Lutetium	Th 90 Thorium	Pa 91 Protactinium	U 92 Uranium	Np 93 (240)	Pu 94 (240)	Am 95 (241)	Cm 96 (247)	Bk 97 (248)	Cf 98 (251)	Es 99 (252)	Fm 100 (257)	Md 101 (257)	No 102 (259)	Lr 103 (262)																																												



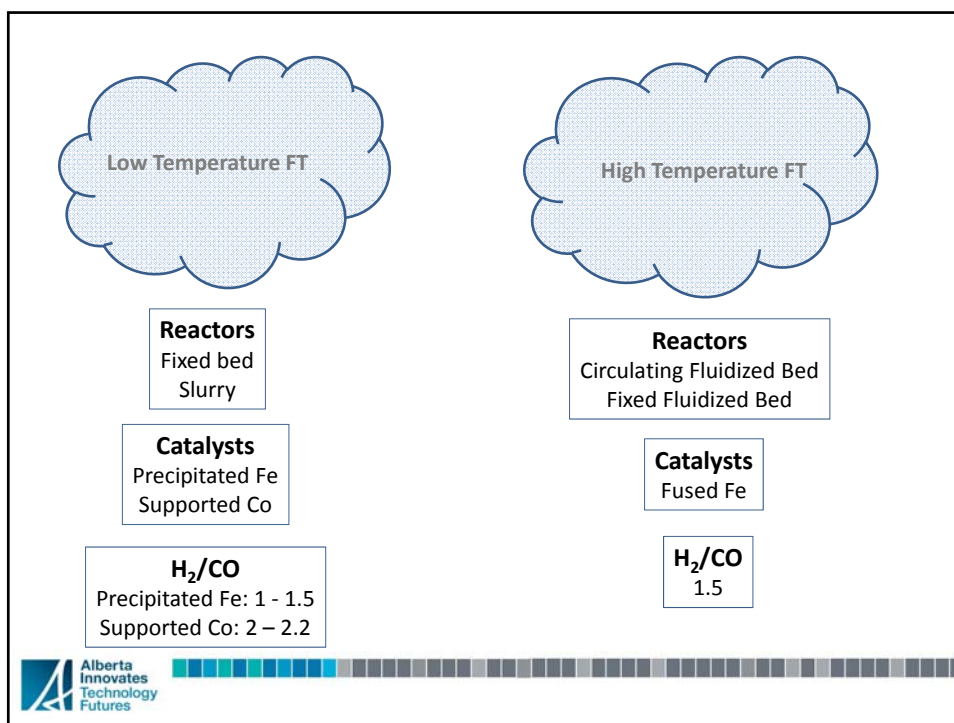


Table 1. Representative Generic Fischer–Tropsch Syncrude Compositions from Cobalt-based LTFT (Co-LTFT), Iron-based LTFT (Fe-LTFT) and Iron-based HTFT (Fe-HTFT) Synthesis

syncrude composition (mass %) ^{(a),(b)}

carbon range	compound class	Co-LTFT	Fe-LTFT	Fe-HTFT
Oil and Gaseous Products				
C ₁	paraffin	5.6	4.3	12.7
	olefin	0.1	1.0	5.6
C ₂	paraffin	1.0	1.0	4.5
	olefins	3.4	6.0	21.2
C ₃ –C ₄	paraffins	1.8	1.8	3.0
	olefins	7.8	7.7	25.8
C ₅ –C ₁₀	paraffins	12.0	3.3	4.3
	aromatics	0	0	1.7
	oxygenates	0.2	1.3	1.6
C ₁₁ –C ₂₂	olefins	1.1	5.7	4.8
	paraffins	20.8	13.5	0.9
	aromatics	0	0	0.8
	oxygenates	0	0.3	0.5
C ₂₂ +	olefins	0	0.7	1.6
	paraffins	44.6	49.2	0.4
	aromatics	0	0	0.7
	oxygenates	0	0	0.2
Aqueous Product				
C ₁ –C ₅	alcohols	1.4	3.9	4.5
	carbonyls	0	0	3.9
	carboxylic acids	0.2	0.3	1.3

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De Klerk, 2009

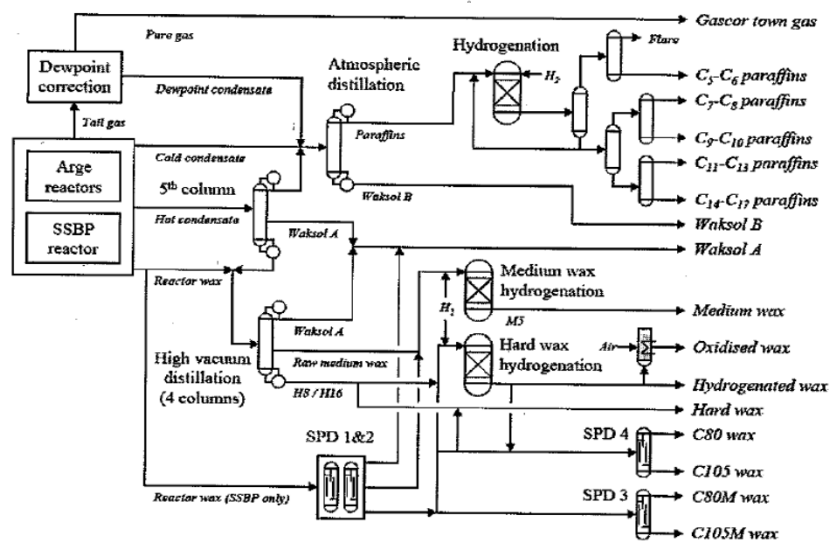
Table 10
 Typical composition of water soluble oxygenated products with iron catalysts

Compound	LTFT ¹	HTFT ²
	230°C	340°C
Non-acid chemicals		
Ethanal (acetaldehyde)	0.5	2
Propanal	0.1	0.5
2 Propanone (acetone)	4	23
2 Butanone (MEK)	0.3	6
Methanol	24	0.5
Ethanol	45	40
1 Propanol	13	12
2 Propanol	1	5
1 Butanol	5	4
2 Butanol		1
2 Me 1 Propanol		1
Acids (mass % distribution)		
CH ₃ COOH		70
C ₂ H ₃ COOH		16
C ₃ H ₇ COOH		9
Acid content of water (mass %)	0.4	1.2

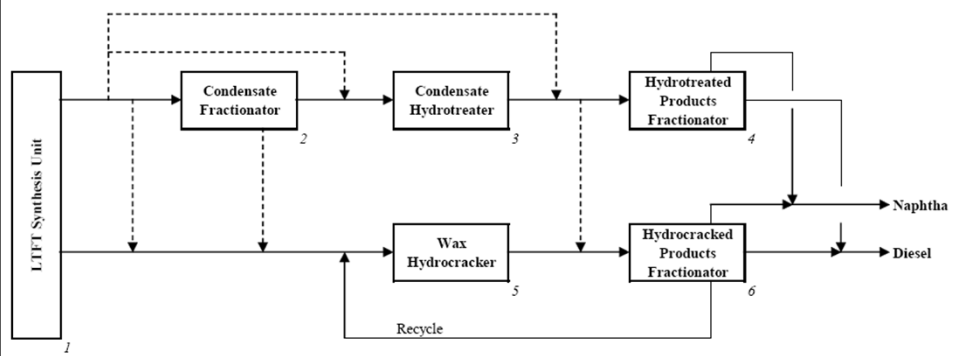
1 Precipitated iron catalyst

2 Fused iron catalyst

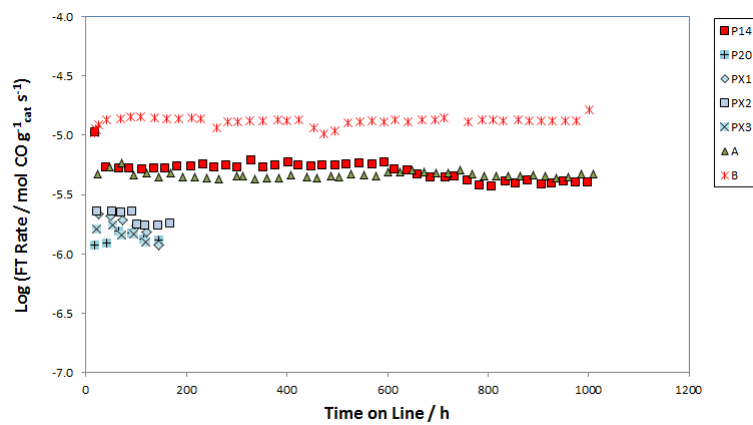
LT-FT Refinery: Chemicals



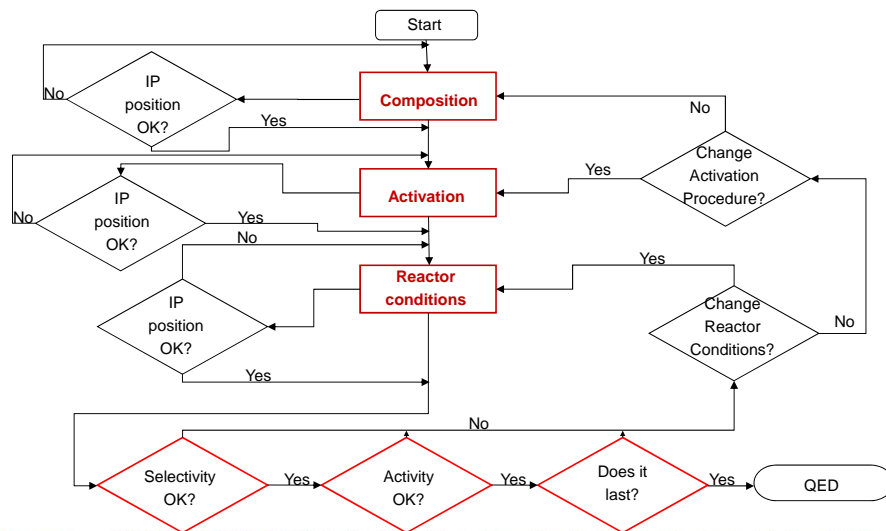
LT-FT Refinery: Diesel



Research and Development needs



Research framework...



Conclusions

- Syngas, a powerful reagent
- FT is versatile, mitigates economic risk
- Research needs in FT catalyst improvement

Thank you!

Questions?