Deutsche Bank
Markets Research

Industry
China's Coal to Olefins Industry

Date
2 July 2014

Asia
China

Energy
Chemicals

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F.I.T.T. for investors

Coal, to Syngas, to Methanol, to Olefins

Only in China

Converting China's coal into olefins (ethylene and propylene) is a multi-step, multi-industry process. Coal is first converted to syngas; syngas is then converted to methanol; methanol is thereafter converted to olefins. In this FITT report we look through the chain of China's coal-to-olefins industry by focusing largely on the economics and processes involved. In subsequent FITT Reports we will also consider China's coal-to-urea, coal-to-liquids and coal-to-syngas industries. Globally, only China uses coal to make industrial quantities of urea, methanol and now potentially, olefins.

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The economics

Using US$ 110/ bbl naphtha to produce olefins is expensive (US$ 1,185/ ton); using US$ 42/ ton coal from Inner Mongolia is less expensive (US$ 640/ ton); but using US$ 5/ mmBtu natural gas from North America / Middle East is the least expensive (US$ 338/ ton) way to produce olefins. It's a slow moving train, but its coming as N. America starts to add low cost shale-gas-to-olefin capacity 2017-18e. As China sets out to build its uniquely-China coal-to-olefins industry, we contemplate the long-term contradictions of: 1) China's coal-to-olefin industry displacing its naphtha-to-olefin industry; and 2) China's push to find its cheap shale gas only to displace its various coal-to industries.

Conclusions and potential beneficiaries

We suspect: 1) the NDRC's ambitious time table for Coal-to-Olefin and Coal-to-Methanol (CTO/ CTM) development in China (Appendix 1-2) will take longer to implement than designed; and 2) shale gas in China will also develop at a snail's pace and thus be less transformational, due to a lack of competition in the market and various price controls throughout the system. Yingde Gases (2168 HK – Buy) has been a primary beneficiary of China's developing CTO/ CTM industry. Starting from a low base, even a slower development pace than Plan should support Yingde's growth. Sinopec Corp. (386 HK) has six CTO (2), MTO (3) and/ or GTO (1) projects, with 1 already operating and 2 scheduled for start-up in 2016e. The risk to these projects is an abundance of low cost shale gas coming to China anytime soon; we suspect this is not going to happen. The lack of success globally in developing Coal-to-MEG technology has led us to reiterate our Buy ratings on Nan Ya Plastics (1303 TT – Buy) and Lotte Chemicals (011170 KS - Buy); both benefit from higher MEG prices in Asia.

Valuation and risks

We value most of our commodity companies on a discounted cash flow model. The DCF model allows for the input of differing commodity prices over a multi-year period. The Hong Kong stock market trades mostly off of PE valuations and as a result, we will use both longer term (DCF) and shorter term (PE) valuation metrics to assess the value of most of our companies. The principal risk to China's CTO/ MTO build out ironically comes from China's drive to find its very own cheap, abundant shale gas. Coal-to-olefins is not cost competitive relative to cheap natural gas-to-olefins. We expect delayed implementation of China's CTO/ MTO build out vs. the 5-Year Plan (2011-15e) due to on-going debates in Beijing surrounding scarcity of water, air pollution and the economics of coal-to-chemicals.

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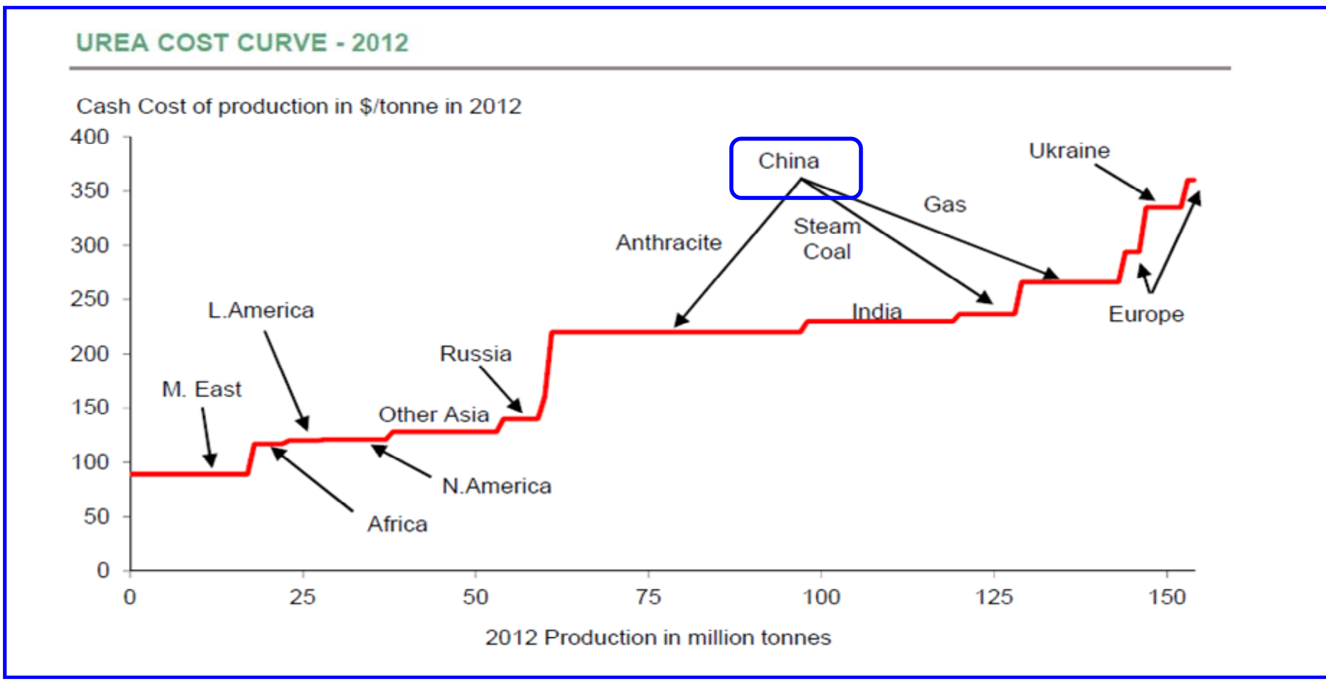
Executive summary

Full of contradictions – just like China

Only China produces industrial amounts of urea from coal. Producing urea from coal is expensive. China is the world's largest producer of urea (38% of global supply) **despite** being its principal high-cost producer (Figure 1). We suspect that China's urea production is at risk to increasing amounts of cheap global natural gas (urea) from the Middle East (associated gas), North America (shale gas), Africa (associated gas) and potentially even China itself (shale gas).

Producing urea from coal is expensive (US$ 250-300/ ton). Producing urea from natural gas is cheap (US$ 100-150/ ton). Will China be pushed off the Urea cost curve any time soon? Time is a relative concept; it may take 20-years for cheap gas to spread around the world; or 10-years for cheap gas to become more expensive particularly out of North America. It's a balancing act.

Figure 1: Worldwide cost to produce urea



Source: Fertecon; Deutsche Bank

In its most recent 5-Year Plan (2011-15), the Chinese government laid out an aggressive time table for development of its coal-to-olefins (CTO), coal-to-syngas (CTG) and methanol-to-olefins (MTO) industries (Appendix 1-3).

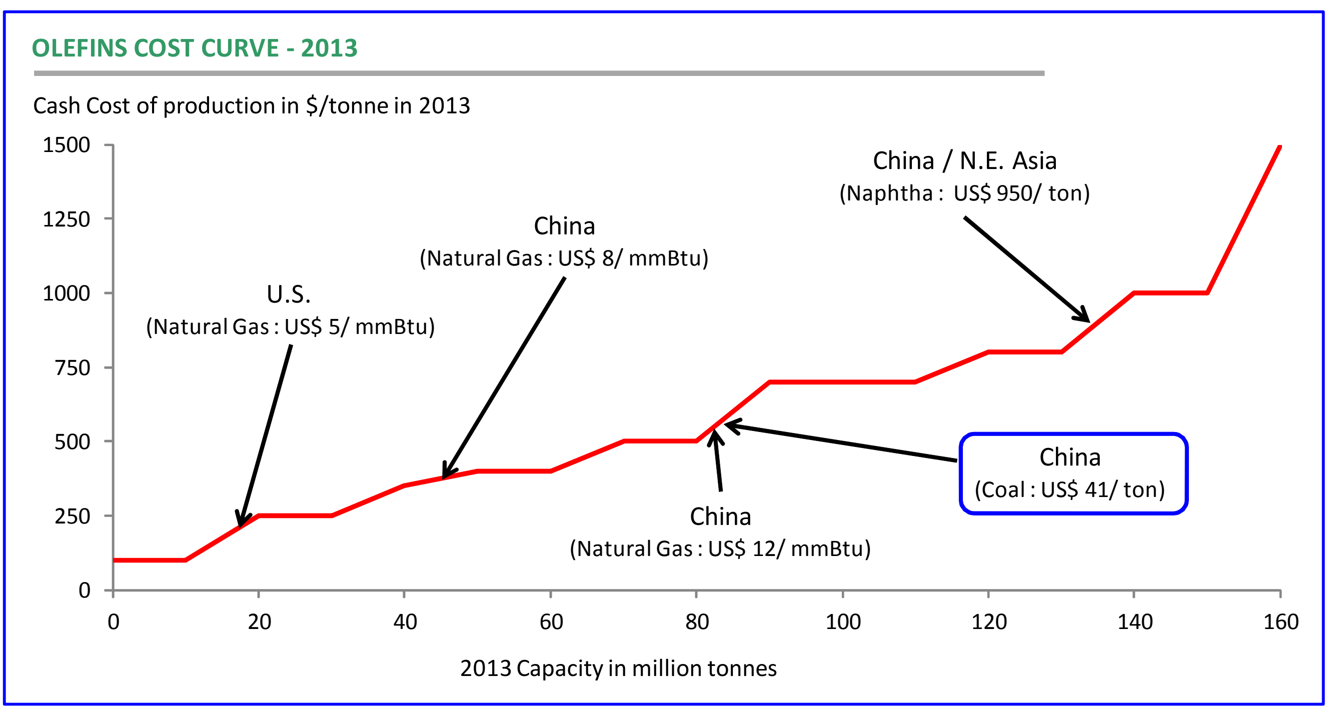
The economics of China coal-to-olefins (ethylene / propylene) **is competitive** relative to the world's naphtha-to-olefins industry (Figure 2, Figure 20 & Figure 92-93). The world's naphtha-to-olefins industry is Asia-based. Ninety percent

(90%) of Asia's olefin (ethylene) capacity uses naphtha as a feedstock (Appendix 6-10). Asia produces 34% of global ethylene. A fast-growing China CTO industry would displace its own naphtha to olefins industry (24% of global ethylene capacity). Somehow, this strategy does not make much sense; although it would produce short-term China GDP growth.

The economics of China coal-to-olefins however **is not competitive** relative to a growing North American and Middle Eastern natural gas-to-olefins industry (Figure 2, Figure 20, and Figure 94). From a cost perspective, a fast-growing China CTO industry would displace its own naphtha to olefins industry but then be displaced itself by a lower-cost North American and Middle Eastern natural gas-to-olefins industry. Somehow, this strategy makes even less sense; except for the fact that it creates plenty of China GDP by both building and then dismantling multiple China industry chains.

China's coal-to-olefins and / or coal-to-urea do not make economic sense in a world awash in low-cost natural gas. Notwithstanding, China continues to grow its coal-to industries; maybe on the prospect that the world's growing supplies of cheap natural gas could be short-lived.

Figure 2: Worldwide production cost of olefins by feedstock



Source: Company data;, IHS, Deutsche Bank

The production of olefins from coal requires an abundance of water (Figure 98) and produces an abundance of CO_2 emissions (Figure 102). The addition of one 600k tpa CTO facility in Beijing would increase provincial CO_2 emissions by 14%. China's abundant water resource (Figure 95) is located in the South and South West part of the country; its coal resources are located in the North and North West part of the country (Figure 11-12) – bad luck.

The world does not use coal to produce industrial quantities of olefins, or urea, or methanol, or synthetic natural gas (syngas) - only China uses its coal for these purposes. China is currently the world's largest producer of both urea and methanol ("Methanol" pages 38-66) and it's all done with coal. (South Africa uses coal to produce "liquids", principally diesel and gasoline; as did Germany during World War II.) China's current CTO/ MTO operating capacity is a tiny 0.6 / 1.76 mln tpa respectively or 0.4% / 1.7% of global ethylene and propylene capacity (153.2 / 103.0 mln tpa). China's CTO/ MTO capacity represents only 0.92% of the world's total ethylene and propylene capacity (256.2 mln tpa). Yet, China's NDRC has approved an additional 6.9 mln tpa and "pre-approved" 13.4 mln tpa of CTO/ MTO capacity (Appendix 1-2) and caught the world's attention. If it weren't for China's world-scale, high(er) cost coal to urea and methanol industries, we would ignore China's recent hype about building millions of tons of CTO/ MTO capacity over the next few years.

Given ongoing debates at the highest levels of Chinese government about CO_2 emissions and water scarcity; as well as ongoing debates about infrastructure spend and industrial overcapacity, we estimate that China could add 4.1 mln tps of MTO capacity (Figure 51) and 4.5 mln tpa of CTO capacity (Figure 75) through 2018. This would represent 42% of the NDRC's approved and pre-approved CTO/ MTO projects as contemplated in its 5-Year Plan (2011-15). It's a start; but we suspect it may prove to be a very slow start relative to Plan.

Bottom line, we are skeptical of China building a global scale coal to olefins industry over the coming decade. We look at the economics of coal to olefins relative to natural gas to olefins and wonder where to with China's shale gas revolution; we consider the CO_2 emissions and question the government's sincerity about cleaning up the environment; and then we consider China's water scarcity and question if China has enough water to "frac" its way to abundant shale gas and build a global CTO industry all at the same time.

Commercial prospects

The industrial gas (oxygen) requirement of a coal-to-olefins plant is 2.5 times more than that of a comparable steel production facility. A 600k Tpa coal-to-olefins production facility requires oxygen capacity of 8,500 mcf / hour vs. 3,400 mcf / hour for a similar sized steel production facility. In our opinion, Yingde Gases (2168 HK – Buy) has clearly been and should continue to be the primary beneficiary of China's push into coal-to-chemicals.

In 2010, Yingde received a 240k Nm^3/ hour contract from the Shenhua Group to supply its Shenhua Baotou coal-to-olefins project. The Shenhua contract increased Yingde's outstanding oxygen capacity by 56% off a (low) base of 421k Nm^3/ hour year-end 2009. In November 2013, Yingde received a second 240k Nm^3/ hour contract from China Coal Group (Parent company) for its CTO project in Shannxi province due on line 2016e. At the time of signing, Yingde had 1.33 mln Nm^3/ hour of oxygen capacity. Yingde has been a clear beneficiary so far of China's push into coal-to-chemicals. Hangzhou Hangyang (002430 CH – Non-rated) is China's largest producer of Air Separation Units (ASUs). According to Guangdong Oil & Gas Association, Hangzhou Hangyang holds more than 40% market share in China's ASU market.

China Shenhua Energy (1088 HK), China Petroleum & Chemical Corporation - Sinopec (386 HK) and China Coal Group / China Coal Energy (1898 HK – Hold) all are front runners in China's developing CTO / CTM industry. We suspect that the three companies will likely remain at the forefront of this industry. Of these companies, only Sinopec has naphtha-to-olefin production capacity.

Royal Dutch Shell (RDSA LN – Hold); Siemens (SIE GY – Buy); KBR Inc (KBR US – Buy) and General Electric (GE US – Buy) all supply coal gasification units to China and worldwide. Shell's (SCGP) technology is the most widely used coal-to-syngas process. Shell started its coal gasification technology in 1976 and has been licensing its technology in China since 2000. Up to 1H2013, Shell had 21 coal gasification units operating in China; the majority of these units are used for producing coal-based urea and methanol.

China's methanol industry is world scale. China's methanol capacity (49.4 mln tons) represents 51% of global capacity (Figure 53 / Appendix 4-5). However, methanol production in China is highly fragmented with the top 10 Chinese producers representing only 28% of total capacity. Data from Baidu-Wenku leads us to believe that China has some 300 to 350 known producers of methanol with untold numbers of "tea-pot" producers. Only three of China's top ten methanol producers are publically-listed companies: China BlueChemical (3983 HK – NR); Kingboard Chemicals (148 HK – NR) and Shandong Jiutai Chemical (CEGY SP - NR). Petronas Chemicals (PCHEM MK – Hold) is a large Malaysian producer of methanol and other petrochemicals.

China's 12th 5-Year Plan (2011-15) was officially released in May 2011. On the back of the excitement surrounding this 5-Year Plan and the indicated build up in China's CTO/ CTM industry, the Honk Kong Stock Exchange entertained two IPO listings from EPC (Engineering Procurement and Construction) companies: 1) Wison Engineering (2236 HK); and 2) Sinopec Engineering (2386 HK – Buy). We expect these two companies to grab the lion's share of CTO/ MTO construction contracts in China.

The price of MEG is the main share price driver for Nan Ya Plastics (1303 TT – Buy) with a correlation of 84%. Despite a relatively low sales contribution (19%), we believe NYP is the key MEG play in the Asia region. There are limited chemical companies with MEG exposures in Asia, while NYP is the second-largest MEG producer globally. Based on our supply demand outlook, we expect MEG prices to expand by 13% in the next two years due to tight supplies. This should bode well for NYP's fundamentals and share price. We believe that the lack of successful Coal-to-MEG technology globally will keep the Chinese out of this market and therefore support global MEG prices.

Lotte Chemicals (011170 KS – Buy) owns / operates 1.1mtpa of MEG capacity. MEG provides Lotte with up to 40% of its operating profit, which is one of the highest in the region. Considering 63% share price correlation to MEG price, Lotte Chemical also looks well positioned to benefit from improving MEG fundamentals as CTMeg developments continue to disappoint.

Of the companies mentioned above and in Appendix 19, we believe Yingde Gases (2168 HK – Buy) is the most levered to China's developing CTO industry.

Model updated:24 June 2014

Running the numbers

Asia

Hong Kong

Chemicals

Yingde Gases

Reuters: 2168.HK | Bloomberg: 2168 HK

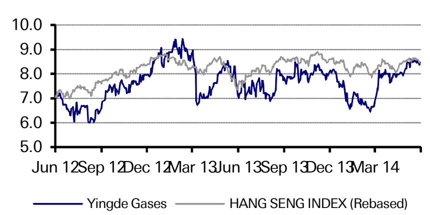
Buy

Price (25 Jun 14)	HKD 8.46
Target Price	HKD 9.60
52 Week range	HKD 6.45 - 8.60
Market Cap (m)	HKDm 15,286
	USDm 1,972

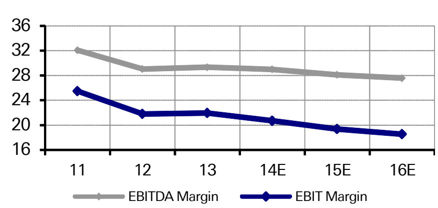
Company Profile

Yingde Gases is a leading industrial gas producer in China.

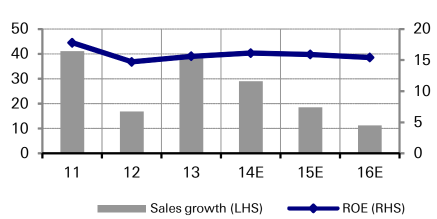
Price Performance



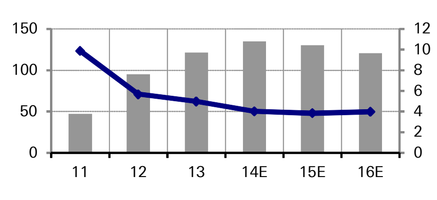
Margin Trends



Growth & Profitability



Solvency



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Fiscal year end 31-Dec	2011	2012	2013	2014E	2015E	2016E
Financial Summary						
DB EPS (CNY)	0.46	0.43	0.50	0.58	0.63	0.68
Reported EPS (CNY)	0.46	0.43	0.50	0.58	0.63	0.68
DPS (CNY)	0.13	0.15	0.18	0.21	0.23	0.25
BVPS (CNY)	2.8	3.0	3.4	3.8	4.2	4.7
Weighted average shares (m)	1,807	1,807	1,807	1,807	1,807	1,807
Average market cap (CNYm)	10,845	11,166	11,399	12,285	12,285	12,285
Enterprise value (CNYm)	12,830	15,748	18,381	21,085	21,771	22,038
Valuation Metrics						
P/E (DB) (x)	13.1	14.5	12.6	11.8	10.7	10.0
P/E (Reported) (x)	13.1	14.5	12.6	11.8	10.7	10.0
P/BV (x)	2.38	2.11	1.90	1.79	1.61	1.45
FCF Yield (%)	nm	nm	nm	nm	0.1	3.7
Dividend Yield (%)	2.2	2.4	2.9	3.1	3.4	3.6
EV/Sales (x)	3.0	3.2	2.7	2.4	2.1	1.9
EV/EBITDA (x)	9.4	10.9	9.1	8.2	7.4	6.8
EV/EBIT (x)	11.9	14.6	12.2	11.5	10.7	10.2
Income Statement (CNYm)						
Sales revenue	4,240	4,956	6,866	8,854	10,498	11,680
Gross profit	1,730	1,931	2,656	3,370	3,900	4,259
EBITDA	1,360	1,439	2,013	2,566	2,950	3,219
Depreciation	276	348	496	723	904	1,042
Amortisation	4	9	9	9	9	9
EBIT	1,080	1,081	1,508	1,833	2,036	2,168
Net interest income(expense)	-110	-191	-303	-456	-529	-544
Associates/affiliates	0	-4	-20	-10	0	0
Exceptionals/extraordinaries	0	0	0	0	0	0
Other pre-tax income/(expense)	11	20	18	18	18	18
Profit before tax	981	907	1,203	1,386	1,525	1,642
Income tax expense	146	136	294	339	373	401
Minorities	5	1	2	2	2	2
Other post-tax income/(expense)	0	0	0	0	0	0
Net profit	831	770	907	1,045	1,150	1,238
DB adjustments (including dilution)	0	0	0	0	0	0
DB Net profit	831	770	907	1,045	1,150	1,238
Cash Flow (CNYm)						
Cash flow from operations	975	919	1,265	2,738	2,640	2,789
Net Capex	-2,177	-3,778	-2,691	-3,900	-2,625	-2,336
Free cash flow	-1,203	-2,859	-1,426	-1,162	15	453
Equity raised/(bought back)	0	0	0	0	0	0
Dividends paid	-181	-241	-271	-325	-375	-412
Net inc/(dec) in borrowings	1,284	2,928	885	1,500	1,000	0
Other investing/financing cash flows	-204	-245	579	0	0	0
Net cash flow	-303	-418	-233	13	640	41
Change in working capital	*-120*	*796*	*-487*	*638*	*259*	*0*
Balance Sheet (CNYm)						
Cash and other liquid assets	958	1,350	342	36	352	87
Tangible fixed assets	6,069	9,761	11,951	15,128	16,848	18,142
Goodwill/intangible assets	62	59	57	57	57	57
Associates/investments	400	745	685	675	675	675
Other assets	2,336	2,879	3,516	3,720	4,106	4,383
Total assets	9,825	14,793	16,552	19,616	22,038	23,343
Interest bearing debt	3,331	6,615	7,904	9,404	10,404	10,404
Other liabilities	1,491	2,631	2,418	3,260	3,904	4,383
Total liabilities	4,821	9,246	10,322	12,664	14,308	14,787
Shareholders' equity	4,991	5,486	6,125	6,844	7,620	8,445
Minorities	12	61	105	107	109	112
Total shareholders' equity	5,003	5,547	6,230	6,952	7,729	8,557
Net debt	*2,372*	*5,265*	*7,562*	*9,368*	*10,052*	*10,317*
Key Company Metrics						
Sales growth (%)	41.1	16.9	38.5	29.0	18.6	11.3
DB EPS growth (%)	43.9	-7.3	17.2	15.2	10.1	7.6
EBITDA Margin (%)	32.1	29.0	29.3	29.0	28.1	27.6
EBIT Margin (%)	25.5	21.8	22.0	20.7	19.4	18.6
Payout ratio (%)	28.3	35.2	35.9	35.9	35.9	35.9
ROE (%)	17.8	14.7	15.6	16.1	15.9	15.4
Capex/sales (%)	51.4	76.3	39.2	44.0	25.0	20.0
Capex/depreciation (x)	7.8	10.6	5.3	5.3	2.9	2.2
Net debt/equity (%)	47.4	94.9	121.4	134.8	130.0	120.6
Net interest cover (x)	9.9	5.7	5.0	4.0	3.9	4.0

Source: Company data, Deutsche Bank estimates

Model updated:19 June 2014

Running the numbers

Asia

Taiwan

Chemicals

Nan Ya Plastics

Reuters: 1303.TW Bloomberg: 1303 TT

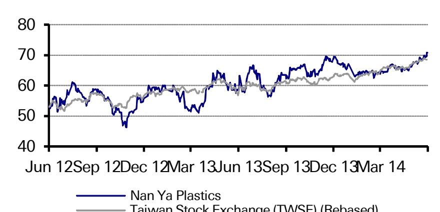
Buy

Price (25 Jun 14)	TWD 70.80
Target Price	TWD 81.00
52 Week range	TWD 56.30 - 70.80
Market Cap (m)	TWDm 561,502
	USDm 18,725

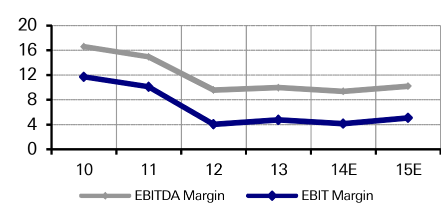
Company Profile

Established in 1958 Nan Ya Plastics is one of the core members of the Formosa Plastics Group. The company has subsidiaries in China and the US and has exposures in downstream petrochemical (PET, MEG, BPA), plastics processing (films, plasticizers), electronic materials (epoxy, CCL) businesses. In addition to its core businesses, Nan Ya Plastics holds important equity investments in Formosa Petrochemical (6505 TT), Nanya PCB (8046 TT), Nanya Tech (2408 TT), and Mailiao Power (unlisted).

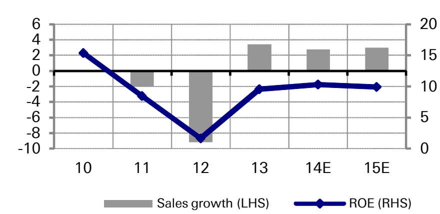
Price Performance



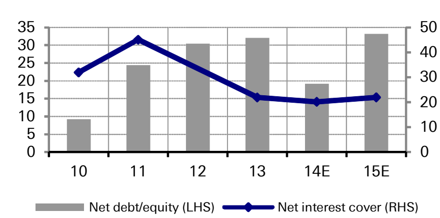
Margin Trends



Growth & Profitability



Solvency



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Fiscal year end 31-Dec	2010	2011	2012	2013	2014E	2015E
Financial Summary						
DB EPS (TWD)	5.22	2.95	0.54	3.19	3.74	3.69
Reported EPS (TWD)	5.22	2.95	0.54	3.19	3.74	3.69
DPS (TWD)	4.69	2.10	0.30	2.50	2.93	2.90
BVPS (TWD)	46.2	43.2	40.3	35.6	36.8	37.6
Weighted average shares (m)	7,852	7,852	7,852	7,931	7,931	7,931
Average market cap (TWDm)	495,781	581,155	456,659	483,935	561,502	561,502
Enterprise value (TWDm)	428,205	440,929	332,348	345,792	355,766	368,845
Valuation Metrics						
P/E (DB) (x)	12.1	25.1	108.3	19.1	19.0	19.2
P/E (Reported) (x)	12.1	25.1	108.3	19.1	19.0	19.2
P/BV (x)	1.57	1.39	1.39	1.93	1.92	1.88
FCF Yield (%)	8.5	7.2	4.7	3.6	13.6	3.3
Dividend Yield (%)	7.4	2.8	0.5	4.1	4.1	4.1
EV/Sales (x)	1.3	1.3	1.1	1.1	1.1	1.1
EV/EBITDA (x)	7.6	8.9	11.6	11.2	11.9	11.0
EV/EBIT (x)	10.8	13.2	27.3	23.3	26.8	22.0
Income Statement (TWDm)						
Sales revenue	337,785	330,999	300,707	311,005	319,532	329,125
Gross profit	57,570	51,400	29,122	32,667	31,601	35,456
EBITDA	56,060	49,461	28,774	30,982	29,973	33,597
Depreciation	15,036	14,905	15,228	14,744	15,264	15,783
Amortisation	1,477	1,163	1,376	1,414	1,414	1,030
EBIT	39,548	33,393	12,170	14,823	13,295	16,784
Net interest income(expense)	-1,239	-741	52	-676	-661	-765
Associates/affiliates	0	0	0	0	0	0
Exceptionals/extraordinaries	0	0	0	0	0	0
Other pre-tax income/(expense)	11,810	662	-6,770	16,822	21,780	18,574
Profit before tax	50,118	33,314	5,453	30,969	34,415	34,593
Income tax expense	8,443	9,095	1,895	5,894	4,676	5,189
Minorities	701	1,076	-658	-197	114	113
Other post-tax income/(expense)	0	0	0	0	0	0
Net profit	40,974	23,143	4,216	25,272	29,625	29,291
DB adjustments (including dilution)	0	0	0	0	0	0
DB Net profit	40,974	23,143	4,216	25,272	29,625	29,291
Cash Flow (TWDm)						
Cash flow from operations	56,792	52,181	36,310	25,427	90,219	32,211
Net Capex	-14,547	-10,497	-14,706	-7,780	-13,812	-13,812
Free cash flow	42,245	41,684	21,605	17,646	76,407	18,399
Equity raised/(bought back)	0	0	0	0	0	0
Dividends paid	-15,274	-36,820	-16,473	-2,354	-19,827	-23,241
Net inc/(dec) in borrowings	32,818	30,664	21,367	54,670	395	11,261
Other investing/financing cash flows	-39,647	-43,874	-29,487	-70,756	-20,403	-41,851
Net cash flow	20,142	-8,347	-2,989	-794	36,573	-35,432
Change in working capital	*0*	*0*	*0*	*0*	*0*	*0*
Balance Sheet (TWDm)						
Cash and other liquid assets	82,063	68,684	63,836	67,710	104,283	68,851
Tangible fixed assets	147,261	147,830	146,291	147,811	146,358	144,387
Goodwill/intangible assets	1,926	2,675	2,216	247	247	247
Associates/investments	106,853	102,892	96,299	128,058	159,818	191,577
Other assets	122,396	148,284	142,974	180,684	145,561	149,160
Total assets	460,499	470,364	451,616	524,510	556,267	554,221
Interest bearing debt	109,357	136,382	142,295	162,378	163,003	172,297
Other liabilities	56,081	56,747	51,577	66,784	88,007	70,504
Total liabilities	165,438	193,129	193,872	229,163	251,009	242,800
Shareholders' equity	283,078	264,619	246,566	282,451	292,248	298,298
Minorities	11,983	12,616	11,178	12,896	13,010	13,123
Total shareholders' equity	295,062	277,235	257,744	295,348	305,258	311,421
Net debt	*27,294*	*67,698*	*78,459*	*94,668*	*58,720*	*103,446*
Key Company Metrics						
Sales growth (%)	nm	-2.0	-9.2	3.4	2.7	3.0
DB EPS growth (%)	na	-43.5	-81.8	493.5	17.2	-1.1
EBITDA Margin (%)	16.6	14.9	9.6	10.0	9.4	10.2
EBIT Margin (%)	11.7	10.1	4.0	4.8	4.2	5.1
Payout ratio (%)	89.9	71.2	55.8	78.5	78.5	78.5
ROE (%)	15.4	8.5	1.6	9.6	10.3	9.9
Capex/sales (%)	4.4	3.2	5.3	2.8	4.3	4.2
Capex/depreciation (x)	0.9	0.7	1.0	0.5	0.8	0.8
Net debt/equity (%)	9.3	24.4	30.4	32.1	19.2	33.2
Net interest cover (x)	31.9	45.0	nm	21.9	20.1	21.9

Source: Company data, Deutsche Bank estimates

Model updated:12 June 2014

Running the numbers

Asia

South Korea

Chemicals

Lotte Chemical

Reuters: 011170.KS | Bloomberg: 011170 KS

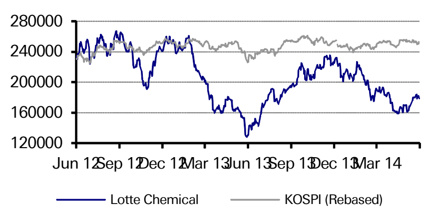
Buy

Price (25 Jun 14)	KRW 178,500
Target Price	KRW 210,000
52 Week range	KRW 130,500 - 235,500
Market Cap (bn)	KRWm 5,687
	USDm 5,584

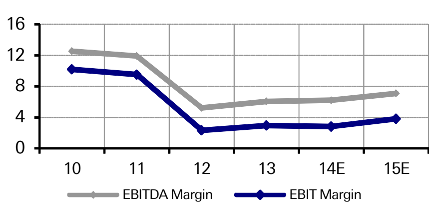
Company Profile

Lotte Chemical is a vertically integrated petrochemical company in Korea, with wide range of products including polyethylene(PE), polypropylene(PP) and ethylene glycol (MEG). Lotte is the major shareholder with a 57% stake and its affiliates include KP Chemical (PET producer) and Titan Chemical (Malaysia based petrochem company).

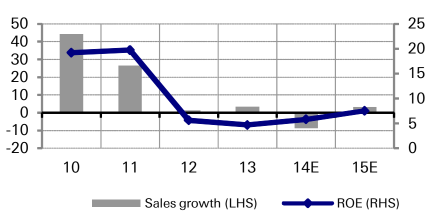
Price Performance



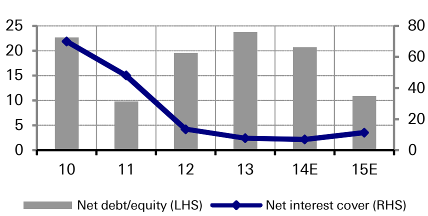
Margin Trends



Growth & Profitability



Solvency



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Fiscal year end 31-Dec	2010	2011	2012	2013	2014E	2015E
Financial Summary						
DB EPS (KRW)	24,667.92	30,701.19	10,196.17	9,037.35	10,939.45	14,988.65
Reported EPS (KRW)	24,667.92	30,701.19	10,196.17	9,037.35	10,939.45	14,988.65
DPS (KRW)	1,750.00	1,750.00	1,000.00	1,000.00	1,200.00	1,500.00
BVPS (KRW)	139,809.5	171,455.4	189,686.8	196,362.8	192,543.3	206,342.7
Weighted average shares (m)	32	32	32	32	34	34
Average market cap (KRWbn)	5,416	11,310	8,640	6,290	5,687	5,687
Enterprise value (KRWbn)	5,252	10,824	8,165	5,895	5,197	4,590
Valuation Metrics						
P/E (DB) (x)	6.9	11.6	26.6	21.8	16.3	11.9
P/E (Reported) (x)	6.9	11.6	26.6	21.8	16.3	11.9
P/BV (x)	1.92	1.74	1.29	1.18	0.93	0.87
FCF Yield (%)	13.8	9.4	nm	3.0	1.9	10.4
Dividend Yield (%)	1.0	0.5	0.4	0.5	0.7	0.8
EV/Sales (x)	0.4	0.7	0.5	0.4	0.3	0.3
EV/EBITDA (x)	3.4	5.8	9.8	5.9	5.6	4.2
EV/EBIT (x)	4.2	7.3	22.0	12.1	12.3	7.8
Income Statement (KRWbn)						
Sales revenue	12,403	15,700	15,903	16,439	14,997	15,480
Gross profit	1,930	2,265	1,247	1,411	1,384	1,566
EBITDA	1,553	1,870	832	994	929	1,097
Depreciation	285	376	457	505	505	505
Amortisation	5	3	3	2	2	2
EBIT	1,263	1,491	372	487	422	590
Net interest income(expense)	-18	-31	-28	-63	-61	-52
Associates/affiliates	126	0	0	0	0	0
Exceptionals/extraordinaries	0	0	0	0	0	0
Other pre-tax income/(expense)	-184	66	43	-49	134	140
Profit before tax	1,187	1,526	387	375	495	678
Income tax expense	292	394	60	89	120	164
Minorities	109	154	2	-2	0	0
Other post-tax income/(expense)	0	0	0	0	0	0
Net profit	786	978	325	288	375	514
DB adjustments (including dilution)	0	0	0	0	0	0
DB Net profit	786	978	325	288	375	514
Cash Flow (KRWbn)						
Cash flow from operations	1,088	1,974	382	463	405	924
Net Capex	-338	-913	-582	-274	-289	-289
Free cash flow	750	1,060	-200	190	115	635
Equity raised/(bought back)	0	0	3	-2	0	0
Dividends paid	-73	-65	-70	-34	-32	-41
Net inc/(dec) in borrowings	533	215	125	544	-357	17
Other investing/financing cash flows	-1,412	-147	-81	-352	39	3
Net cash flow	-201	1,062	-222	346	-234	614
Change in working capital	*-103*	*-3*	*-504*	*-537*	*-451*	*-69*
Balance Sheet (KRWbn)						
Cash and other liquid assets	490	1,251	745	979	745	1,358
Tangible fixed assets	3,771	4,308	4,421	4,187	3,947	3,708
Goodwill/intangible assets	25	39	33	24	22	20
Associates/investments	1,825	1,787	1,706	1,930	1,903	1,912
Other assets	2,502	3,361	3,468	3,569	3,927	4,096
Total assets	8,613	10,747	10,372	10,688	10,543	11,094
Interest bearing debt	1,620	1,858	1,935	2,476	2,118	2,135
Other liabilities	2,006	2,731	2,353	1,917	1,787	1,848
Total liabilities	3,626	4,589	4,288	4,393	3,905	3,983
Shareholders' equity	4,454	5,463	6,043	6,256	6,600	7,072
Minorities	532	695	41	38	38	38
Total shareholders' equity	4,987	6,158	6,084	6,294	6,638	7,111
Net debt	*1,130*	*607*	*1,190*	*1,497*	*1,374*	*777*
Key Company Metrics						
Sales growth (%)	44.3	26.6	1.3	3.4	-8.8	3.2
DB EPS growth (%)	-9.7	24.5	-66.8	-11.4	21.0	37.0
EBITDA Margin (%)	12.5	11.9	5.2	6.0	6.2	7.1
EBIT Margin (%)	10.2	9.5	2.3	3.0	2.8	3.8
Payout ratio (%)	7.1	5.7	9.8	11.1	11.0	10.0
ROE (%)	19.2	19.7	5.6	4.7	5.8	7.5
Capex/sales (%)	3.0	5.9	3.8	1.8	1.9	1.9
Capex/depreciation (x)	1.3	2.5	1.3	0.6	0.6	0.6
Net debt/equity (%)	22.7	9.8	19.6	23.8	20.7	10.9
Net interest cover (x)	69.9	48.1	13.4	7.7	6.9	11.3

Source: Company data, Deutsche Bank estimates

Introduction

Some of the basics

The world's coal-to industry has a long history.

In this FITT (Fundamental Industry Thought-leading Thematic) report, we look at China's coal-to-chemical industry. In subsequent FITT reports we will tackle China's coal-to-liquids, coal to urea/ ammonia and coal to synthetic natural gas industries. China's "Coal-to" industry is both a developing (CTOlefins, CTLiquids and CTGas) and a developed (CTUrea /Ammonia and CTMethanol) industry relative to the rest of the world. Coal to technology has been around for more than a century. China has improved on the technology used in the US during the 1960's; while the US improved on the technology used in Germany / South Africa in the 1930-40s; while Germany / South Africa improved on the technology developed in the UK during 1860s when coal was used to produce kerosene liquid for lamps.

Coal, to Syngas, to Methanol, to Olefins …

We will first look at some of the basics of China's coal resource / industry and then move on to examine why and how China converts it's coal into synthetic gas ("Syngas") from which methanol is produced and thereafter used as a feedstock to produce olefins, mostly ethylene and propylene.

Synthetic natural gas or "Syngas"

Syngas: the feedstock for the world's "coal-to" industry

Syngas is synthesized from coal. It is a mixture of carbon monoxide (c. 63% by volume) and hydrogen (c. 27% by volume) with trace amounts of argon / nitrogen (c. 7.0%) carbon dioxide (c.1.5%), sulfur-containing compounds (c.1.4%) and methane (c.0.03%). It serves as a building block for the production of olefins (ethylene and propylene). Syngas can also be used to produce urea (fertilizer) and automotive fuels (diesel and gasoline); it can also be upgraded to "synthetic natural gas" and used as a natural gas (fuel) substitute for power plants and / or other industrial applications.

Old and New "coal to"

Syngas to Methanol, Syngas to Urea/ Ammonia, Syngas to Acetone and Coal to calcium carbide to PVC are all referred to as "traditional coal to chemical" processes. Syngas to ethylene, propylene, gasoline and diesel are referred to as "new coal to chemical" processes. The conversion of Syngas into Ethylene Glycol (MEG) and Syngas to Benzene is still in its infancy. In the following pages we will explain how China's coal is being converted into syngas and thereafter upgraded into various industrial products. Most of the world's "Coal-to" industry is currently based in and / or developing in China. The developed world seems wholly uninterested in the industry.

High, medium and low Btu syngas

Syngas can be classified by heating value into High, Medium and Low-Btu gas (Figure 3) each of which is useful for different processes. High-Btu gas is composed of over 90% methane and has a heating value of 920-1,000 Btu/ft3. High-Btu "synthetic natural gas" can be used as a substitute for natural gas. Medium-Btu synthetic gas has a lower heating value of 250-550 Btu/ft3. Medium-Btu synthetic gas is used as a source of hydrogen to produce methanol, olefins and "liquid" fuels such as gasoline and diesel. Medium-Btu synthetic gas can also be "upgraded" into High-Btu gas through a process called methanation. Low-Btu syngas has the lowest heating value among the three types of syngas and is typically used by electric power companies to generate electricity. Transforming raw syngas into Low, Medium and High synthetic natural gas entails various steps which we outline in this report.

In Figure 3 we list the heat values (Btu / cubic foot) of various hydrocarbons:

Figure 3: Hydrocarbon heating values

	Btu/lb	Btu/ft3	Energy density (Medium-Btu = 1)
Gas fuels			
High-Btu gas (a.k.a. "Synthetic Natural Gas")		920 - 1000	2.4
Medium-Btu gas - feedstock for producing coal chemicals		250 - 550	1
Low-Btu gas		100 - 250	0.4
Natural gas	19,750	983	2.5
Hydrogen	51,628	275	0.7
Carbon monoxide	4,368	323	0.8
Methane	21,433	910	2.3
Ethane	20,295	1,630	4.1
Propane	19,834	2,371	5.9
Butane	19,976	2,977	7.4
Ethylene	20,525	1,530	3.8
Propylene	19,683	2,185	5.5
Liquid fuels			
Crude oil	18,352	1,110,810	2,777
Gasoline	18,679	838,687	2,097
Diesel	18,320	1,022,866	2,557
Fischer-Tropsch diesel	18,593	1,052,922	2,632
LPG	20,038	671,751	1,679
LNG	20,908	587,360	1,468
Methanol	8,639	425,903	1,065
Ethanol	11,587	571,239	1,428
Solid fuels			
Lignite	7,198	388,707	972
Bituminous	8,998	418,400	1,046
Coking coal	12,300	639,600	1,599
Anthracite	12,597	623,551	1,559

Notes:

1) Lower Heating Value ("LHV") excludes water vapor's heat of vaporization.

2) For crude oil, we assume sweet light crude is used. Unlike heavy crude oil, light oil has a lower density than water.

3) For liquid fuels and natural gas, the energy density of each fuel may vary in different seasons. For example, in winter, small quantities of propane (which has a higher value of methane) may add to natural gas to increase the overall heating value of natural gas (a form of blending). In China, the composition and certain properties of diesel and gasoline may be different between southern and northern provinces.

Source: U.S. Department of Energy, The Engineering Toolbox, Deutsche Bank

In Figure 4 we price the hydrocarbons noted above in terms of their heat value or US$ / mmBtu. This is the starting point to develop a better understanding of the economics behind China's push into coal-to-chemicals, coal-to-liquids (gasoline and diesel) and coal-to-synthetic natural gas.

- If we can convert US$ 2.50 / mmBtu (China bituminous coal) into US$ 31.9 / mmBtu (China ethylene) at a cost less than US$ 29.4 / mmBtu, then we make a profit.

Figure 4: Hydrocarbon price per unit heating value (US$/mmBtu)

	Heating Value	Price in China				Price per unit heating value
	Btu/lb	*Price Quotation* **NOTE** *in China's market*		*Price (US$)*		*US$/mmBtu*
Gas fuels						
Natural gas	**19,750**	**1.73**	*RMB/m3*	**7.8**	*US$/mcf*	**7.5**
Ethylene	**20,525**	**8,985**	*RMB/ton*	**1,442**	*US$/ton*	**31.9**
Propylene	**19,683**	**8,090**	*RMB/ton*	**1,299**	*US$/ton*	**29.9**
Liquid fuels						
Gasoline	**18,679**	**8,231**	*RMB/ton*	**3.49**	*US$/gallon*	**32.1**
Diesel	**18,320**	**7,320**	*RMB/ton*	**3.80**	*US$/gallon*	**29.1**
LPG	**20,038**	**5,320**	*RMB/ton*	**1.87**	*US$/gallon*	**19.3**
LNG	**20,908**	**5,200**	*RMB/ton*	**1.83**	*US$/gallon*	**18.1**
Methanol	**8,639**	**2,686**	*RMB/ton*	**431**	*US$/ton*	**22.6**
Solid fuels						
Lignite *(3500 Kcal)*	**6,298**	**214**	*RMB/ton*	**34**	*US$/ton*	**2.5**
Bituminous *(5000 Kcal)*	**8,998**	**305**	*RMB/ton*	**49**	*US$/ton*	**2.5**
Coking coal	**12,300**	**460**	*RMB/ton*	**74**	*US$/ton*	**2.7**
Anthracite *(7000 Kcal)*	**12,597**	**774**	*RMB/ton*	**124**	*US$/ton*	**4.5**

NOTES:

Natural Gas: Nationwide average city-gate price post NDRC natural gas price reforms implemented July 2013; VAT excluded

Ethylene & Propylene: Nationwide average retail price; VAT excluded

Gasoline & Diesel: Nationwide average maximum allowed retail price; VAT excluded

LPG & LNG : Average ex-plant price of major refineries; VAT excluded

Methanol: Nationwide average wholesale price; VAT excluded

Coal: Ex-mine price in Shanxi (Bituminous, Coking Coal and Anthracite) and Inner Mongolia (Lignite); VAT excluded

Source: Engineering Toolbox, Bloomberg Finance LP; Deutsche Bank

China – unlocking energy value differentials

The value proposition

The value proposition of China's coal-chemicals industry is explained by: 1) the energy price differentials between various coal qualities/ rank (lignite, bituminous & anthracite) vs. the OPEC supported crude oil (naphtha) price vs. the abundantly cheap natural gas (liquids) supply out of the Middle East (associated natural gas) and North America (shale gas); and 2) the cost differentials between transporting coal – the heavy black sedimentary rock, vs. transporting liquid coal – in the form of methanol, diesel and / or gasoline; vs. the cost of transporting gaseous coal – in the form of syngas or synthetic natural gas. We address these issues in the pages that follow.

China's coal markets

Stranded, low cost, low rank coal is ideal for China's coal-to industry

China has a diverse coal market with multiple prices (Figure 12-13) which is the result of: 1) geographical (production) and industrial (consumption) dislocations; 2) differing transport costs between solid, liquid and gaseous coal over long distances, and 3) standard quality discounts among different coal ranks. China's coal is mined in the north (Inner Mongolia), central-north (Shanxi & Shaanxi) & western (Xinjiang) provinces, but consumed in the eastern provinces of Jiangsu, Zhejiang, Guangdong and others. Stranded bituminous coal reserves in China's far away western province of Xinjiang have a mine mouth cost of ~US$ 22 / ton (US$ 2.0 / mmBtu) whereas the same coal in the eastern port city of Qinghuangdao has a cost of US$ 74 / ton. Lower cost, lower rank, stranded coal, abundant in China's Xinjiang and Inner Mongolia provinces is an ideal feedstock to drive China's "Coal-to" industry.

Lots of coal, but not much oil and gas

China has an abundance of coal reserves and very little oil and /or natural gas reserves (Figure 5-10). China imports 60% (and growing) of its oil needs, 32% (and growing) of its natural gas needs, but only 9% of its annual coal demand. As an aside, low quality / low cost coals from Indonesia and Australia can be imported into Southern China, Guangzhou, at competitive prices relative to China coals from Xinjiang and / or Inner Mongolia delivered to east coast China.

Asia uses high cost oil (i.e. – naphtha) to produce olefins

China's chemical industry uses crude oil (naphtha) as a feedstock to produce its petrochemicals. By law, China still prohibits the use of natural gas (although not Syngas) as a feedstock for the production of petrochemicals. In most parts of Asia, naphtha is the primary feedstock for petrochemicals. We are aware of only two petrochemical producers (Petronas Chemicals and PTTGC) in Asia that use natural gas as a feedstock for producing petrochemicals. All other listed Asian petrochemical producers use naphtha as a feedstock.

The miss-allocation of capital continues

Using US$ 110/ bbl naphtha to produce olefins is expensive (US$ 1,185/ ton); using US$ 42/ ton coal from Inner Mongolia is less expensive (US$ 640/ ton); but using US$ 5/ mmBtu natural gas from North America / Middle East is the least expensive (US$ 338/ ton) way to produce olefins. As China sets out to build its uniquely China coal-to-olefins industry, we contemplate the contradictions of: 1) China's coal-to-olefin industry displacing its naphtha-to-olefin industry; and 2) China's push to find its cheap shale gas only to displace its various coal-to industries. In our view, the miss-allocation of capital continues in China.

Figure 5: Global Coal Reserve (millions of metric tons)

Top-10 Coal Reserves

		Anthracite & Bituminous	Lignite & Sub-bituminous	Total	% Share
1	US	108,501	128,794	237,295	27.6%
2	Russia	49,088	107,922	157,010	18.2%
3	China	62,200	52,300	114,500	13.3%
4	Australia	37,100	39,300	76,400	8.9%
5	India	56,100	4,500	60,600	7.0%
6	Germany	99	40,600	40,699	4.7%
7	Ukraine	15,351	18,522	33,873	3.9%
8	Kazakhstan	21,500	12,100	33,600	3.9%
9	South Africa	30,156	-	30,156	3.5%
10	Other Europe/Eurasia	1,440	20,735	22,175	2.6%
	Total of top-10	381,535	424,773	806,308	93.7%
	Remaining countries	23,227	31,403	54,630	6.3%
	Total world production	404,762	456,176	860,938	100.0%

Classification by region

	Anthracite & Bituminous	Lignite & Sub-bituminous	Total	% Share
Asia Pacific	159,326	106,517	265,843	30.9%
North America	112,835	132,253	245,088	28.5%
Europe & Eurasia	92,990	211,614	304,604	35.4%
Middle East	32,721	174	32,895	3.8%
South & Central America	6,890	5,618	12,508	1.5%
Total	404,762	456,176	860,938	100.0%

Source: BP, Deutsche Bank

Figure 6: Global coal production

Top-10 Coal Producing Countries

		Mln metric tons	% Share
1	China	3,650	46.4%
2	US	922	11.7%
3	India	606	7.7%
4	Australia	431	5.5%
5	Indonesia	386	4.9%
6	Russian Federation	355	4.5%
7	South Africa	260	3.3%
8	Germany	196	2.5%
9	Poland	144	1.8%
10	Kazakhstan	116	1.5%
	Total of top-10	7,067	89.9%
	Remaining countries	798	10.1%
	Total world production	7,865	100.0%

Classification by region

	Mln metric tons	% Share
Asia Pacific	5,218	66.3%
North America	1,281	16.3%
Europe & Eurasia	1,003	12.8%
Africa	264	3.4%
South & Central America	97	1.2%
Middle East	1	0.01%
Total	7,865	100.0%
China	3,650	47.5%
Australia	431	6.3%
Indonesia	386	6.2%
Other APAC	751	6.4%
Total APAC	5,218	66.3%

Note: Include Lignite, Sub-Bituminous/Bituminous coal and Anthracite.

Source: BP, Deutsche Bank

Figure 7: Global natural gas reserve

Top-10 Natural Gas Reserves

		Trillion cubic metres	% Share
1	Iran	33.62	18.0%
2	Russian Federation	32.92	17.6%
3	Qatar	25.06	13.4%
4	Turkmenistan	17.50	9.3%
5	US	8.50	4.5%
6	Saudi Arabia	8.23	4.4%
7	United Arab Emirates	6.09	3.3%
8	Venezuela	5.56	3.0%
9	Nigeria	5.15	2.8%
10	Algeria	4.50	2.4%
	Total of top-10	147.15	78.6%
13	China	3.10	1.7%
	Other reamining countries	37.05	19.8%
		187.29	100.0%

Classification by region

	Trillion cubic metres
Middle East	80.50
Europe & Eurasia	58.40
Asia Pacific	15.45
Africa	14.50
North America	10.84
South & Central America	7.60
	187.29

Note: Only proved reserves is considered - i.e. Geological and engineering information indicates with reasonable certainty that the reserve can be recovered in the future from known reservoirs under existing economic and operating conditions.

Source: BP, Deutsche Bank

Figure 8: Global natural gas production

Top-10 Natural Gas Producing Countries

		Bcf / day	% Share
1	US	65.75	20.3%
2	Russian Federation	57.15	17.6%
3	Iran	15.49	4.8%
4	Qatar	15.15	4.7%
5	Canada	15.10	4.7%
6	Norway	11.09	3.4%
7	China	10.35	3.2%
8	Saudi Arabia	9.92	3.1%
9	Algeria	7.86	2.4%
10	Indonesia	6.86	2.1%
	Total of top-10	214.71	66.2%
	Remaining countries	109.87	33.8%
	Total world production	324.58	100.0%

Classification by region

	Bcf / day	% Share
Europe & Eurasia	99.90	30.8%
North America	86.49	26.6%
Middle East	52.91	16.3%
Asia Pacific	47.30	14.6%
Africa	20.86	6.4%
South & Central Americ	17.11	5.3%
Total	324.58	100.0%

Source: BP, Deutsche Bank

Figure 9: Global oil reserve

Top-10 Oil Reserves

		Billion barrels	% Share
1	Venezuela	298	17.8%
2	Saudi Arabia	266	15.9%
3	Canada	174	10.4%
4	Iran	157	9.4%
5	Iraq	150	9.0%
6	Kuwait	102	6.1%
7	United Arab Emirates	98	5.9%
8	Russian Federation	87	5.2%
9	Libya	48	2.9%
10	Nigeria	37	2.2%
	Total of top-10	1,416	84.8%
14	China	17	1.0%
	Other reamining countries	236	14.1%
		1,669	100%

Classification by region

Middle East	808
South & Central America	328
North America	220
Europe & Eurasia	141
Africa	130
Asia Pacific	41
	1,669

Note: (i) Only proved reserves is considered - i.e. Geological and engineering information indicates with reasonable certainty that the reserve can be recovered in the future from known reservoirs under existing economic and operating conditions.

(ii) Reserves include gas condensate and natural gas liquids (NGLs) as well as crude oil.

Source: BP, Deutsche Bank

Figure 10: Global oil production

Top-10 Oil Producing Countries

		'000 bpd	% Share
1	Saudi Arabia	11,530	13.4%
2	Russian Federation	10,643	12.4%
3	US	8,905	10.3%
4	China	4,155	4.8%
5	Canada	3,741	4.3%
6	Iran	3,680	4.3%
7	United Arab Emirates	3,380	3.9%
8	Kuwait	3,127	3.6%
9	Iraq	3,115	3.6%
10	Mexico	2,911	3.4%
	Total of top-10	55,187	64.1%
	Remaining countries	30,965	35.9%
	Total world productio	86,152	100.0%

Classification by region

	'000 bpd	% Share
Middle East	28,270	32.8%
Europe & Eurasia	17,211	20.0%
North America	15,557	18.1%
Africa	9,442	11.0%
Asia Pacific	8,313	9.6%
South & Central America	7,359	8.5%
Total	86,152	100.0%
OPEC	37,405	43.4%
Non-OPEC	48,747	56.6%
Total	86,152	100.0%

Note: (i) Include crude oil, shale oil, oil sands and natural gas liquids (NGL)
(ii) Exclude liquid fuels from biomass and coal

Source: BP, Deutsche Bank

Figure 11: China coal production flows west to east

Domestic Production (mn ton/year)

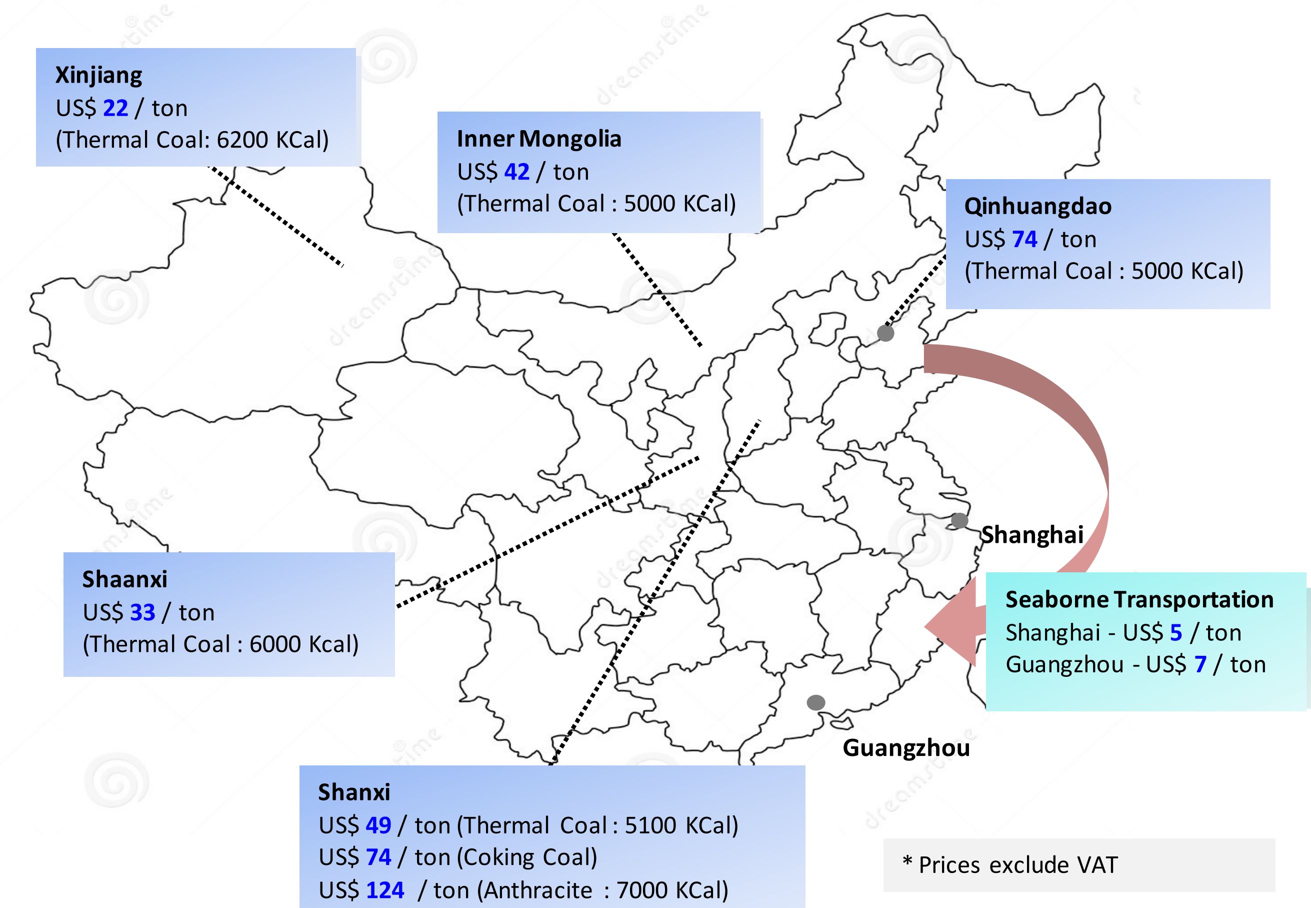
	2009	2010	2011	2012	2013	Share %
Inner Mongolia	601	787	979	1062	994	26.9%
Shanxi	594	730	872	914	960	25.9%
Shaanxi	296	361	411	427	493	13.3%
Sub-total	**1491**	**1878**	**2262**	**2403**	**2447**	66.1%
Other provinces	1559	1362	1258	1227	1253	33.9%
Total	**3050**	**3240**	**3520**	**3630**	**3700**	100.0%

Major consumption area

	Main uses	Coal type	Factors affecting domestic coal demand
Jiangsu	Electricity (c.75%); Cement (c.5%); Steel (c.5%); and Other Industries (c.15%)	Bituminous (4,000 - 5,500 Kcal)	- Economic activities (mainly heavy industries) - Residential
Zhejiang	Electricity (c.75%); Cement (c.5%); Steel (c.5%); and Other Industries (c.15%)	Bituminous (4,000 - 5,500 Kcal)	- Economic activities (mainly light industries) - Residential
Guangdong	Electricity (c.80%); Other Industries (c.20%)	Bituminous, Lignite (4,000 - 5,500 Kcal from China; 3900 - 4500 Kcal from Indonesia)	- Economic activities - Price competition from Indonesian import

Source: BP, China National Coal Association, Deutsche Bank

Figure 12: China's multi-tiered coal price market – promotes a "coal to" industry.



1. Coal prices in the port of Qinhuangdao are affected by numerous factors, including (i) severe weather conditions; and (ii) the annual inspection of the Daqin Railway which causes a temporary interruption in supply each year. The annual inspection in 2013 started on 9 Oct and lasted for 20 days.

2. Seaborne transportation fees move in sympathy with coal prices and serve as an indicator of local sentiment for coal prices.

3. The transport of coal by rail to Eastern China from Xinjiang province remains a bottlemeck. The Xinjiang government is considering plans to expand both its rail capacity and coal production capacity over the coming years.

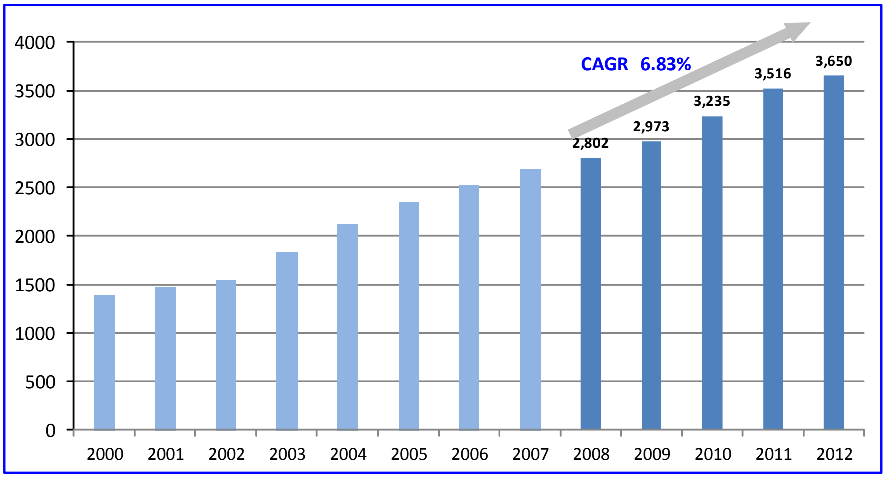
4. Guangzhou is considered the "southern gate" for coal imports into China. Since 2010, electricity producers in southern China have started importing Lignite from Indonesia for the purpose of coal blending (i.e. to mix with high-quality domestic coal) in order to lower the overall domestic coal cost.

5. Shanxi province produced more coal in 2013 than any other province in China. Shanxi coal production however is relatively high cost given (i) high local production taxes; and (ii) under ground (vs. open pit - Inner Mongolia) mining operations. Caol extraction costs in Shanxi are generally higher than Inner Mongolia on a per heating value basis.

6. According to the International Energy Agency, coking coal carries a price premium over thermal coal. Thermal coal is used predominently for generating electricity and its "heat value" is the principal determinent of its market price. Coking coal on the other hand is used principaly for making iron and its value is driven by its inherent properties of "caking" and "strength" rather than heat value.

Source: China National Coal Association, Bloomberg Finance LP; Deutsche Bank

Figure 13: Growth in China's coal production

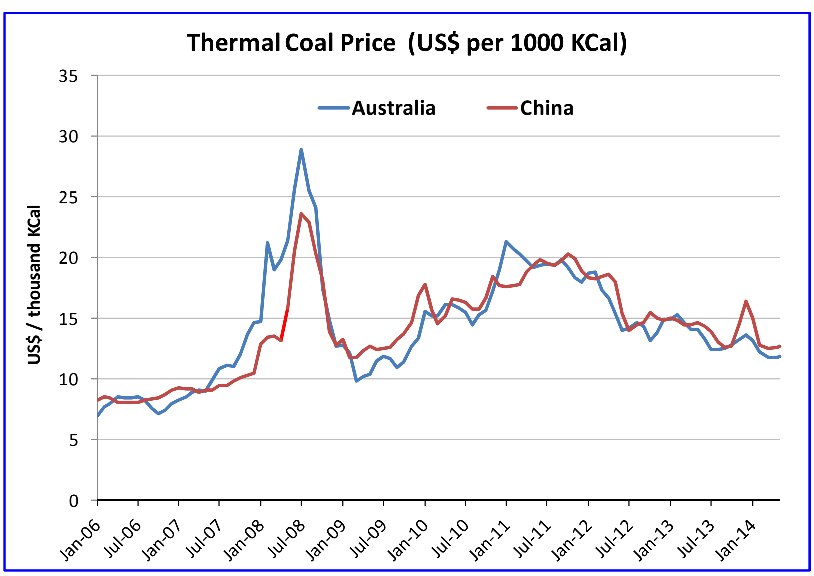


Source: China National Coal Association, Bloomberg Finance LP; Deutsche Bank

China coal and coal-to product prices are for the most part, deregulated.

China's domestic coal prices were deregulated in 2002 and as a result, track international prices reasonably well (Figure 14). In 2012 however, the NDRC mandated a set of "temporary thermal coal price intervention measures" (Figure 15). These "temporary" price measures were indeed done away with in 2013. Similar to China's coal price policy, China's coal to products (urea, methanol and olefins) are also freely priced / traded commodities.

Figure 14: Coal is freely priced according to the market in China



Source: China National Coal Association, Bloomberg Finance LP; Deutsche Bank

Figure 15: China's coal pricing policy – fits and starts

Domestic coal prices have been mainly market-driven since 2002, when the PRC government eliminated the price control measures for coal used in electric power generation. Prior to 2006, however, the PRC government implemented temporary measures to intervene and control unusual fluctuations in thermal coal prices. This, among other reasons, caused thermal coal contract prices for major users to be generally lower than spot market prices during the period. On December 27, 2005, the NDRC announced the elimination of this temporary thermal coal price intervention practice, thus completely removing control over thermal coal prices, including contract prces for major users.

However, on November 30, 2011, to stabilize the coal market and the market prices of thermal coal, the NDRC announce new temporary thermal coal price intervention measures, the NDRC Notice on Enhancing of Administration and Regulation of Thermal Coal Price, promulgated by the NDRC ([2011]No.299)("Notice No. 299"), which provides that (i) control the increase in contract thermal price: (a) for the annual crucial contract coal to be transited for national trans-provincial product transportation, the increase in contract prices in 2012 should be capped at 5% of the prices in 2011; (b) for the thermal coal generated and used by the province (district, city) which itself generates coal, the annual increase in contract prices should not exceed 5% of contract prices of last year; (ii) implement capping restraint price to the thermal coal in market transactions. Since January 1, 2012, the FOB price of thermal coal with a calorific value of 5,500 kcal/kg at nine ports including Qinhuangdao port, Tianjin port an Jingtangport should not exceed Rmb800 per ton. FOB price of other thermal coal should be calculated correspondingly based on the capping price of thermal coal with a calorific value of 5,500 kcal/kg. The market transaction price of thermal coal transported by railway and highway by the parties should not exceed the actual accounting settlement price of the end of April 2011, and should not increase the price by way of changing accounting settlement means.

Source: Prospectus of Inner Mongolia Yitai Coal Co., Ltd (3948.HK), Deutsche Bank

Still waiting

The NDRC does influence the type of coal imported by (i) prohibiting imports of coal with less than 4,544 Kcal/kg heat value; and (ii) setting an import tariff on lignite. Indonesia is not affected by China's lignite import tariff because Indonesia is a member of the "China-ASEAN Free Trade Area". As per the NDRC's "Clean Air Package" issued 27-Sep 2013, high-sulfur coal imports are prohibited, although there were no details as to what defines "high-sulfur" coals. In mid-Jan, the China Securities Journal reported that the NDRC would clarify and implement details surrounding imports of high sulfur / high ash coal. We are still waiting for the details.

Coal imports – only 9% of total demand

According to the China National Coal Association (CNCA), 2013 domestic coal production was 3.7bn tons with imports of 0.33bn tons. Total domestic demand was 3.6bn tons. Imports accounted for only 9% of domestic consumption. Most of China's imported coal is lignite and purchased from Indonesia by China's state-owned power companies.

What is coal?

Coal is a combustible, sedimentary, organic rock, composed mainly of carbon (C), hydrogen (H) and oxygen (O_2). It is formed from vegetation which has been trapped between rocks and altered by the combined effects of pressure and heat over millions of years to form coal seams. Coal is a fossil fuel and is far more abundant than oil or gas.

The degree of change undergone by coal as it matures from soft peat to hard anthracite has an important bearing on coal's physical and chemical properties and is referred to as the 'rank' of the coal. The ranks of coal from those with least to most carbon are: lignite, sub-bituminous, bituminous and anthracite.

Lowest rank – lowest heat value

Lignite or "brown coal" is the lowest rank of coal. It has low heat value (3000-3500 KCal/kg) and high water content (up to 65% of mass). Due to its high water content and low heat value, lignite is generally uneconomical to transport. As a result, most lignite is used for generating electricity in power plants sited close to the mine mouth. Lignite is also an ideal candidate for onsite coal to chemical projects.

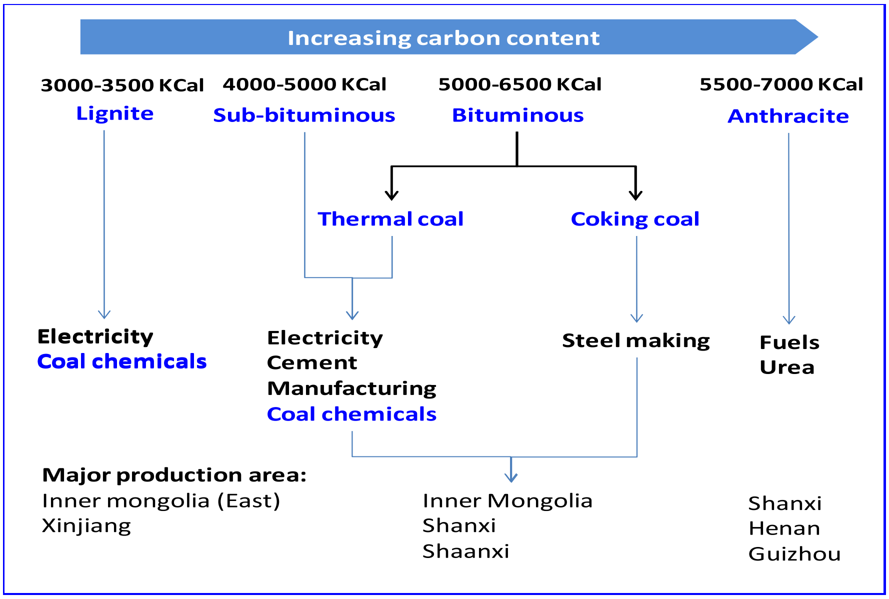
Most prevalent- most commercial

Bituminous coal is of higher quality than Lignite and of poorer quality than Anthracite. Bituminous coal normally contains 3-16% water by mass with heating value ranging from 5000 to 6500Kcal. The majority of China's bituminous coal production comes from Shanxi, Inner Mongolia and Shaanxi provinces. China's bituminous coal is mainly used for generating electricity and producing cement. In terms of usage, bituminous coal can be divided into two sub-types: thermal and coking coal (a.k.a. metallurgical coal). Thermal coal is used for generating electricity/heating and accounts for c.80% of China's total coal demand. Coking coal is primarily used for making "coke" which is necessary to produce steel and iron. Coking coal has different properties than thermal coal, which in their own right add value (other than heat value) in certain industrial processes such as the production of steel.

Highest rank – highest heat value

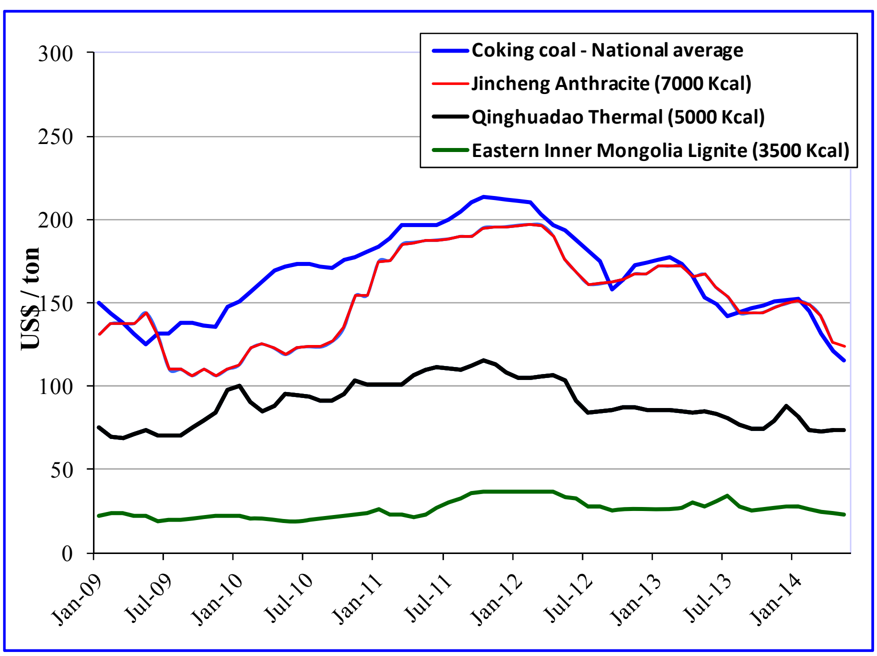
Anthracite is considered the highest rank of coal worldwide. It has the highest heating value (5500-7000KCal) and the lowest moisture level (less than 15% of mass) of all coal types. In China, anthracite is used for power generation (44.4%), cement production (26.3%), urea / ammonia production (16.3%) and iron & steel production (13.0%). We have lifted this insight / data from the Feishang Anthracite Resources Limited (1738 HK) prospectus dated 31 December 2013. China grew its production of anthracite at 4.6% CAGR 2008-12 to a total of 534.4 million tons. Shanxi province (c.32%) and Henan province (c.16%) are China's primary production centers for anthracite. China is a net importer of anthracite (31 mln tons 2012) with most of the imports coming from Vietnam.

Figure 16: Coal types and usages



Source: Deutsche Bank

Figure 17: China's myriad of coal prices (excludes VAT)



Source: Tianjin Port Electronic Transaction Platform; Jincheng Anthracite Mining Group; Jinyou Futures Research; SX Coal; Deutsche Bank

Figure 18: Coal consumption per ton of end product:

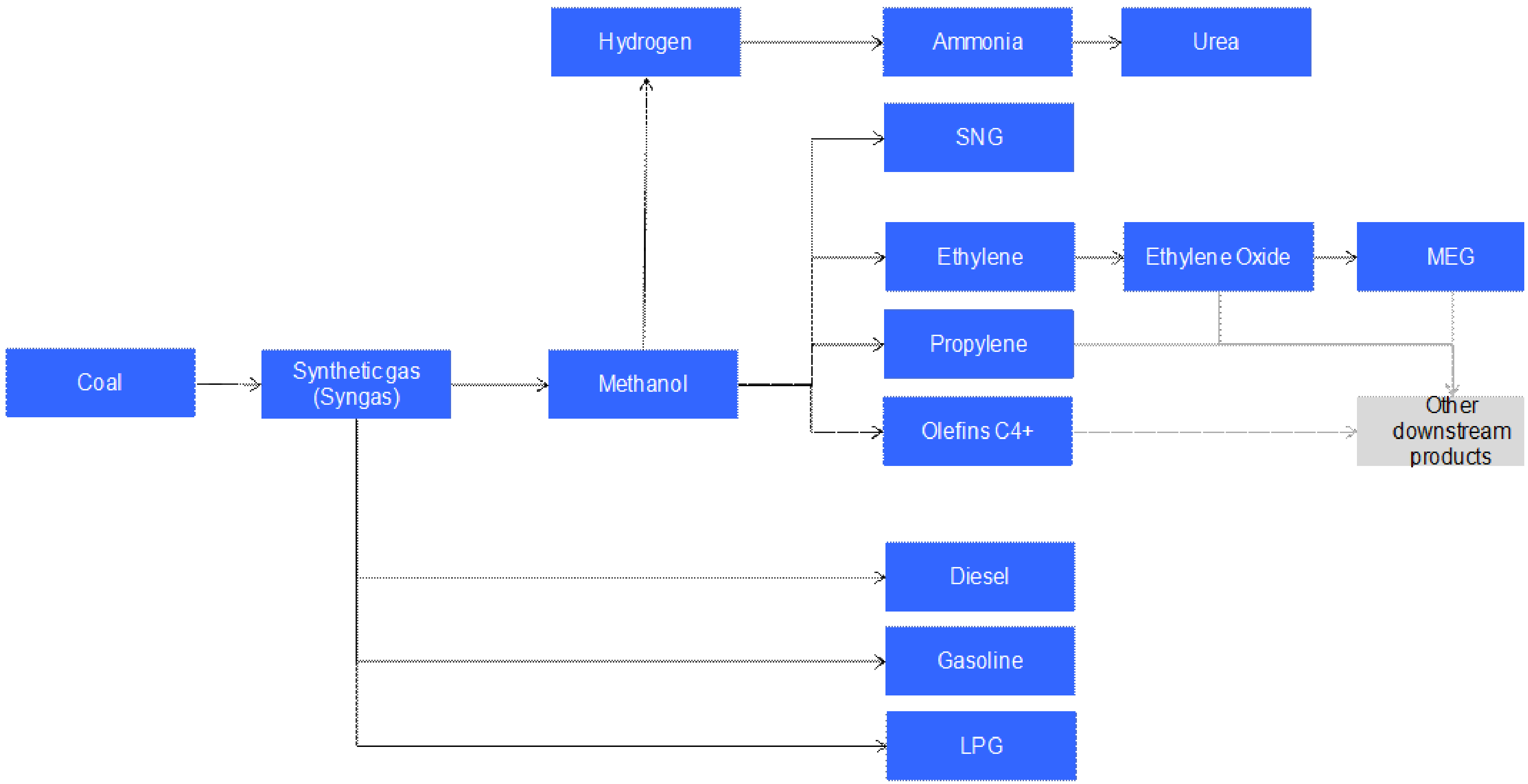
Synthetic Natural Gas	Urea	Methanol	Liquids *	Olefins
0.1 (per mcf)	0.77	1.40	3.50	4.20

Increasing coal consumption per ton product

* "Liquids" is collective class of oil products (gasoline and diesel)
For a coal-to-liquids project, the operator will adjust its optimal product mix by demand of each oil products

Source: Shenhua Group data, DICP, Deutsche Bank

Figure 19: China's coal-to-chemicals industry as contemplated in the country's 12th Five Year Plan (2011-15e)



Source: Deutsche Bank

Syngas

Coal gasification -

Syngas – a bit of H and CO, "shaken not stirred"

Syngas is not a compound or element that can be explained as "C_3Hy" or "HxM_2". Syngas is a mixture of carbon monoxide (CO) and hydrogen (H) without uniform structure and / or proportion.

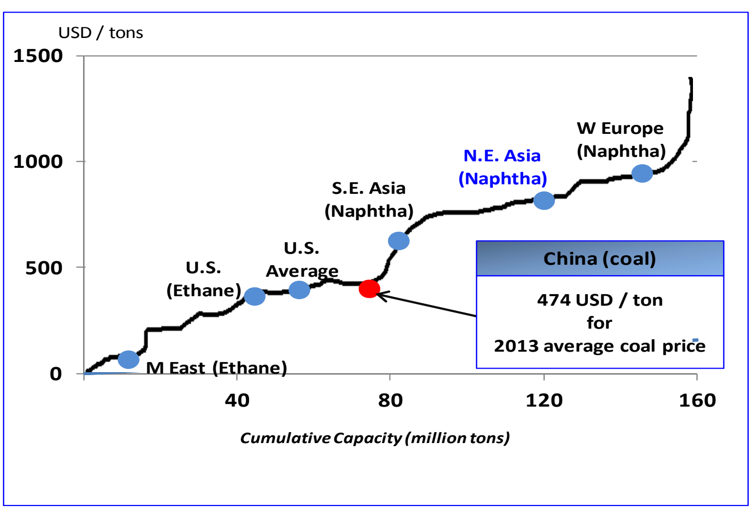
Any carbon containing substance can be "gasified"

Syngas or synthetic natural gas is produced by either (i) the gasification of carbon-rich matters (like coal) and / or (ii) steam reforming of methane (natural gas). Any carbon-containing substance (e.g. coal, biomass, wood, industrial waste, petcoke) can be "gasified" and thereby converted into syngas.

More and more low cost natural gas – China shale?

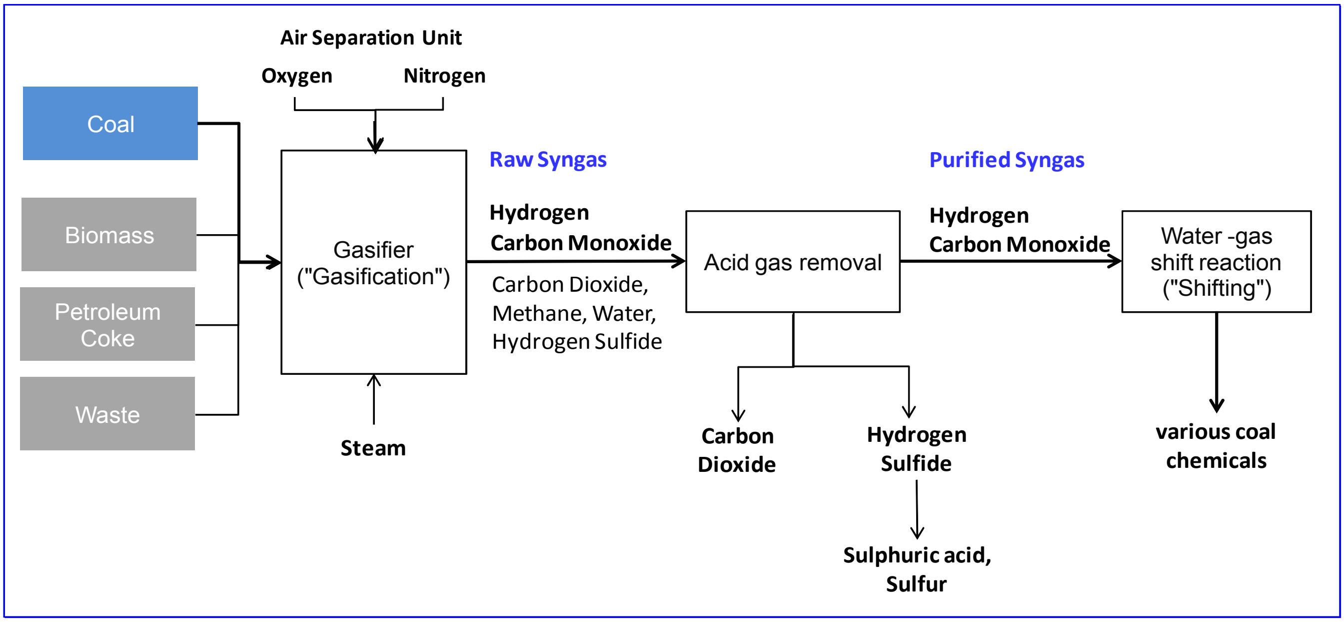
China is using its remote and abundant coal resources in northern China (Inner Mongolia, Shanxi and Shaanxi provinces) and western China (Xinjiang and Ningxia provinces) to produce petrochemicals, fuels (gasoline and diesel), fertilizers and synthetic natural gas. The current economics of China coal-to-olefins is cost efficient relative to the standard Asian fare of using naphtha to produce olefins (Figure 20). However, China's coal-to-olefins is not cost efficient relative to "associated natural gas liquids" to chemicals out of the Middle East and / or "shale gas" to chemicals out of North America.

Figure 20: Ethylene production cost curve (2013)



Source: Company data; IHS Deutsche Bank

Figure 21: Overview – from coal feedstock to purified Syngas



Source: Deutsche Bank

Shell Coal Gasification Process – most widely used

In this analysis we consider the Shell Coal Gasification Process ("SCGP") as opposed to other gasification processes as developed by GE Energy, Lurgi and / or Siemens (Figure 32-33). All four of these coal gasification systems have proven to be effective; yet, all four have slightly different input / output requirements / products. Of the various technologies available for coal gasification, the Shell Coal Gasification Process is most widely used globally and as a result the process that we focus on in this FITT report.

Wet or dry coal

As an example of the differences in gasification technology, both the GE Energy and the Lurgi gasification process call for a coal slurry (rather than coal dust) to be fed into the gasifier. Although the processes / technologies differ the output is roughly the same (Figure 32-33).

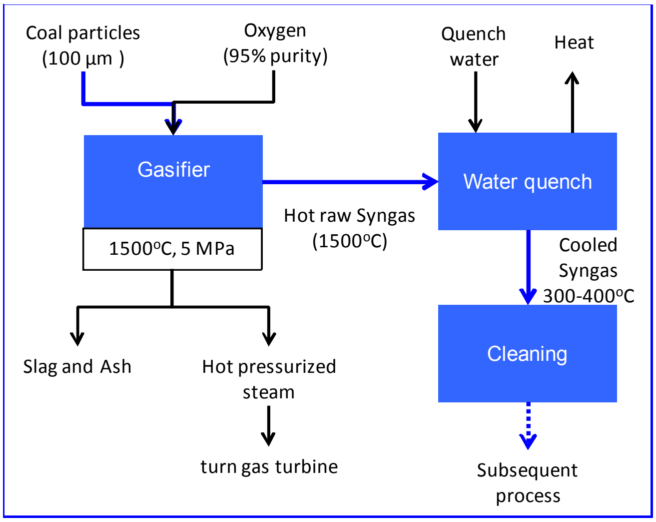
The "gasification" process

The process of converting coal to syngas

Under the Shell SCGP process, dry coal is pulverized in a milling unit and fed into a gasifier which has been pre-heated to 1,400-1,600 °C and placed under 5 MPa of pressure. Compressed oxygen, nitrogen and steam are added to the gasifier. The compressed oxygen (O_2 @ 95% purity) and steam (H_2O) serve as reactants in the "gasification" process (converting coal powder into carbon monoxide and hydrogen) while nitrogen (N) acts as a transport vehicle.

In the presence of oxygen and heat, coal carbon converts to carbon monoxide (CO) and carbon dioxide (CO_2) inside the gasifier. Steam is added; the carbon in the form of CO & CO_2 reacts with steam (H_2O) to form carbon monoxide (CO) and hydrogen (H), known as Raw Syngas (Figure 21-22). At 1,400-1,600 °C, coal ash melts into slag and exits the bottom of the gasifier as molten liquid coal slag which can be re-used as a building material in the construction industry (Figure 22-23).

Figure 22: The coal gasification process



Source: Deutsche Bank

Figure 23: Economics of coal gasification by-products

	US$/ton	Ton/hr	Revenue per year (million US$)
Ash	50	3.5	**1.4**
Slag	25	9.0	**1.8**
Steam	38	27.0	**8.1**
	Total revenue of by-products		**11.3**

We assume the gasifier operates 7,920 hrs per year (24 hrs x 330 days) and all by-products can be sold at market value

Source: Company data; Deutsche Bank

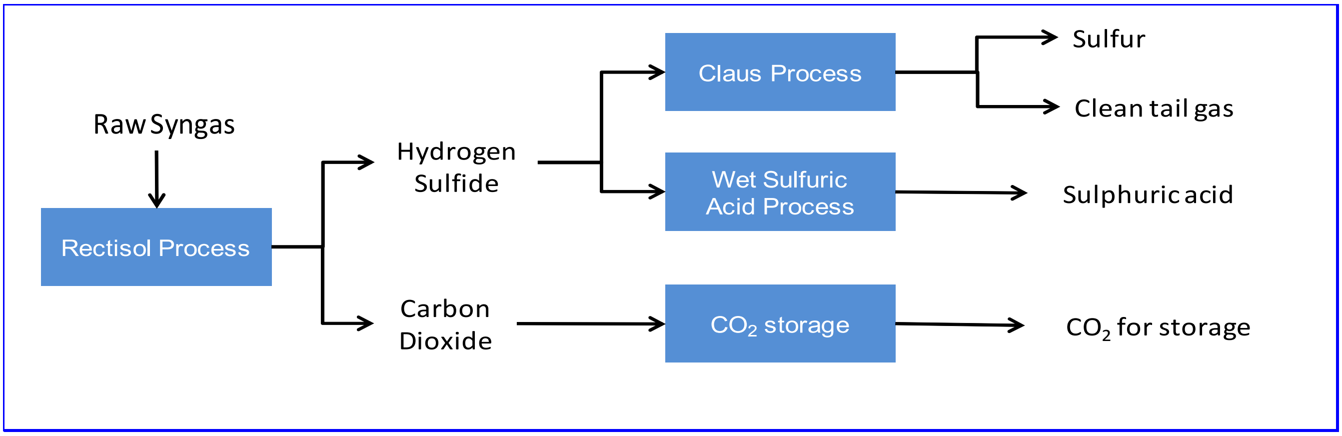
Hot raw Syngas leaving the gasifier can reach 1500°C and needs to be cooled. The cooling is done by water quench for heat recovery. Fresh water is the preferred source used to cool the syngas as brackish (with salts) water will tend to corrode the equipment. High pressure steam will be generated from the cooling process and thereafter either i) released from the system for subsequent processes (e.g. turning the gas turbine), or ii) sold in the market for purposes generally associated with space heating.

The raw syngas clean up process

Cleaning up the syngas to avoid costly complications in later processes

Raw syngas leaving a gasifier consists mostly of hydrogen (H) and carbon monoxide (CO) with small amounts of acid gas (mainly carbon dioxide and hydrogen sulfide) and other impurities (ammonia and mercury). The acid gas has to be removed from the syngas otherwise it will compromise the catalyst used in subsequent coal to chemical synthesis.

Figure 24: Cleaning up Raw Syngas



Source: Deutsche Bank

Get rid of that carbon dioxide

Rectisol Process (Figure 24) - "Rectisol" is an acid gas removal process / technology which uses a refrigerated methanol (-40°C) solvent to separate carbon dioxide, hydrogen sulfide and other impurities (ammonia, mercury) from raw Syngas. The methanol solvent is dispersed from the top of the Rectisol Wash Unit and flows down to cover a collection of many small, silver coated balls; the raw syngas is injected from the bottom of the wash unit and flows upward through the voids of the balls. The spheres coated in cooled methanol provide a large surface area for the syngas and methanol to interact. Carbon dioxide and hydrogen sulfide are absorbed into the cooled methanol at high pressure. Syngas leaving the second methanol bath contains primarily carbon monoxide and hydrogen. The Rectisol process lowers the sulfur and carbon dioxide content in syngas to 0.1 and 10 ppm respectively. The saturated methanol is thereafter cleaned of the carbon dioxide (pressure reduction) and hydrogen sulfide (heat application) and recycled.

The Rectisol Process is licensed by both Linde and Lurgi. The process is inexpensive, available worldwide and used extensively in China. The methanol solvent used in the process carries a cost of roughly US$ 460/ ton. For a Rectisol Wash Unit with processing capacity of 22 mcf (syngas) / hour, roughly 200 tons of methanol per month is required.

Hydrogen sulfide is highly toxic and will normally be converted to two different products: 1) elemental sulfur (Claus Process), and / or 2) sulfuric acid (the Wet Sulfuric Acid Process) depending on economics. The current market price for sulfuric acid and elemental sulfur is US$160/ton and US$32/ton respectively.

The carbon dioxide released from saturated methanol (Rectisol process) can be sold to the market; released into the environment; injected into oil fields and / or saved into inventory. The injection of CO_2 into depleted oil fields 1) dissolves into the crude oil and reduces viscosity, and 2) increase down-hole pressure to force more oil up to the surface for collection. Additional common uses of CO_2 include: 1) food processing / food transport (dry ice); 2) water treatment / PH control; and 3) beverage industry / carbonation of drinks.

Figure 25: Rectisol Wash Unit by Linde at Jilin, China

Source: The Linde Group, Deutsche Bank

Get rid of that deadly hydrogen sulfide

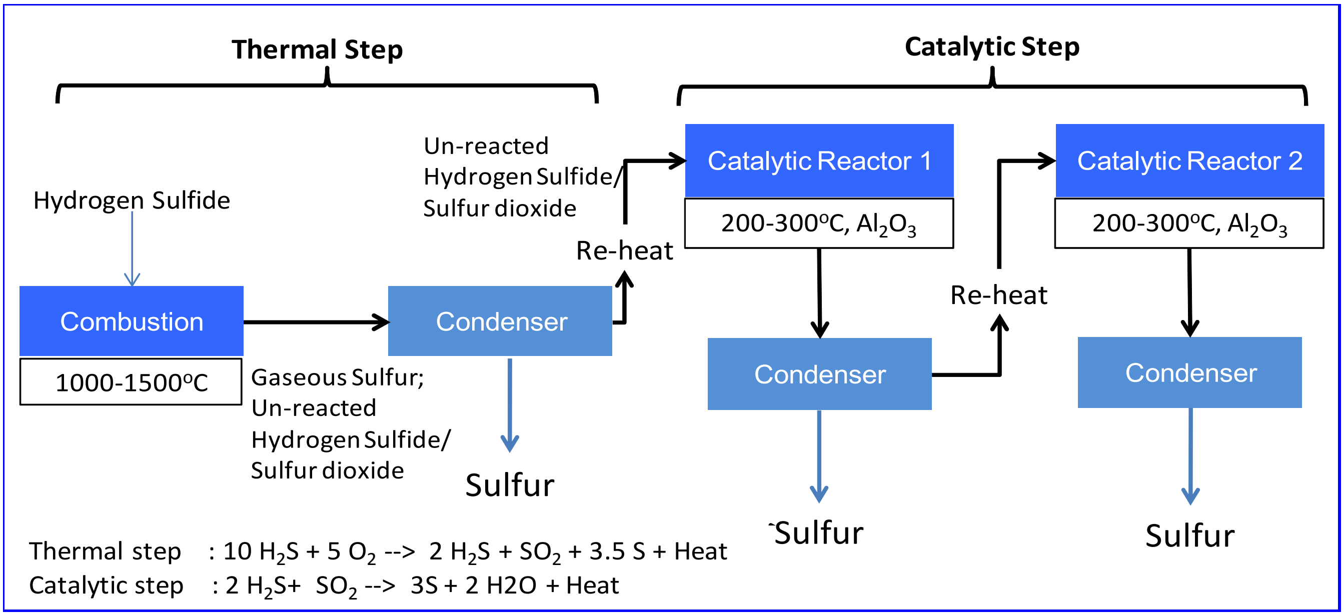
The **Claus Process** (Figure 26) - "Claus" is a desulfurizing process that converts gaseous hydrogen sulfide to elemental sulfur. The Claus process can be divided into two steps: a thermal process and a catalytic process.

In the thermal step, hydrogen sulfide is fed into a combustion chamber at a temperature of 1000-1500°C and pressure of 70k Pa. One-third of the hydrogen sulfide is oxidized to sulfur dioxide; two-thirds remains as hydrogen sulfide. Sulfur dioxide will further react with the remaining hydrogen sulfide to form sulfur in gaseous form. The hot gas (rich in gaseous sulfur) is cooled and condensed in a heat exchanger. The condensed liquid sulfur is separated from the remaining un-reacted gas and collected for storage. The un-reacted gas will be process further through the catalytic stage.

In the catalytic step, the un-reacted gas is re-heated and fed into the first catalytic reactor at a temperature of 300 °C in the presence of an aluminum/ titanium-based catalyst. Roughly 20% of the hydrogen sulfide is converted into gaseous sulfur. The gas mixture (containing gaseous sulfur and un-reacted hydrogen sulfide / sulfur dioxide) leaving the first catalytic reactor is cooled in another condenser. The gaseous sulfur is condensed into liquid sulfur and separated from the remaining un-reacted gas at the outlet of the condenser. The liquid sulfur is sent to storage.

The un-reacted gas leaving the condenser is sent to another re-heater and the process is repeated for a second and third and / or fourth time at successively lower reactor temperatures. The thermal step converts ~70% of sulfur (end product) and the catalytic step converts the remaining 30%.

Figure 26: The Claus Process which converts hydrogen sulfide to elemental sulfur



Source: Deutsche Bank

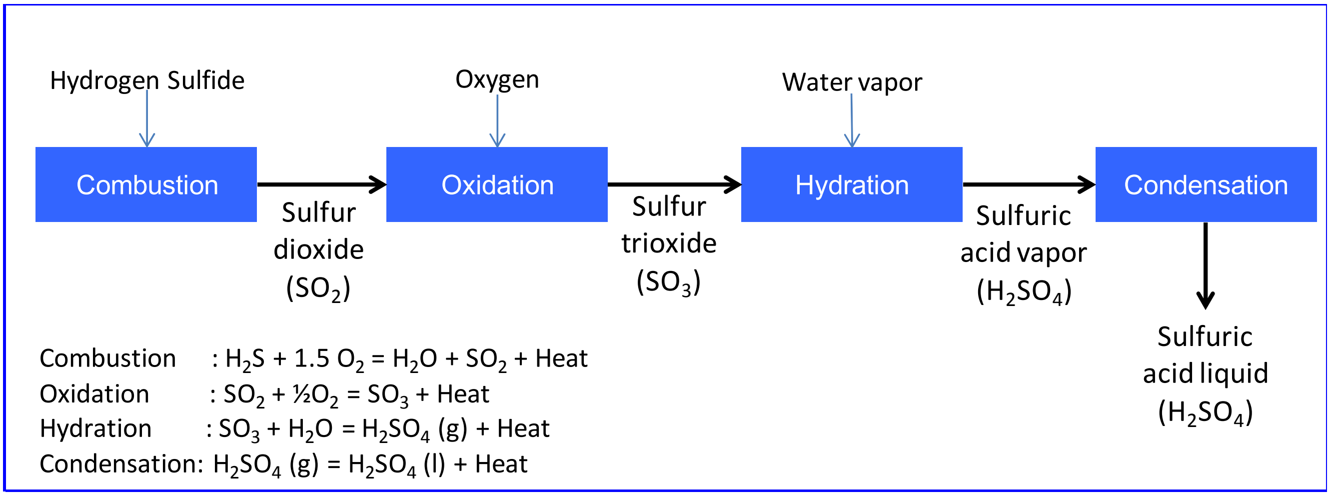
The **Wet Sulfuric Acid Process** (Figure 27) - “WSA” converts hydrogen sulfide into commercial grade sulfuric acid.

Hydrogen sulfide gas is first combusted to convert hydrogen sulfide to sulfur dioxide (SO_2). The gas is then heated or cooled as the case may be to the required inlet temperature of the converter. Sulfur dioxide undergoes oxidation to sulfur trioxide (SO_3) in the presence of the catalyst. At the exit mouth of the converter the gas is cooled with water vapor which allows SO_3 to react with water to form sulphuric acid (H_2SO_4) in the gas phase.

The cooled gas enters the WSA condenser which condenses the sulphuric acid gas to form the liquid product. Sulphuric acid condenses in the tubes and flow downward counter-current to the rising hot process gas. This contact with the hot process gas concentrates the acid to the desired product acid concentration.

The sulfuric acid collects in the brick lined lower section of the WSA condenser where it is pumped out and cooled before it is delivered onward to storage. The principal uses of sulfuric acid include mineral processing, fertilizer manufacturing, oil refining and chemical synthesis.

Figure 27: The Wet Sulfuric Acid Process which converts hydrogen sulfide to sulfuric acid



Source: Deutsche Bank

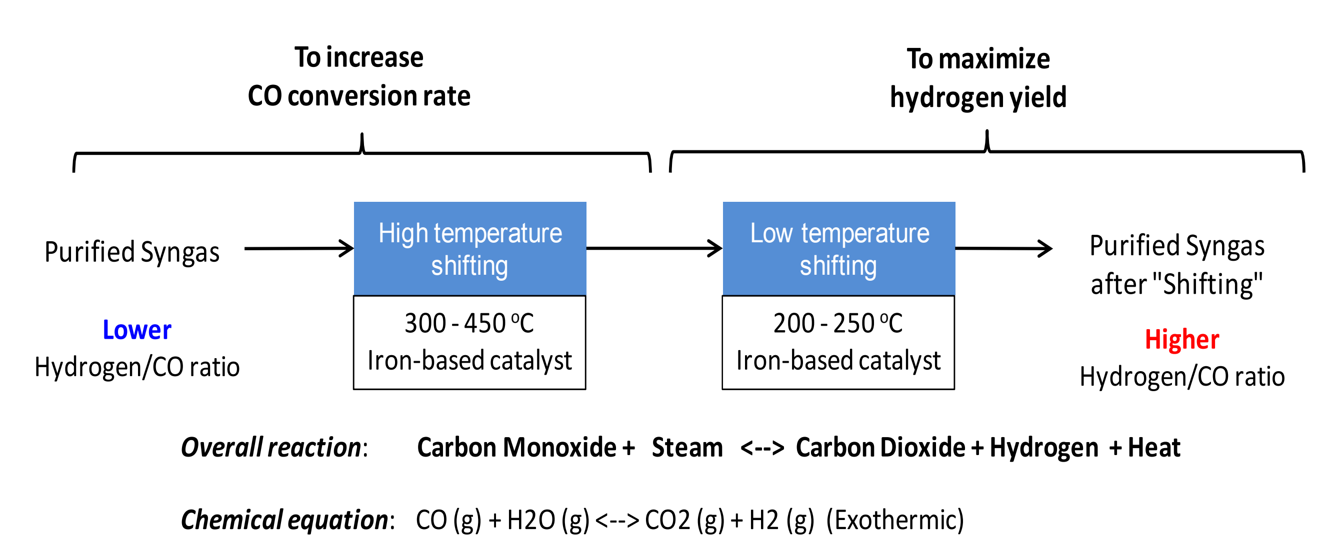
The water-gas shift reaction

Upgrade syngas to a CO-to-H ratio of 1:2

The **Water-gas Shift Reaction** ("shifting") is used to increase the ratio of hydrogen to carbon monoxide in purified Syngas. This is achieved by adding steam (water–H2O) to the purified Syngas and passing it through a series of steps under an iron / copper-based catalyst. The process converts the carbon monoxide (CO) contained in the purified Syngas to carbon dioxide (CO_2) by stealing an additional oxygen molecule from the steam / water. Stripped of its oxygen molecule, water (H_2O) becomes two molecules of hydrogen (H). This is the "water-gas-shift" reaction referred to in all "coal-to" processes.

Raw syngas exiting a Shell SCGP coal gasifier generally contains 63% carbon monoxide and 27% hydrogen by volume, which is a ratio of 1:0.43. Purified and "shifted" syngas ready for methanol synthesis and thereafter olefin production should have a CO / hydrogen ratio of 1:2. The water shift process rearranges the molecules at hand to produce a mixture of carbon monoxide and hydrogen at an optimal ratio of 1:2.

Figure 28: Overview: Water-gas shift reaction



Source: Deutsche Bank

Striking the right balance

The "high temperature shift" speeds up the shifting reaction but also leads to incomplete conversion of steam (water) to hydrogen. The higher temperature may actually cause the normal "shift" reaction to reverse thereby causing hydrogen and carbon dioxide to convert back to steam and carbon monoxide. The water-gas shift reversal is caused by too much heat. The water-gas shift reaction in its own right gives off heat. The heat released during the shift together with the heat (steam) supplied externally can cause elevated temperatures inside the reactor. Very high temperatures will cause the shift reaction to reverse – thereby reducing the hydrogen yield of the process. In order to strike a balance between the reaction rate and the maximize hydrogen yield, Syngas has to pass through two "shift" stages: 1) the "High Temperature Shift", and 2) the "Low Temperature Shift". The two-step shift process maximizes the hydrogen yield from the reaction.

Equipment used in the coal-to-syngas process

Dime a dozen

The gasifier (Figure 29-33) is one of the more important pieces of equipment for coal-to-chemical projects. The gasifier converts coal to syngas. The coal to syngas reaction depends on the type of gasification technology used: Shell, Siemens, Lurgi, KBR and GE Energy all have licensed gasification technology. Shell's (SCGP) technology is the most widely used coal-to-syngas process.

Almost 40 years of development.

Shell started its coal gasification technology in 1976 and has been licensing its technology in China since 2000. Up to 1H2013, Shell had 21 coal gasification units operating in China; the majority of these units are used for producing coal-based urea and methanol.

Figure 29: Coal gasifier (Shenhua CTL)

Source: Siemens, Deutsche Bank

Figure 30: Critical components of Shell gasifier

Components	Current authorized vendors	Local vendors?
Gasifier internal parts	Wuxi Huaguang Boiler, Dongfang boiler	Yes
Coal burners	SMDERI	Yes
Lignition starters	HTYZ	Yes
Sluicing valves	Honshen Antiwear	Yes
Coal flow diverter valve	Hefei MRI	Yes
Coal mass flow measure device	No local vendors	No
Aeration devices	Xi'an baode, AT&M	Yes

Source: Deutsche Bank

2,000 tons of coal will get you 5,000 mcf/ hour for the day

A standard Shell gasifier (diameter of 4.8 meters, weight of 1,300 tons) has a Syngas capacity of 4,600-5,300 mcf / hour and requires 2,000 tons of coal feedstock per day. Nearly all critical components of the Shell gasifier are manufactured in China. The major authorized local vendors of the Shell gasification unit include Shanghai Boiler Works Company (BOIZ CH / private company) and Dongfang Boiler Group (subsidiary of Dongfang Electric Corp – 1072 HK; Buy).

The inner wall of a Shell coal-gasifier consists of glass water tubes which are arranged side-by-side vertically, and held together by a flat steel sheet. The wall temperature is controlled by circulating water through the glass tubes. Slag covers the surface of the glass water tubes and thus provides a protective layer. The gasifier wall has an estimated life span of 20 years. Most other gasification process technologies use heat-resistant brick walls that need to be replaced every two-years. The replacement of a heat-resistant brick wall per gasifier costs ~US$0.75 million and requires a two month shutdown.

GE Energy coal gasification technology (formerly Texaco gasification technology) has been in China for more than 20 years. However, since 2005, GE has won few contracts from the China market as domestic coal gasification technology gains market share at GE's expense. The GE Energy (Texaco) gasifier uses refractory brick as the main material for the walls of the gasifier. Syngas from the GE Energy gasifier has a lower heating value (than others) because the coal is injected as slurry (water accounts for 40% of the mixture by mass) rather than as coal dust.

Figure 31: Major Shell coal gasification projects in China

	Products	Coal usage (ton/day)	Syngas (Nm^3/hr)
Sinopec Shell Yueyang	**Ammonia / Urea**	**2,000**	**142,000**
Sinopec Hubei Chemical	**Ammonia / Urea**	**2,000**	**142,000**
Shenhua Inner Mongolia Direct Coal Liquefaction	**Hydrogen**	**4,000**	**300,000**
Datang Power	**Coal to synthetic natural gas**	**2800 x 3**	**~600,000**

Source: Company data, Water in Synthetic Fuel Production; Deutsche Bank

Figure 32: Reaction condition: Shell (SCGP) vs. GE Energy

	Shell (SCGP)	*Unit*	*GE Energy*
Reaction condition			
Temperature	1400 -1700	°C	1300 - 1400
Pressure (Mpa/psi)	2.46 / 357		4.22 / 612
Physical form of Coal for injection	Coal powder		Coal slurry
Composition by volume			
Hydrogen	26.7	%	30.3
Carbon Monoxide	63.1	%	39.6
Total of hydrogen and CO	**89.8**	**%**	**69.9**
Carbon Dioxide	1.5	%	10.8
Methane	0.03	%	0.1
Hydrogen Sulfide	1.3	%	1
Water moisture	2.0	%	16.5
Others	5.4	%	1.7
Total	100	%	100
Carbon Conversion Efficiency	> 99%		96 - 98%

Source: Company data; Water in Synthetic Fuel Production; Deutsche Bank

Figure 33: A comparison of global coal gasification technologies

	Shell SCGP	GE Energy	Siemens
Coal suitability	- Lignite Anthracite Bituminous - High ash and / or sulfur content suitable - Coal processed as powder	- Lignite Anthracite Bituminous - High ash and / or sulfur content suitable - Coal processed as slurry	- Lignite Anthracite Bituminous
Oxygen requirement	400 units of oxygen required per 1000 unit Syngas (Lower than GE by 15-25%)	330 units of oxygen required per 1000 unit Syngas	400 units of oxygen required per 1000 unit Syngas
Gasifier wall	Sepcial-designed membrane (No brick refractory wall) 20 years useful life	Brick refractory wall 2 years lifetime	Both "special-designed membrane" and "brick refractory wall" are available
Capital cost	Higher	Lower	Highest
Effective Syngas yield (Hydrogen and CO)	95%	80%	90%
Operating condition			
Temperature	1400 - 1600 ^{o}C	Lower than Shell	Same as Shell
Pressure	4 MPa	Higher than Shell	Same as Shell
Repair and maintainence	Low	High	Low
Equipment supplied locally	Most critical parts supplied locally	Most critical parts supplied locally	Few critical parts

Source: Company data; Water in Synthetic Fuel Production; Deutsche Bank

Yingde's business

The Air Separation Unit (Figure 34) is another critical piece of equipment in converting coal to syngas. The ASU (Air Separation Unit) separates atmospheric air into gaseous / liquid oxygen, nitrogen, argon and sometimes other inert gases (Neon, Krypton and Xenon) by cryogenic distillation. Industrial gases are principally used in the steel, chemical, refining, metallurgy, and food processing industries. ASU technology is well-developed globally.

Coal gasification requires lots of pure oxygen

A coal-to-chemicals project requires compressed pure oxygen for the coal gasification process (Figure 21, Figure 22 & Figure 27). Nitrogen is also required for subsequent steps in coal to chemicals production (e.g. for producing MEG and ammonia/ urea). The average industrial gas volume required in the coal-to-chemical process is higher than most industrial processes. For example, a coal-to-olefins plant with 600,000 ton/ year capacity needs installed oxygen capacity of 8,500 mcf / hr while a steel mill with 1,000,000 ton/ year capacity needs only 5,300 mcf / hr.

Yingde is China's largest industrial gas provider

The largest A.S.U. manufactured globally has oxygen capacity of 200k Nm3/ hour (5,700 mcf / hr). An average-sized ASU has capacity of 30-60k Nm3/ hour. The global industrial gas market is dominated by several big corporate names: Air Liquide (AI FP; Buy), Linde (LIN GY; Buy), Praxair (PX US; Buy), and Air Products and Chemicals Inc (APD US; Buy), all of which operate in China. Yingde Gases (2168 HK - Buy) is China's largest industrial gases provider by revenue and a major competitor (in China) to the international suppliers. Yingde has two large ASU service contracts for Coal-to-Chemical projects: 1) the Shenhua Baotou CTO project (4 x 60k Nm3/ hr); and 2) the China Coal CTO project (4 x 60k Nm3/ hr.).

Industrial gases - a growing industry in China

The industrial gas market in China is growing at CAGR of 11.1% pa (2007-13) and the business opportunity is shifting from more traditional industrial customers (steel, refining and petrochemicals) to "new economy" customers (CTO, CTM, Healthcare; and Technology). Hangzhou Hengyang Company Ltd (002430 CH) is China's largest manufacturer ASUs.

Stand alone economics for the transformation of coal to syngas is in short supply. We continue to search for this information. Notwithstanding, syngas economics are captured in industry and our integrated CTM cost models (Figure 64-71) as well as industry and our CTO cost models (Figure 87-91).

Figure 34: A.S.U. for Shenhua Baotou (2,100 mcf/hr x 4)

Source: Linde, Deutsche Bank

Methanol

What is it?

Step two of three

The second step in producing olefins (ethylene and propylene) from coal is the conversion of Syngas into Methanol, which among other things (Figure 35) serves as a feedstock for CTOlefins, CTLiquids. CTUrea/ Ammonia and most "Coal-to" end products.

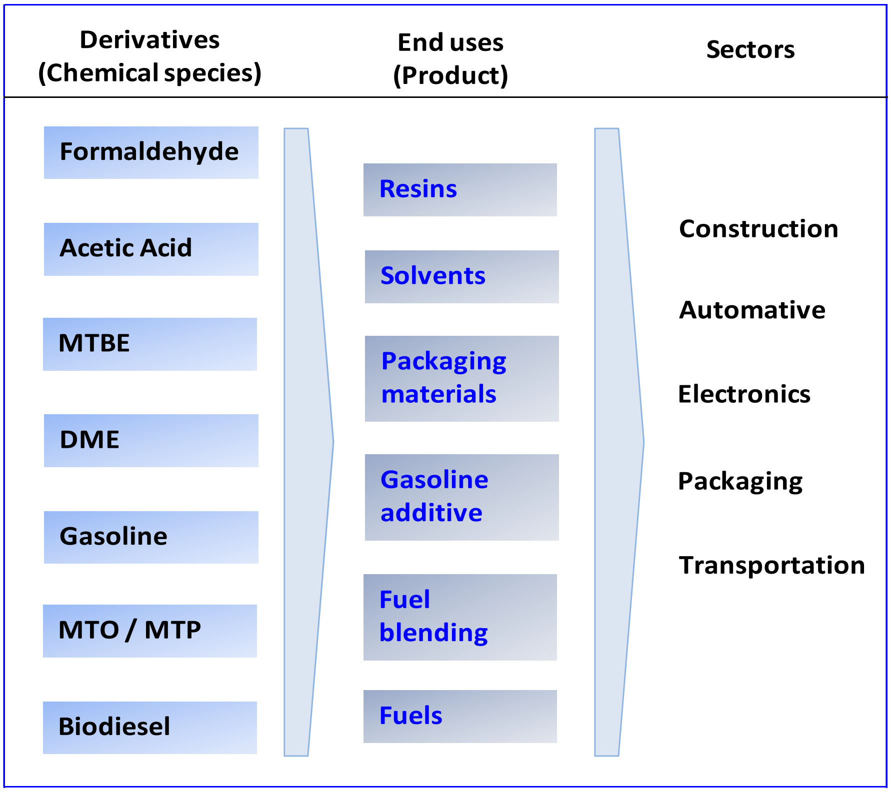
Syngas is mostly produced from natural gas (70%) rather than coal (11%).

Syngas is a mixture of hydrogen and carbon monoxide. Syngas can be made from a wide array of feedstocks including natural gas, coal, oil / naphtha / fuel oil / coke, wood and biomass. Today, 70% of global methanol production comes from the synthesis of natural gas into syngas while 11% comes from the synthesis of coal to syngas. The remaining 19% of methanol production comes predominantly from the synthesis of oil products / naphtha / fuel oil into syngas. Currently, one-hundred percent (100%) of the world's Coal-to-Methanol ("CTM") production is based in China.

Fuel (mixing) applications / the construction industry / other industrial products

Methanol is a light, colorless and flammable liquid. It is corrosive to certain metals (ICE engines) and it burns without smoke and / or a noticeable flame. The chemical formula for methanol is CH_3OH. Globally, methanol is used 1) in energy / fuel applications (30-35%), 2) in producing formaldehyde (30-35%) which in turn is principally used as an adhesive in the construction industry, and 3) in producing other industrial products (30-35%). Figure 35-38 provide a glimpse into the many uses of methanol in today's global economy.

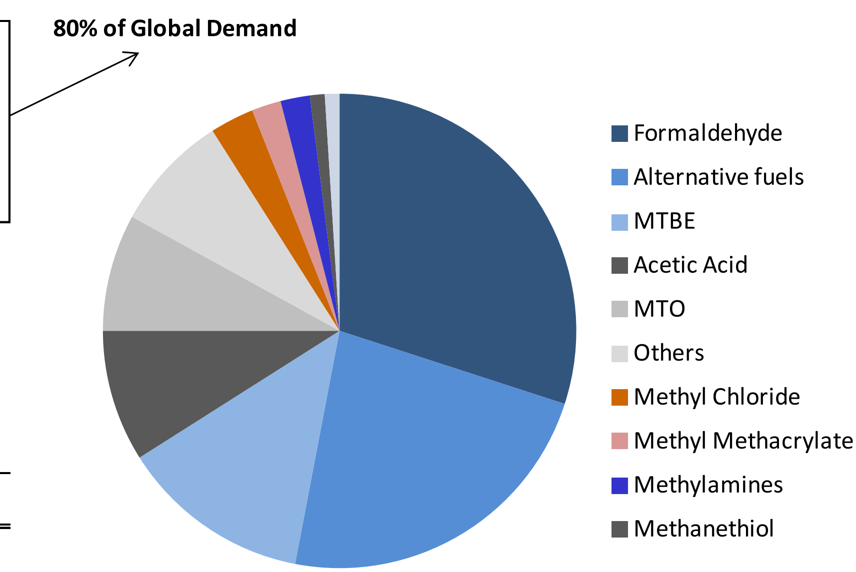
Figure 35: Summary on methanol's major uses



Source: Methanol Institute, Methanol Market Services Asia, Deutsche Bank

Figure 36: Global Demand for methanol (2012)

Formaldehyde	***30%***
Alternative fuels	***23%***
MTBE	***13%***
Acetic Acid	***9%***
MTO	***8%***
Others	8%
Methyl Chloride	3%
Methyl Methacrylate	2%
Methylamines	2%
Methanethiol	1%
DMT	1%
	100%



Source: Methanol Institute, Methanol Market Services Asia, Deutsche Bank

In Figure 37-38 we consider the uses of methanol in terms of energy (fuels) and non-energy related uses.

Figure 37: Application of methanol – non-energy related

Formaldehyde	Formaldehyde is mainly used for making **resins** in textile and construction industries, **adhensive** for industrial uses and **disinfectants**.
Acetic Acid / Pure Terephthalic Acid	Acetic Acid / Pure Terephthalic Acid is mainly used for making vinyl acetate and trreftalic acid which are used for the synthesis of polyethylene terephthlate (PET). PET is used for making **plastic containers, glass fibers and Dacron**.
MTO	Methanol to Olefins - MTO is mainly used for making polyethylene and polypropylene. Polyethylene / Polypropylene are used for making **plastic bags, plastic containers and packaging materials**.

Source: Methanex, Deutsche Bank

Figure 38: Application on methanol – energy-related

Fuel Additive	Methyl tertiary-butyl ether (MTBE) is made from methanol and is used to **make gasoline burn cleaner** with fewer emissions. Its use is controversial in the US and Europe. In 2003, several US states banned methanol and started replacing MTBE with ethanol.
Fuel Blending	Methanol can be mixed directly with gasoline and used as a transport fuel.
DME	Dimethyl ether (DME) is a common gaseous fuel used for cooking and heating principally in Asia. DME can also be mixed with gasolie and / or LPG to be used as **a transportation fuel.**
Biodiesel	Biodiesel is a fuel made from biological products such as corn and vegetable oils, and is being mixed with methanol to produce **a renewable diesel fuel alternative.**

Source: Methanex, Deutsche Bank

Smaller amounts of methanol are also used globally to produce:

Methyl Chloride is a colorless, extremely flammable and toxic organic gas. It was once used as a refrigerant and gasoline additive. Due to its toxicity and flammability, these "retail" uses have been curtailed at least in developed countries. Methyl chloride is today used principally as 1) a chemical intermediary in the production of silicon polymers, 2) a solvent in the production of rubber, and 3) for various applications in refineries.

Methyl Methacrylate (MMA) is a colorless, liquid organic compound. MMA is used as a chemical intermediate in the manufacture of poly-MMA plastics and as a modifier for PVC. It is also used as a cementing agent by orthopedic surgeons in hip and knee replacements.

Methylamine is a colorless organic gas (CH_3NH_2) and a derivative of ammonia. It is principally used as building block for the synthesis other chemical compounds such as solvents, pesticides and pharmaceutical products. ,

Methanethiol is a colorless organic gas (Ch_3SH). It is used 1) as a dietary additive in animal feed, and 2) as a precursor in the production of pesticides.

Dimethyl terephthalate (DMT) is a white solid organic compound. It is used 1) in the production of polyethylene terephthalate (PET) which is used to make plastic containers, and 2) in the production of polytrimethylene terephthalate (PTT) which is used to make carpet fibers.

Methanol to olefins (MTO) - of which methanol to propylene (MTP) is a sub-segment, is anticipated to be a growth industry in China over the coming decade. The technology used in synthesizing MTO/ MTP has been developed over the past 30 years and seems well developed / mature but underutilized both globally and in China. We suspect this has to do more with economics than anything else. The technology used to convert methanol to Mono-ethylene Glycol or "MEG remains in its infancy.

Global methanol market

The methanol Supply, Demand and Capacity numbers noted throughout this report follow industry practice and do not include methanol consumed by way of the vertically integrated Coal-to-Olefins (CTO) process.

However:

1. The China numbers, and, therefore, by default the global numbers, include Chinese producers of methanol that not only sell methanol to third parties but may also have downstream production processes to convert methanol to DME, MTBE, Acetic Acid and / or other products as an aside; and

2. The China numbers and, therefore, by default the global numbers include "co-production" of ammonia/ methanol. Methanol is (also) a byproduct of the coal to ammonia process. Globally, only China uses coal to produce commercial quantities of ammonia / urea; all other countries use natural gas to produce commercial ammonia/ urea. As a result, only in China do we see methanol production as a byproduct of the coal-to-ammonia production process.

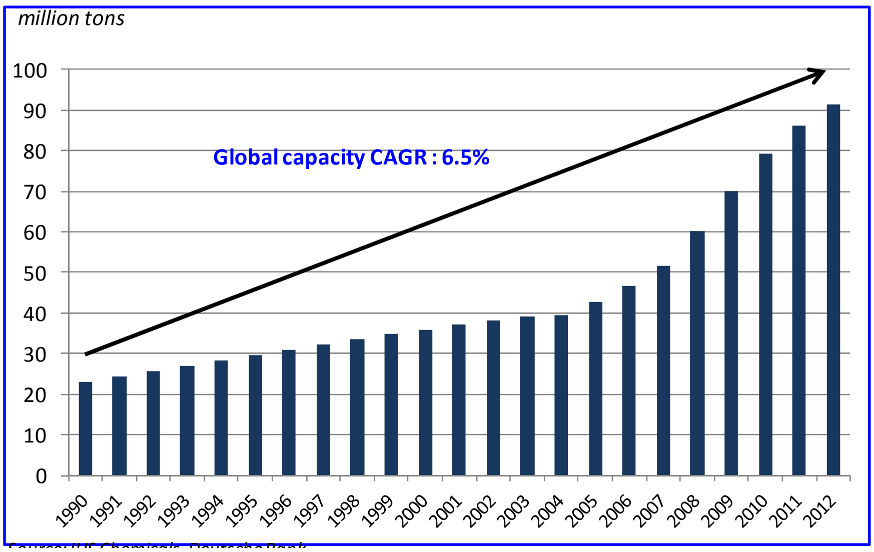
We estimate that 28% (12.7 mln tons) of China's "stand-alone" methanol capacity (45.4 mln tons) is affiliated with the co-production of ammonia / methanol.

Supply – Demand and Growth

From 1990 through 2012, global methanol capacity (Figure 39) grew from 23 million tons to 91.4 mln tons, a CAGR of 6.5%. Over the same period of time, global methanol production (Figure 40) grew from 17.5 to 61.1 million tons, a

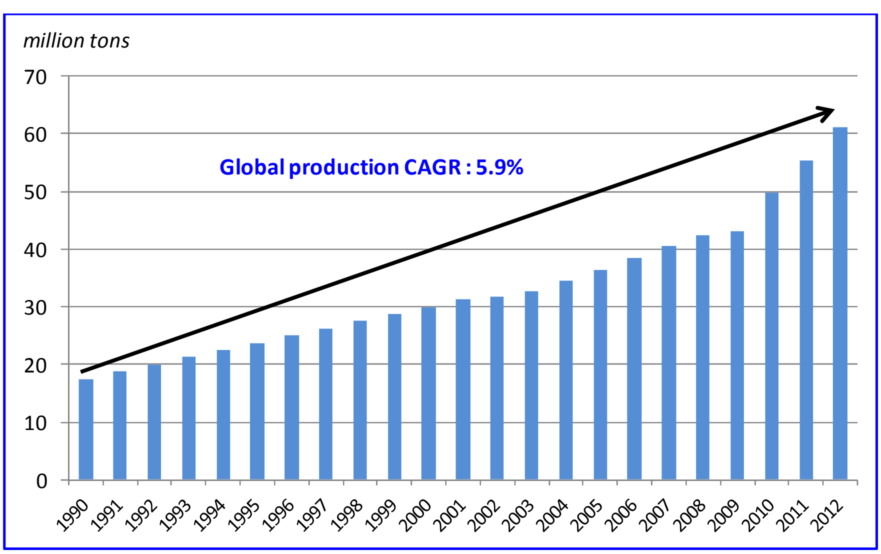
CAGR of 5.9%. Since 1990 methanol capacity has outgrown methanol production leading to a decline in utilization rates from 76% (1990) to 67% (2012). There is excess capacity in today's global methanol market (Figure 41).

Figure 39: Global methanol capacity (1990-2012)



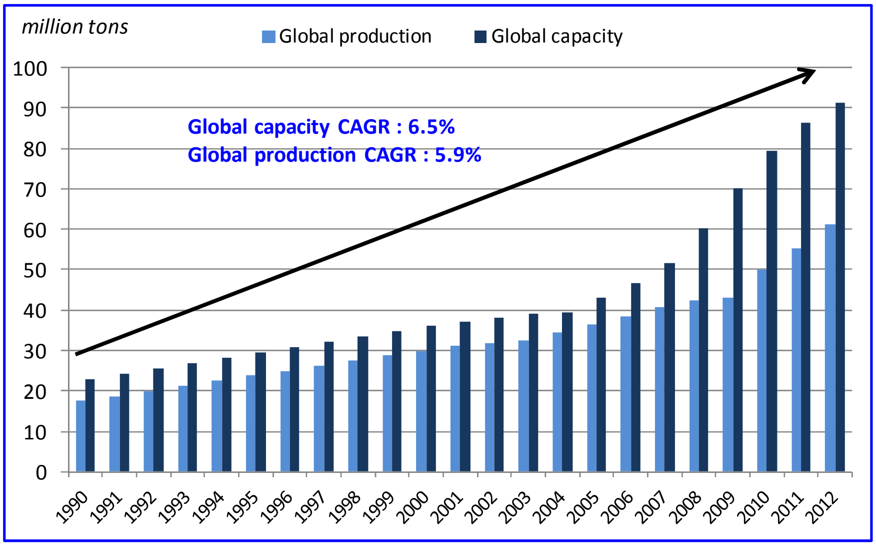
Source: IHS Chemicals; Deutsche Bank

Figure 40: Global methanol production (1990 – 2012)



Source: IHS Chemicals; Deutsche Bank

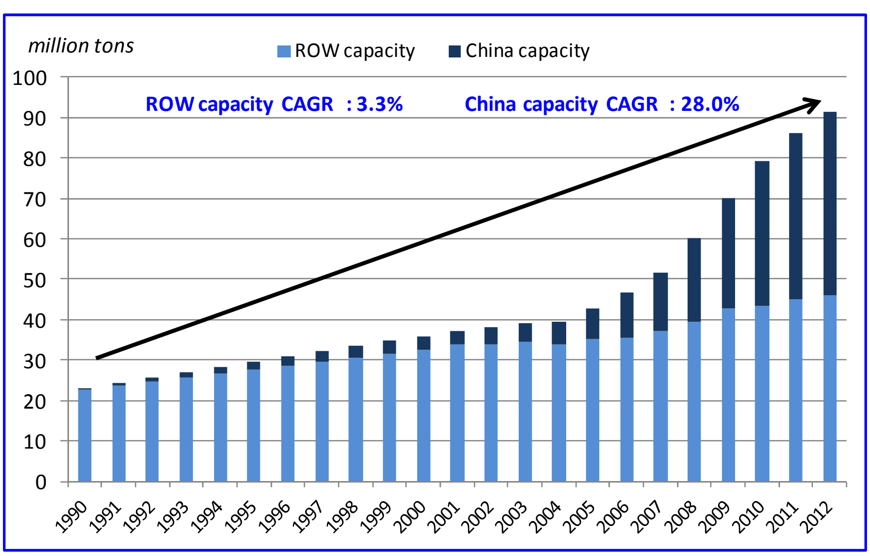
Figure 41: Global methanol – too much capacity



Source: IHS Chemicals; Deutsche Bank

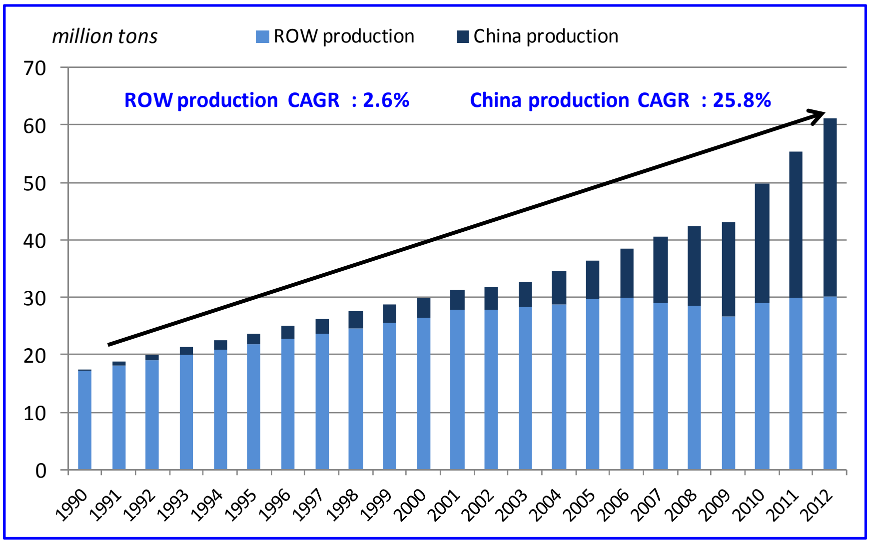
In 2002, China's methanol capacity represented just 10% of global capacity; by 2012, it represented 50% of global capacity (Figure 42). The overcapacity in the global methanol market as well as the recent surge in global production growth is coming from China (Figure 42-43). Global methanol capacity growth (x-China) 1990-2012 has been a modest 3.3% CAGR; China's methanol capacity growth 1990-2012 has been a gigantic 28% CAGR (Figure 42). Global methanol production growth (x-China) 1990-2012 has been a modest 2.6% CAGR; China's methanol production growth 1990-2012 has been a substantial 25.8% CAGR (Figure 43).

Figure 42: China methanol capacity vs. Rest of the World (1990-2012)



Source: IHS Chemicals; Deutsche Bank

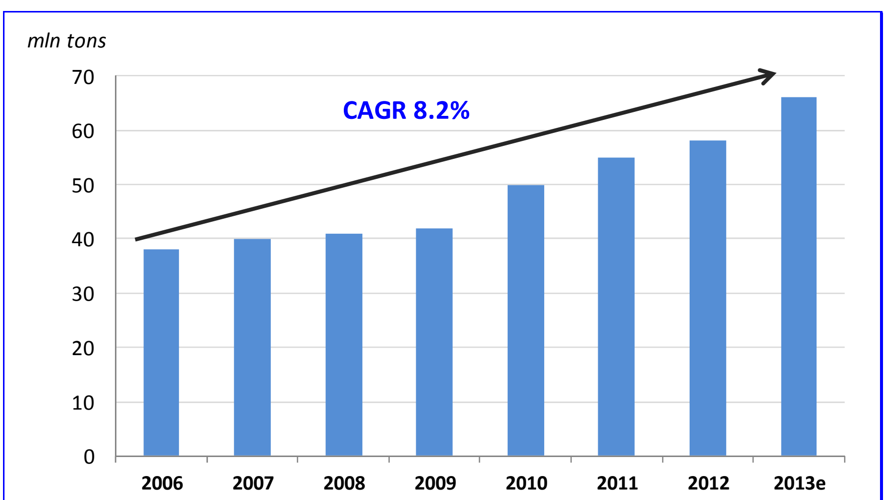
Figure 43: China methanol production vs. Rest of the World (1990-2012)



Source: IHS Chemicals; Deutsche Bank

Global demand for methanol 2006-13 has grown at 8.2% CAGR (Figure 44). Global demand for methanol (x-China) 2006-13 has grown at a miserly 1.4% CAGR. China's demand for methanol 2006-13 has grown at a considerable 22.4% CAGR (Figure 45).

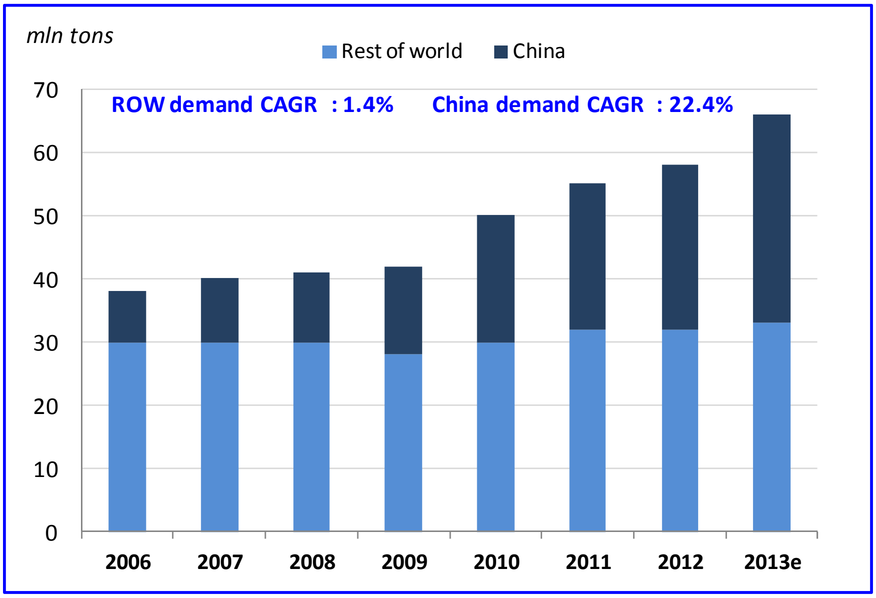
Figure 44: Global methanol demand / consumption (2006-13e)



	2006	2007	2008	2009	2010	2011	2012	2013e
World consumption	38	40	41	42	50	55	58	66

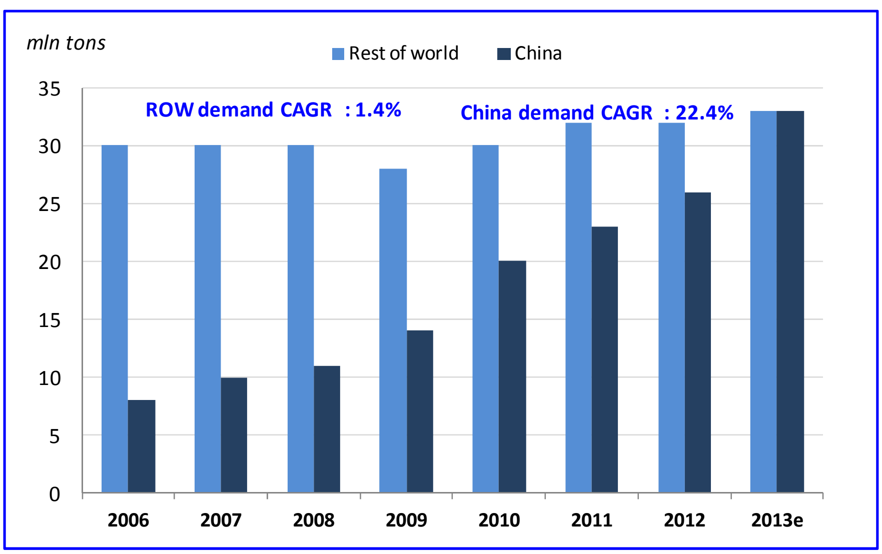
Source: IHS Chemicals; Deutsche Bank

Figure 45: Methanol consumption China vs. Rest of the World (2006-13e)



Source: IHS Chemicals; Deutsche Bank

Figure 46: Methanol consumption China vs. Rest of the World (2006-13e)



Source: IHS Chemicals; Deutsche Bank

What is causing China's consumption of methanol to grow 16x (2006-13e) faster than the rest of the world? Similarly, but over a longer term period, what is causing China's capacity and production of methanol (1990-2012) to grow at 9x the rate of the rest of the world? The world does not care much for methanol; but China seems to have insatiable demand for the stuff.

China's supercharged growth for its demand of methanol is coming from multiple streams (Figure 47-49); however; the two most prominent end-demand segments seem to be: 1) methanol for MTO (methanol to olefins), and 2) methanol for blending with gasoline. We also argue that China's supercharged growth rates are also being influenced by small base effect.

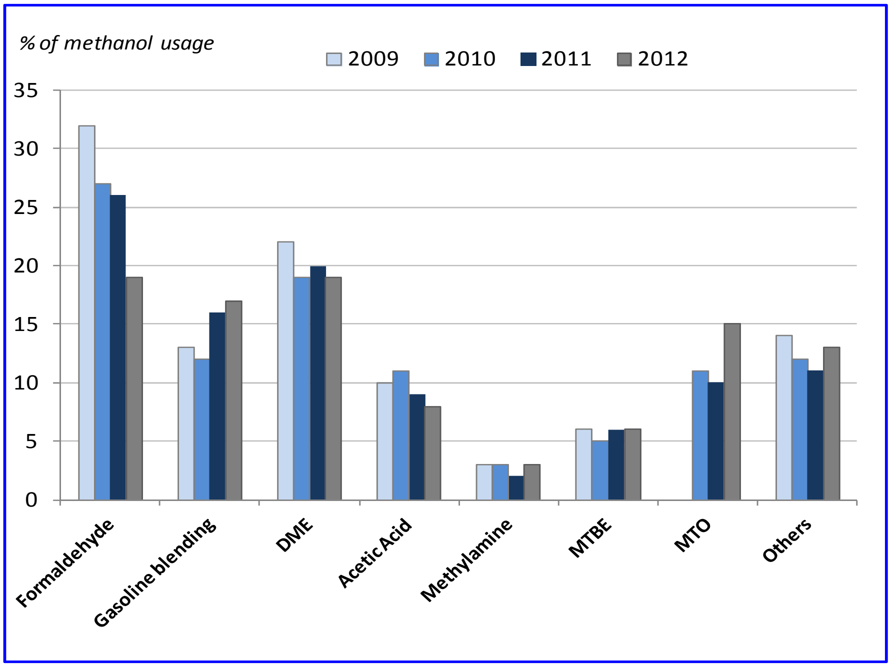
Figure 47: China's methanol consumption by end-product demand

(Millions of tons)	2009	2010	2011	2012	2009-12 CAGR %
Formaldehyde	*5.28*	*5.65*	*6.64*	*5.85*	*3.5%*
Gasoline blending	*2.15*	*2.51*	*4.09*	*5.23*	*34.6%*
DME	*3.63*	*3.98*	*5.11*	*5.85*	*17.2%*
Acetic Acid	*1.65*	*2.30*	*2.30*	*2.46*	*14.3%*
Methylamine	*0.50*	*0.63*	*0.51*	*0.92*	*23.1%*
MTBE	*0.99*	*1.05*	*1.53*	*1.85*	*23.1%*
MTO	*0.00*	*2.30*	*2.55*	*4.62*	*41.6%*
Others	*2.31*	*2.51*	*2.81*	*4.00*	*20.1%*
Total	*16.51*	*20.93*	*25.54*	*30.79*	23.1%

	% of total methanol consumption			
	2009	2010	2011	2012
Formaldehyde	32.0%	27.0%	26.0%	19.0%
Gasoline blending	13.0%	12.0%	16.0%	17.0%
DME	22.0%	19.0%	20.0%	19.0%
Acetic Acid	10.0%	11.0%	9.0%	8.0%
Methylamine	3.0%	3.0%	2.0%	3.0%
MTBE	6.0%	5.0%	6.0%	6.0%
MTO	0.0%	11.0%	10.0%	15.0%
Others	14.0%	12.0%	11.0%	13.0%

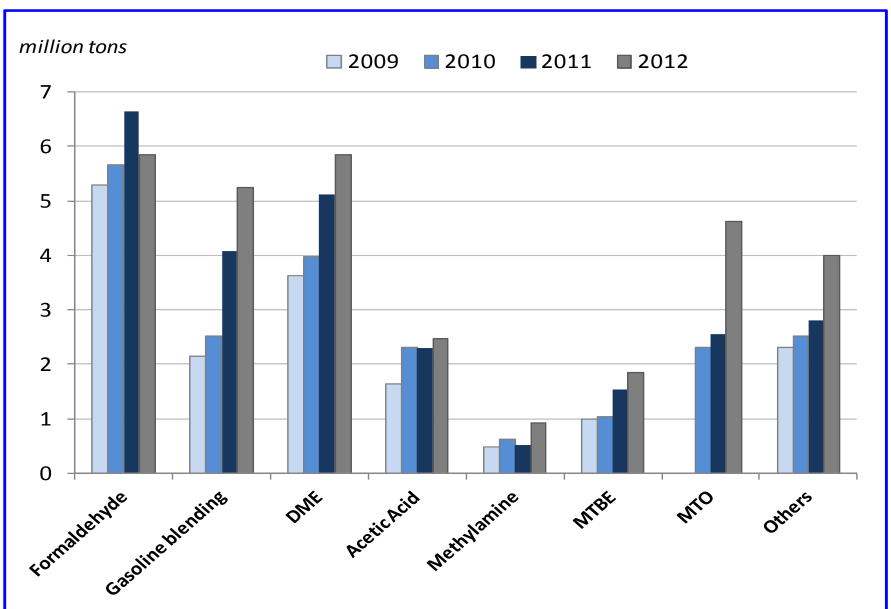
Source: Zhengzhou Commodity Exchange, Deutsche Bank

Figure 48: China's methanol consumption as % end product demand



Source: Zhengzhou Commodity Exchange, Deutsche Bank

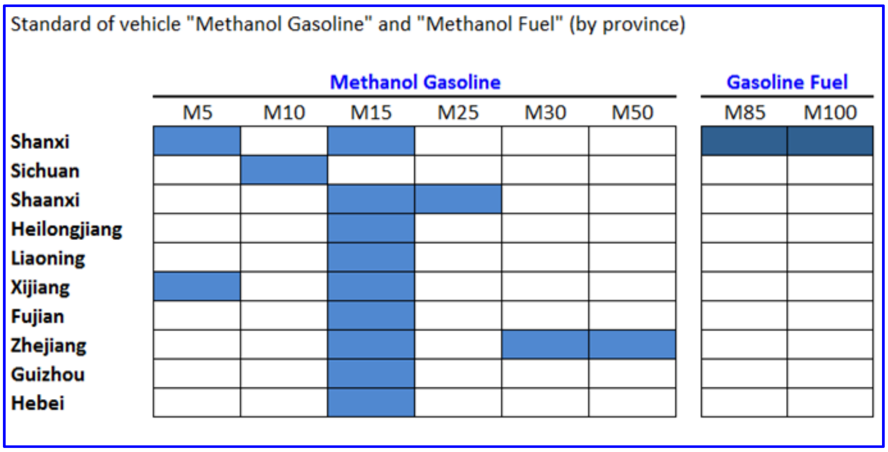
Figure 49: China's methanol consumption (mln tons) by end product demand



Source: Zhengzhou Commodity Exchange, Deutsche Bank

On 01-November 2009, China's Bureau for Standardization released a document on "Methanol fuel for vehicle use". The document focused on M-fuel quality testing, fuel logo / labeling, fuel storage as well as transportation and production safety standards. On 29-February 2012, the Ministry of Industry and Information Technology of China started an M-blend fuel testing program in Shanxi, Shanghai, and Shaanxi provinces. This fuel testing program ended in 2013, without additional comment from Beijing authorities. Since November 2009, ten provincial governments have published standards (and are using M-blended petrol) for the blending methanol with gasoline:

Figure 50: Provinces in China that have issues methanol blending standards



Source: NDRC; Deutsche Bank

China consumed 86.3 mln tons of gasoline in 2012 and used 5.23 mln tons of methanol for gasoline blending. It seems as if 6-7% of China's gasoline pool has been blended with methanol. Neither the national PRC government nor provincial governments have mandated the use of methanol as a gasoline blending agent. We suspect that much of China's "overcapacity" / buildup in methanol capacity (Figure 42) is in anticipation of a national roll out of a mandated or otherwise M15 gasoline standard. We suspect that the +30% CAGR growth (2009-12) of methanol into gasoline blending (Figure 47) could very easily remain super-charged over the next 5-year period (2013-18e). Any move by the Chinese government to approve a national M15 gasoline standard would logically hasten the growth of methanol consumption in China.

The other super-sized growth engine (2009-12) of methanol consumption in China has been MTO or methanol-to-olefins (Figure 47). Notwithstanding, we suspect that the recent 2010-12 CAGR growth rate (41.6% CAGR) will slow for two reasons: 1) base effect – even the most optimistic of government projections 2013-18e delivers a CAGR of only 40.3% (Figure 51); and 2) delays, non-approvals, inability to execute, lack of credit, environmental concerns etc. should continue to plague some of these projects. We estimate MTO capacity through 2018e of 5.86 mln tons vs. 1.76 mln tons in 2013. This would represent a 5-year (2013-18e) CAGR of 27.2% (Figure 51) vs. 41.6% over the previous 5-year period.

We suspect that overall methanol consumption growth in China will slow modestly to low double digit from its 2008-13 CAGR of 23.1% (Figure 47):

- Methanol into gasoline blending growth continues at break-neck speed (2013-18e);
- Methanol to olefins growth slows by 30% (from 40.3% to 27.2% CAGR) over the coming 5-years (Figure 51– "Case 1 to Case 3");
- Methanol into formaldehyde growth (Figure 47) does not seem to be going anywhere fast – despite China's construction boom. We suspect growth rates will moderate (2013-18e) as China slows its economy and frets about real estate bubbles;
- Methanol into Acetic acid should grow at GDP plus 1-2% according to the DB Global Chemical group – this seems about right given China's GDP growth rate +10% pa 2008-12. Acetic acid is principally used to produce plastic containers. With China's GDP growth rate slowing to 7-8% pa 2013-18e, methanol demand into acetic acid should also slow;
- DME and MTBE are also used for gasoline blending. We suspect methanol used for energy blending remains strong; although DME is also used as an additive for LPG, which is being substituted by piped natural gas.

Our estimate (Case 3 – DB Estimate) for slower MTO capacity growth 2013-18e (27.2% CAGR) vs. the government's Case1 (40.3% CAGR) can be seen in Figure 51 below.

Figure 51: Estimates of China's MTO capacity & growth 2013-2018e.

		China Capacity additions (mtpa)						Cummulated China expected capacity (mtpa)					
		In operation	2014e	2015e	2016e	2017e	2018e	In operation	2014e	2015e	2016e	2017e	2018e
Methanol to Olefin ("MTO")													
Case 1													
Already commenced production	*Assumes 100% realized*	1.76						1.76	1.76	1.76	1.76	1.76	1.76
Received NDRC approval	*Assumes 100% realized*		1.40	0.60		1.25	1.25	0.00	1.40	2.00	2.00	3.25	4.50
Potential Note 1	*Assumes 100% realized*		1.20	1.00	0.60	0.25	0.25	0.00	1.20	2.20	2.80	3.05	3.30
	Total	*1.76*	*2.60*	*1.60*	*0.60*	*1.50*	*1.50*	*1.76*	*4.36*	*5.96*	*6.56*	*8.06*	*9.56*
								Case 1 : MTO CAGR (2013-2018e) :					40.3%
								Case 1: Methanol CAGR due to MTO (2013-2018e):					40.3%
Case 2													
Already commenced production	*Assumes 100% realized*	1.76						1.76	1.76	1.76	1.76	1.76	1.76
Received NDRC approval	*Assumes 80% realized*		1.12	0.48		1.00	1.00	0.00	1.12	1.60	1.60	2.60	3.60
Potential	*Assumes 50% realized*		0.60	0.50	0.30	0.13	0.13	0.00	0.60	1.10	1.40	1.53	1.65
	Total	*1.76*	*1.72*	*0.98*	*0.30*	*1.13*	*1.13*	*1.76*	*3.48*	*4.46*	*4.76*	*5.89*	*7.01*
								Case 2 : MTO CAGR (2013-2018e) :					31.8%
								Case 2: Methanol CAGR due to MTO (2013-2018e):					31.8%
Case 3 (DB Estimate)													
Already commenced production	*Assumes 100% realized*	1.76						1.76	1.76	1.76	1.76	1.76	1.76
Received NDRC approval	*Assumes 69% realized*		0.82	0.54		0.87	0.87	0.00	0.82	1.36	1.36	2.23	3.10
Potential	*Assumes 30% realized*		0.36	0.00	0.18	0.23	0.23	0.00	0.36	0.36	0.54	0.77	1.00
	Total	*1.76*	*1.18*	*0.54*	*0.18*	*1.10*	*1.10*	*1.76*	*2.94*	*3.48*	*3.66*	*4.76*	*5.86*
								Case 3 : MTO CAGR (2013-2018e) :					27.2%
								Case 3: Methanol CAGR due to MTO (2013-2018e):					27.2%

NOTES
1) For full list of methanol-to-olefins (MTO) and coal-to-olefins (CTO) projects, please refer to Appendix 3 and 4 respectively.
2) For Case 1, we assume the MTO capacity without completion date to be evenly distributed across 2017-18e.

Source: NDRC; Company data; Deutsche Bank

Global production of methanol (Figure 52) is dominated by China, with large global natural gas producers (Trinidad, Saudi Arabia, Iran and Russia) filling in the ranks. The shale gas revolution in North America is expected to increase methanol capacity from that region beginning in 2017e. All we can see in the near future is an oversupplied global methanol market.

Figure 52: Global methanol production (2012)

Top-10 Methanol Producing Countries

		% Share
1	China	47.9
2	Trinidad	7.8
3	Saudi Arabia	7.7
4	Iran	5.7
5	Russian Federation	5.3
	Total of top-5	74.4
	Remaining countries	25.6
	Total	100

Classification by Region

	% Share
Asia Pacific	62
Middle East and Africa	18
Latin America	12
Europe	6
North America	2
Total	100

Major methanol producers worldwide:

- Methanex	US
- Methanol Holdings (Trinidad) Ltd.	Trinidad
- Saudi Methanol	Saudi Arabia
- Zagros Petrochemical	Iran

Source: Merchant Research & Consulting Limited, Deutsche Bank

China's methanol industry (not including CTO) is fragmented with the 10 largest methanol producers representing only 28% of estimated total capacity (Figure 53). Henan Coal and Chemical Industry Group is China's largest methanol producer with capacity of 1.9 million tons per year. Data from Baidu-Wenku leads us to believe that China has some 300 to 350 known producers of methanol with untold numbers of "tea-pot" producers.

In Figure 54, we list some of the larger methanol producers in Asia (x-China) and the Middle East. From the Middle East, Iran, Saudi and Oman are large, low-cost, natural gas producers of methanol. Looking across the world, Methanex (MX CN) is the largest producer of methanol with 7.3 mln tons of capacity.

Figure 53: Methanol producers in China (2013)

COMPANY NAME:	BBRG Ticker	CAPACITY (mtpa)	LOCATION: Production facilities	Stand-alone / Integrated	COMMENTS:
China Methanol producers:					
Henan Coal and Chemical (HNCC)	Private	1.90	Henan	Integrated	Manufactures ethylene glycol (EG) from coal. Methanol sold to third parties.
Yankuang Group	Private	1.70	Shandong	Integrated	SOE engaged in coal mining, coal chemicals and power generation. Methanol is used for acetic acid
China BlueChem	3983 HK	1.60	Hainan, I-Mongolia	Stand-alone	SOE- part of the CNOOC Group. Manufactures gas and coal-based fertilizer; methanol principally sold to third parties to south-western China via distributors
Kingboard Chemicals	148 HK	1.40	Hainan, Chongqing	Partially integrated	Produces Printed Circuit Boards, Laminates and Chemicals. Methanol sold to third parties.
Shanghai Coking & Chemical Co.	Private	1.40	Shanghai	Partially integrated	Comprehensive coal-based chemical company. Largest city-gas producer in Shanghai; methanol products principally sold as vehicle fuels.
Shanghai Huayi	Private	1.40	Shanghai	Integrated	Comprehensive coal-based chemical company. Methanol to acetic acid, fibers & polymers.
Huadian Yulin Natural Gas Chemical	Private	1.40	Shaanxi	Integrated	Huadian bought into Shaanxi Yulin Natural Gas Chemical Company in 2010 to develop coal-chemical business. Methanol used for producing acetic acid, fibers & polymers.
Shandong Jiutai Chemical	CEGY SP	1.30	Inner Mongolia Shandong	Integrated	Methanol is used for producing DME / sold to spot market. Methanol will be used as feedstock for the Company's MTO project due on line 2015e
Inner Mongolia Berun Group	Private	1.00	Inner Mongolia	Stand-alone	Methanol is sold to third parties on contract basis / at spot market
Chongqing Kabeile	Private	0.85	Chongqing	Stand-alone	Methanol is sold to third parties on contract basis / at spot market
Pingmei Lantian	Private	0.73	Henan	Integrated	Methanol is used for producing DME
East Hope Group	Private	0.70	Chongqing	Integrated	Principal business is animal feed. Methanol is used for producing acetic acid and DME
ENN Group	Private	0.60	I-Mongolia / Jiangsu	Partially integrated	Parent company of ENN Energy (2688:HK); a leading city-gas operator in China; methanol is used for producing DME and for sale to third parties.
Donghua Energy	Private	0.60	Inner Mongolia	Stand-alone	Methanol is sold to third parties on contract basis / at spot market
Gansu Huating	Private	0.60	Gansu	Stand-alone	Methanol is sold to third parties on contract basis / at spot market
Shaanxi Xianyang	Private	0.60	Shaanxi	Stand-alone	Methanol is sold to third parties on contract basis / at spot market
Baofeng Energy	Private	0.40	Ningxia	Stand-alone	Methanol is sold to third parties on contract basis / at spot market
Jiangsu Sopo	600746 CH	0.54	Jiangsu	Stand-alone	Comprehensive coal-based chemical producer: methanol, baking soda, caustic soda & bleach.
Qinghai Golmud	Private	0.42	Qinghai	Stand-alone	Methanol is sold to third parties on contract basis / at spot market
Hebei Kaiyue	Private	0.40	Hebei	Partially integrated	Methanol is used for producing Formaldehyde and for sale to third parties
Henan Junma	Private	0.40	Henan	Partially integrated	Conglomerate engaged in power generation, hotel management & chemical production; methanol is used for producing acetic acid and for sale to third parties
Hulun Buir Dongneng	Private	0.40	Inner Mongolia	Integrated	Methanol is used for producing DME
Shanxi Feng Xi New Energy	Private	0.28	Shanxi	Stand-alone	Methanol is sold as vehicle fuel and downstream petrochemical producers
Total identified capacity (mlns tons)		20.62			
Remaing capacity (over 300 producers)		28.77			
Total Methanol capacity in China (mlns tons)		49.39			

Source: Company data; Deutsche Bank

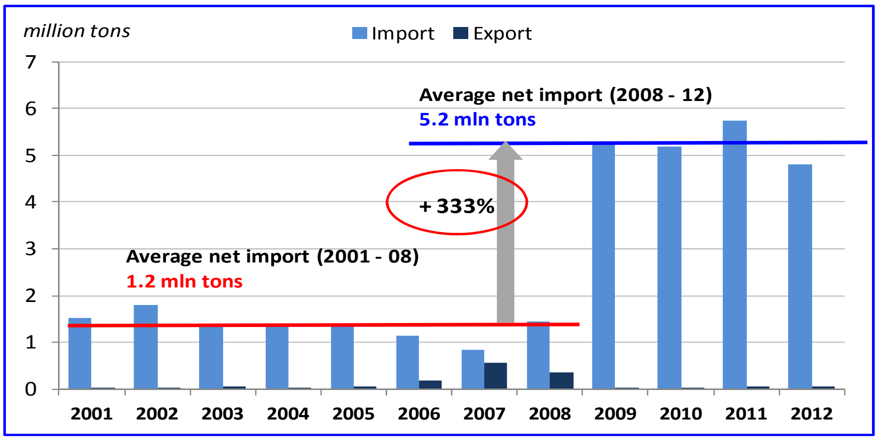
Figure 54: Methanol producers Asia (x-China) and Middle East

COMPANY NAME:	BBRG Ticker	CAPACITY (mtpa)	LOCATION: Production facilities	Stand-alone / Integrated	COMMENTS:
Other Asia / Middle East Methanol producers:					
Azerbaijan Methanol Co.	Private	N/A	Azerbaijan	Partially integrated	Methanol is used for producing methanol and Formaldehyde for sale
GPIC	Private	0.45	Bahrain	Stand-alone	Comprehensive petrochemical company; other products include urea and methanol
Gujarat Narmada	Private	0.30	India	Integrated	Methanol is used for producing acetic acid
Sojitz Corporation	2768 JP	0.70	Indonesia	Integrated	Methanol is sold to third parties on contract basis
Fanavaran Petrochemicals	Private	1.00	Iran	NA	NA
Kharg	Private	0.66	Iran	Stand-alone	Comprehensive petrochemical company
Zagros PC	Private	3.30	Iran	Stand-alone	Largest methanol producer in Iran; principally sold to overseas market
Mitsubishi CORP.	8058 JP	N/A	Japan	Integrated	Multi-line producer of chemical products: health care and industrial.
Mitsubishi Gas Chemical	4182 JP	2.43	Japan	Stand-alone	Methanol is sold to third parties on contract basis
Mitsui & Co., Ltd.	8031 JP	N/A	Japan	Integrated	Methanol is used for producing olefins
Nylex Berhad	NYL MK	N/A	Malaysia	Integrated	Multi-line producer of chemicals: vinyl-coated fabrics and plastics.
Petronas Chemicals	PCHEM MK	2.36	Malaysia	Integrated	Methanol is used for producing olefins: ethylene, propylene and derivatives;
Oman Methanol	Private	1.05	Oman	Stand-alone	Methanol is sold to third parties, principaly overseas;
Salalah Methanol	Private	1.30	Oman	Integrated	Methanol sold to overseas customers;
Qatar Fuel Additives (QAFAC)	Private	0.99	Qatar	Partially integrated	Methanol is used to produce MTBE and methanol for export
Ibn Sina	Private	1.00	Saudi Arabia	Partially integrated	Methanol is used to produce MTBE and methanol
Chemanol	CHEMANOL AB	0.23	Saudi Arabia	Integrated	Methanol is used for producing Formaldehyde and derivatives of Formaldehyde
SABIC	SABIC AB	2.43	Saudi Arabia	Stand-alone	Comprehensive petrochemical company. Methanol is principally for sale to third parties
SIPCHEM	SIPCHEM AB	1.20	Saudi Arabia	Stand-alone	A Saudi Arabia's producer with its methanol product shipped to overseas customers
Lee Chang Yung Chemical	1704 TT	N/A	Taiwan	Stand-alone	Comprehensive petrochemical company producing solvents, coatings, inks & antifreeze
Total identified capacity (mln tons)		19.39			

Source: Company data, Deutsche Bank

Figure 55 below caught our attention when looking at China's methanol trade flows. China's methanol imports increased 3-fold in 2009 through 2012 relative to average imports 2001-08. What happened in 2008-09? That is, other than the collapse of the world's financial system? Why in 2009 did China start to import 3x more methanol than previous years? China's methanol production 2008-09 (Figure 43) grew +18.1% vs. demand growth of 27.3% (Figure 45).

Figure 55: China's Methanol import and export



Source: WIND, Deutsche Bank

We think two things were happening that lead to this massive increase in China's methanol imports beginning 2009: 1) On 01-November 2009 China's Bureau of Standardization released a document on "Methanol fuel for vehicle use"; and 2) in 2009, Saudi Arabia and Iran added 1.83 mln tpa of new low-cost capacity, while in 2010, the Middle East added another 1.57 mln tons of new low-cost capacity (Figure 56).

We suspect that the large increase in China's methanol imports 2009 (Figure 55) were the result of 1) concern throughout 2009 that Methanol 15 (M15) blending with gasoline would soon become the national standard in China, and 2) at least partial substitution of high(er) cost coal-to-methanol production in China with lower cost imports from the Middle East (Figure 71). Just as a reference, we suspect that associated gas from the Middle East can be priced significantly below the US$ 5/ mmBtu that we use as a reference price for US shale gas to methanol production (Figure 71). As an example if we price natural gas at US$ 2.5/ mmBtu rather than US$ 5.0/ mmBtu, the cost of methanol from natural gas production in our Figure 71 model would be US$ 164 / ton not US$ 240/ ton. Methanol imports into China remain high at around 5 million tons per year (2013e).

China exports a small amount of methanol to Korea, the Philippines and Indonesia. China's exports of methanol to Korea, the Philippines and Indonesia have consistently been less than 30,000 tons per year per export destination.

Worldwide methanol capacity is presented in Appendix 4 and 5.

Figure 56: Methanol – ME capacity additions vs. China imports from ME

Methanol capcity in the Middle East (2008-12)

('000 tpa)	2008	2009	2010	2011	2012
- Bahrain	425	425	450	450	450
- Iran	3,394	4,244	5,044	5,044	5,044
- Oman	1,050	1,050	1,700	2,350	2,350
- Saudi Arabia	6,200	7,180	7,280	7,280	7,280
- Qatar	990	990	990	990	990
Total ME Capacity	12,059	13,889	15,464	16,114	16,114
Marginal ME Capacity		1,830	1,575	650	----

China's imports of methanol from ME (2008-12e)

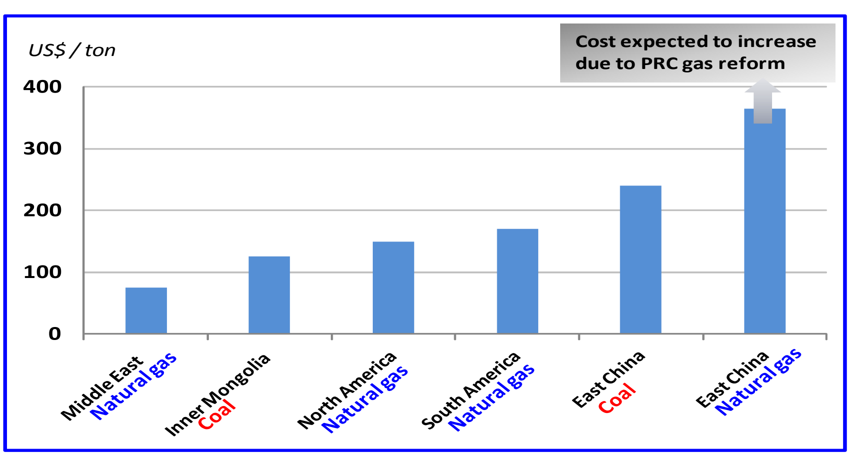
('000 tpa)	2008	2009	2010	2011	2012
- Bahrain	10	150	200	160	200
- Iran	300	900	2,100	2,300	600
- Oman	200	400	700	1,000	900
- Saudi Arabia	400	1,800	700	900	1,600
- Qatar	20	400	420	400	300
China Imports from ME	930	3,650	4,120	4,760	3,600
Marginal China imports from ME		2,720	470	640	(1,160)

Source: IHS, Deutsche Bank

From the perspective of feedstock(s), 1) only Europe uses a small amount of petroleum to produce a small amount of methanol; 2) only China uses a lot of coal to produce a lot of methanol; and 3) most of the world uses cheap natural gas to produce methanol. Of the world's methanol production, 1) 70% comes from natural gas; 2) 11% comes from (China's) coal; and 3) 19% comes from oil products / naphtha / fuel oil into syngas into methanol.

Looking forward, we expect 1) the Middle East to continue to be the world's low cost supplier (price taker) of methanol; 2) China to be the world's marginal cost producer (price setter) of methanol; and 3) the US to aggressively grow its methanol capacity on the back of cheap shale gas that may cause problems for China's higher cost coal-to-methanol producers (Figure 57).

Figure 57: Global methanol production cost



Source: IHS, Deutsche Bank

Misallocation of capital … to keep PetroChina above water on gas imports

Natural gas price reforms in China have driven up the price of domestic natural gas to such a degree that it is no longer competitive to coal in terms of cost (US$) per mmBtu (Figure 4). This is good for coal producers; bad for natural gas producers – as price should start to weigh on demand; and horrendous for the environment. It also does not bode well for government policy, which has a stated objective to move 20-30% of primary energy consumption into natural gas from its current 3-4% of primary energy consumption.

In a recent (15 April 2014) publication of OGP – China Oil, Gas & Petrochemicals, we read that China is facing three "major challenges" in converting over to natural gas from coal:

- The replacement of coal with natural gas (will) require massive financial support (subsidies) not only for equipment but for higher natural gas costs. The coal price for producing a Kwh of heat is about Rmb 0.09, while that of natural gas is between 3 to 5x higher at Rmb 0.3 to 0.45/ kwh.
- China's natural gas pipeline system is controlled by its three oil giants: PetroChina (857 HK; Buy), Sinopec (386 HK) and CNOOC (883 HK; Hold). This dominance over China's natural gas pipeline infrastructure reduces the flow of needed capital into private pipeline infrastructure which deters the fast and efficient flow of natural gas across China.
- China had a natural gas shortage of more than 10 Bcm in 2013.

Methanol synthesis from syngas

Converting syngas into methanol

Methanol (CH_3OH) is produced from syngas. Syngas is produced from natural gas (methane), coal, oil / naphtha / fuel oil / coke, wood and any other carbon bearing biomass. In China, coal is the principal feedstock used to produce syngas which is thereafter converted into methanol. Syngas is converted into methanol in a gas phase reaction at high temperature and pressure under a copper-based catalyst (Figure 58). In this section we look at the conversion of syngas (a mixture of hydrogen and carbon monoxide) into methanol.

China's modern coal-to-chemicals industry began to develop in early 1980s.

The production of methanol from syngas has become more important in China with the on-going development of the country's coal to chemical industry. China's coal-to-chemical industry began in the early 1980s with the production of synthetic ammonia from coal gas. China's coal-to-olefins industry began in the late 1980s with a pilot project developed by the Dalian Institute of Chemical Physics (DICP). China's first MTO project was completed in April 1991 and required 1 ton of methanol / day as feedstock. There is no evidence as to whether the original coal to methanol synthesis technology as developed by DICP was imported or developed domestically.

The water-gas shift

Methanol is industrially produced from purified syngas. Before converting pure syngas to methanol, raw syngas must go through 1) the Rectisol or Wet Sulfuric Acid process (Figure 26-27) to remove CO_2 and sulfur impurities; and 2) the "shifting" process (Figure 28) to adjust / increase the ratio of H and CO to 2:1. Substances with a higher hydrogen-to-carbon ratio (methane) require less "shifting" in the "water-gas shift" process. Substances a lower hydrogen-to-carbon ratio (oil and oil products) require more "shifting" in the water-gas shift process. Less "water-gas shift" means lower cost in the form of energy and catalyst inputs to the "shift" process.

The Syngas to methanol (vapor) reaction:

Purified, shifted syngas is fed into a methanol synthesis reactor (Figure 58). The syngas (CO and H at an optimal ratio of 2:1) reacts across the surface of a fixed bed copper catalyst at a temperature of 300-400°C and pressure of 25-35 Mpa to form methanol (CH_3OH) vapor. The initial heat source for the reactor is provided by an external source. The reaction of syngas across the copper catalyst to produce methanol is exothermic – it produces its own heat.

In the fixed-bed reactor, the control of reaction temperature is achieved by removing reaction heat with un-reacted syngas. Hydrogen has a high heat capacity and as a result, hydrogen-rich, un-reacted syngas also serves as a carrier of heat away from the reaction / reactor vessel. In the syngas to methanol conversion process, syngas is used both as a feedstock and a heat (removal) carrier.

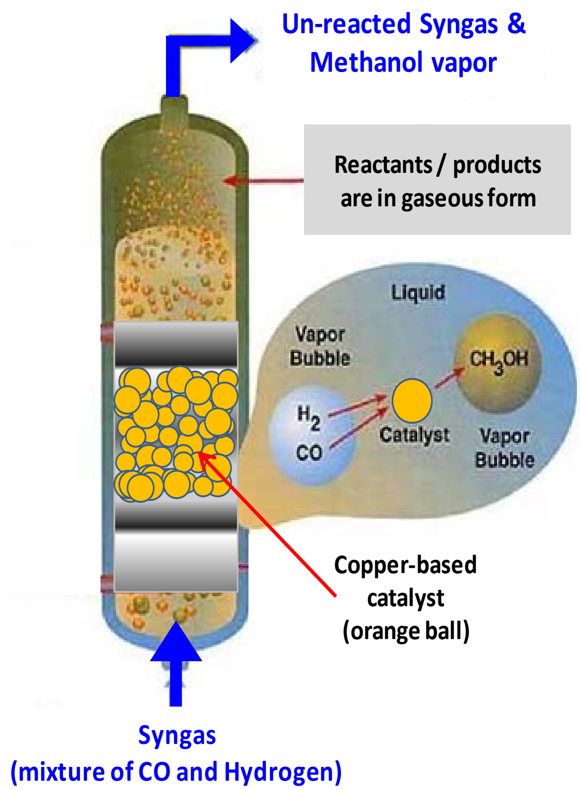
Hydrogen (H) has a high "heat capacity". "Heat capacity" is not the same as "heat(ing) value". "Heat capacity" is the ability of a substance to absorb heat. "Heating value" is the amount of heat released from a substance when combusted. Hydrogen has a high "heat capacity" which means that it can absorb more heat than most other substances. This property makes hydrogen an ideal candidate for absorbing the heat in the syngas-to-methanol reaction.

The product gas leaving the methanol reactor contains 5 to 8% methanol vapor by volume. The reaming 92-95% of the product gas is "un-reacted syngas" and water vapor which is a by-product of methanol synthesis. The un-reacted syngas is recycled back into the reactor for additional processing.

The boiling point for methanol is 65°C. The methanol vapor exiting the reactor at 300-400 °C is thereafter cooled by air fans and / or water cooled condensers so that the methanol vapor condenses into liquid Crude Methanol (contains c.18% of water by weight). The crude methanol will then be transferred to storage tanks for further refining and purification (Figure 59).

- **Approximately 1 ton of coal is needed to produce 55 mcf of syngas;**
- **Approximately 77 mcf of Syngas is required to produce 1 ton of methanol; and**
- **Approximately 1.4 tons of coal (feedstock) is required to produce 1 ton of methanol.**

Figure 58: Reactor for methanol synthesis



A typical methanol synthesis reactor in China

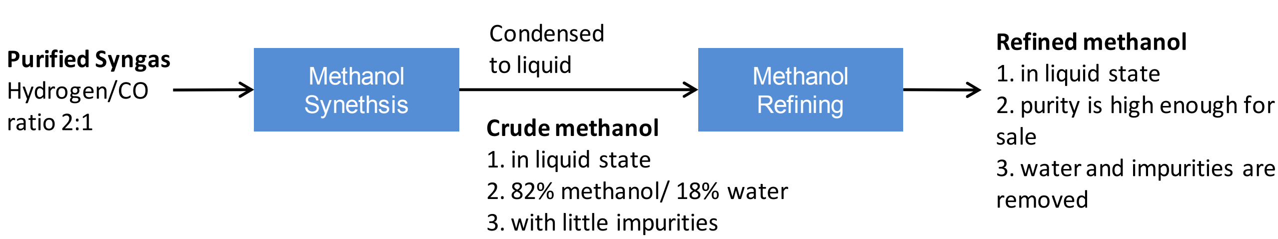
NOTES

1) The height for a 0.2 mtpa reactor is normally 10 - 15 metres high.

2) All components/parts of the reactor can be produced and are currently produced in China

Source: U.S. Department of Energy., Deutsche Bank

Figure 59: Syngas to methanol – process flow chart



***Overall reaction*:** **Carbon Monoxide + Hydrogen <--> Methanol + Heat**

***Chemical equation*:** CO (g) + 2 H_2 (g) <--> CH3OH (g) (Exothermic)

Source: Deutsche Bank

More about the catalysts

Methanol is normally synthesized under a copper-based catalyst (a mixture of copper, zinc oxide and alumina). Copper is the catalyst. Zinc oxide is used to 1) react with alumina to avoid dimethyl ether (DME) formation, 2) prevent the copper from being poisoned by forming zinc sulfide, and 3) prevent agglomeration or "caking" of copper particles. Zinc oxide is not a catalyst. Zinc oxide is normally added to the copper catalyst to avoid catalyst poisoning. Zinc oxide will react with sulfur in hydrogen sulfide to form zinc sulfide. Hydrogen sulfide is the major substance that causes catalyst poisoning during methanol synthesis. The catalyst is said to be "poisoned" when the catalyst no longer functions optimally and needs to be replaced.

The "Claus Process" (Figure 26) is a desulfurizing process used in the conversion of raw syngas to pure syngas. The Claus Process converts hydrogen sulfide to elemental sulfur. The "Wet Sulfuric Acid Process" (Figure 27) is also used in the process of converting raw syngas into pure syngas. The Wet Sulfuric Acid Process converts hydrogen sulfide into sulfuric acid. Both of these processes reduce syngas hydrogen sulfide that would otherwise poison the copper catalyst that is used to convert purified syngas into methanol.

Methanol refining:

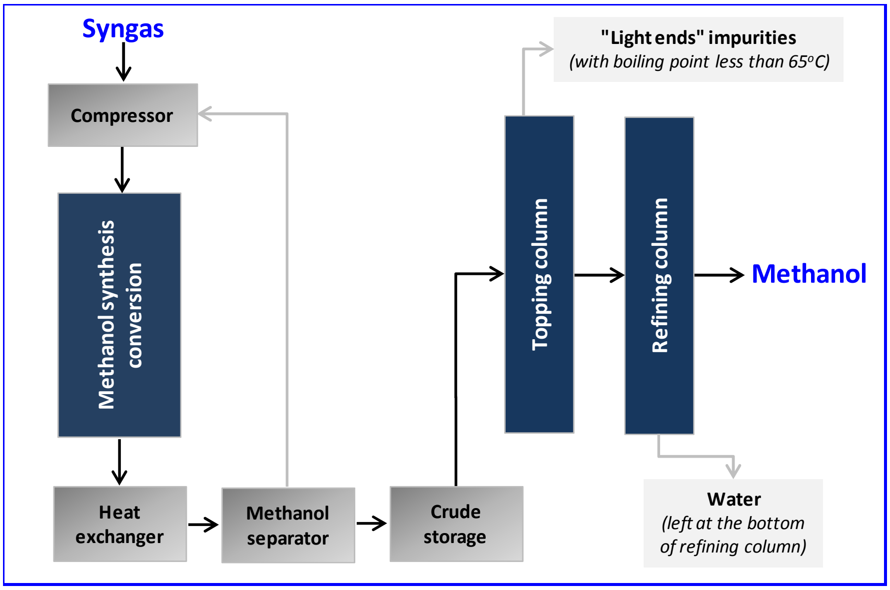
Methanol distillation is achieved in two distinct distillation columns – a topping column and a refining column (Figure 60-61). The topping column is used for removing impurities with low boiling points ("light ends"). "Light ends" are substances with boiling point lower than that of methanol (65°C). By heating at a temperature slightly lower than the boiling point of methanol (65°C), the "light ends" will be vaporized and stripped out from the top of topping column.

After the "topping" process, the remaining liquid (mainly water and methanol) is transferred to a "refining column" for further processing. During the refining process, the liquid is boiled again at a temperature higher than 65°C but less than 100°C. At a temperature higher 65°C, methanol vaporizes, rises to the top of refining column, and condenses back to liquid methanol for storage. The temperature at the top of the refining column is cooler than at the bottom of the column where the heat source is located. This differential in temperature causes the methanol vapor to condense into liquid towards the top of the column. The water is left in the refining column.

Figure 60: Methanol distillation column in Shenhua Ningxia project

Source: Linde, Deutsche Bank

Figure 61: The methanol refining process



Source: Siemens, Deutsche Bank

Methanol production costs

In the financial models below, we consider the costs to produce methanol in China.

In Figure 68, we look at: 1) the cost to produce methanol in Inner Mongolia from self-sourced coal; vs. 2) the cost to produce methanol in Inner Mongolia from 3rd party purchased coal; in both cases the transport of methanol to east cost China (Jiangsu province) is considered.

In Figure 69, we look at 1) the cost to produce methanol in Inner Mongolia from self-sourced coal plus transport cost to the east coast (Jiangsu) of China; vs. 2) the cost to produce methanol on the east coast of China (Jiangsu) from 3rd party purchased coal.

In Figure 70, we look at 1) the cost to produce methanol in Inner Mongolia from self-sourced coal plus the transport cost to the east coast (Jiangsu) of China; vs. 2) the cost to produce methanol on the east coast of China (Jiangsu) from 3rd party purchased natural gas.

Finally, in Figure 71, we look at 1) the cost to produce methanol in Inner Mongolia from self-sourced coal plus the transport cost to the east coast (Jiangsu) of China; vs. 2) the cost to produce methanol in North America using US$ 5.0/ mmBtu Henry Hub natural gas.

We conclude that:

1. The all in cost to produce methanol from self-sourced coal in Inner Mongolia and deliver it to east coast China (US$ 237/ ton of methanol)

is only slightly less expensive than producing methanol on the east coast of China sourcing it via 3rd party coal purchases (US$ 253/ ton).

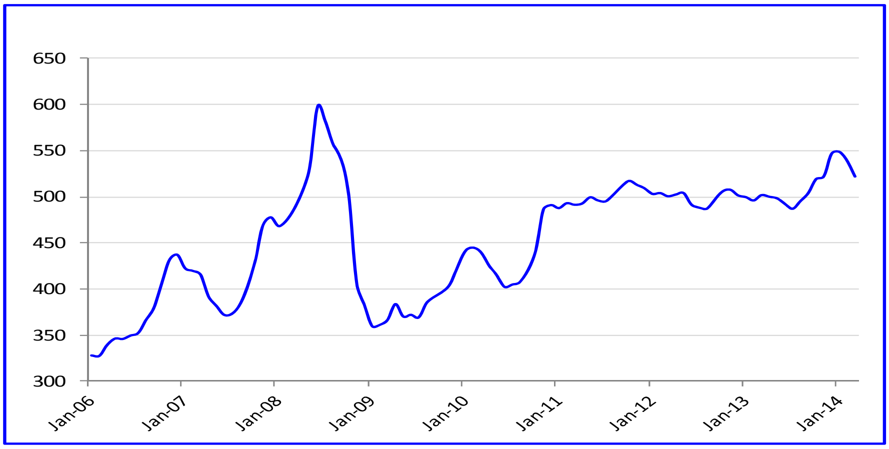
2. The all in cost to produce methanol from self-sourced coal in Inner Mongolia and deliver it to east coast China (US$ 263/ ton of methanol) is materially less expensive than producing methanol on the east coast of China and sourcing it via 3rd party natural gas purchases (US$ 505/ ton).

3. The all in cost to produce methanol from 3rd party coal in Inner Mongolia and deliver it to east coast China (US$ 263/ ton of methanol) is slightly more expensive than producing methanol on the east coast of China and sourcing it via 3rd party coal purchases (US$ 253/ ton).

4. The all in cost to produce methanol from coal in China is quite similar to the cost of methanol production in the USA assuming US$ 5.0 / mmBtu for the price of natural gas. If we insert an "associated" natural gas price assumption of US$ 2.50/ mmBtu in this model, our all in production cost would be US$ 164/ ton methanol.

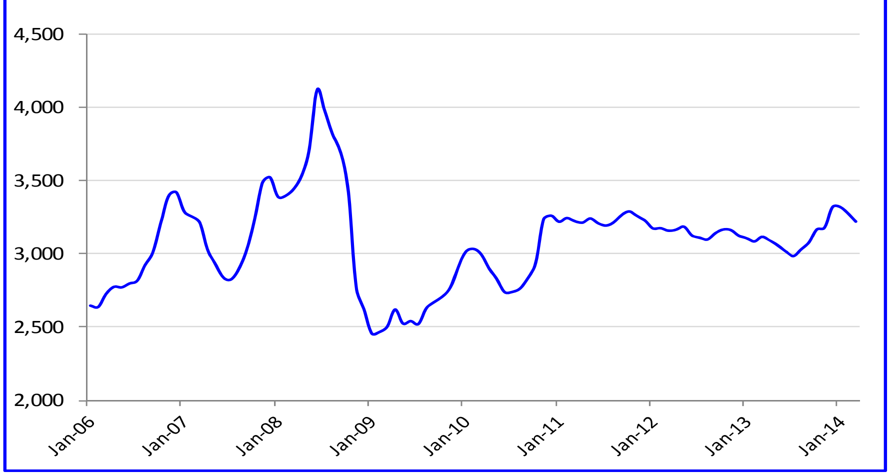
As per NDRC data, the average wholesale transaction price of methanol in China's thirty six largest cities can be seen in Figure 62 and Figure 63. The data tells us that: 1) the average wholesale transaction price of methanol in China is being set from the marginal cost of production using natural gas (not coal) as a feedstock; and that 2) coal based methanol production in China should be wildly profitable.

Figure 62: Wholesale price – China methanol (US$ / ton)



Source: NDRC; CEIC; Deutsche Bank

Figure 63: Wholesale price – China methanol (Rmb / ton)



Source: NDRC; CEIC; Deutsche Bank

Figure 64: Key Assumptions for Methanol cost analysis

Key Assumptions:

1. **Assumes 1.4 tons of bituminous coal is used to produce 1 ton of methanol**
2. **Assumes that the coal cost from self-owned mines is 20% less than coal purchased from third parties**
3. **Assumes that all methanol is sold into eastern China markets and competes with Middle Eastern imports**
4. **Assumes the production capacity of CTM and GTM to be 600k TPA methanol**
5. **Assumes the total investment of CTM project (6.0 billion Rmb) is 40% of CTO project (15.0 billion Rmb); and the depreciable amount (4.8 billion Rmb) to be 80% of CTM's total investment (6.0 billion Rmb)**
6. **Assumes the total investment of GTM project (China) to be 5.5 billion Rmb, which is 30% less than a similar plant in the US (7.8 billion Rmb) estimated by Valero**
7. **Assumes the useful life of plant & machinery to be 15 years and the depreciation expenses spread evenly over the olefins products**

Source: Deutsche Bank

Figure 65: Sensitivity of coal price on methanol cost – Inner Mongolia "self-owned coal mines" vs "purchased coal"

Case 1 : Inner Mongolia / self-owned coal mines			Case 2 : Inner Mongolia / purchased coal		
Change in coal price	Methanol cost (USD / ton)	Compare with current methanol cost	Change in coal price	Methanol cost (USD / ton)	Compare with current methanol cost
-10%	232	-2.0%	-10%	247	-2.3%
-5%	234	-1.0%	-5%	250	-1.2%
0%	237	0.0%	0%	253	0.0%
+5%	239	1.0%	+5%	256	1.2%
+10%	242	2.0%	+10%	259	2.3%
+15%	244	3.0%	+15%	262	3.5%
+20%	246	4.0%	+20%	265	4.6%
+30%	251	6.1%	+30%	271	7.0%
+50%	261	10.1%	+50%	283	11.6%

Source: Deutsche Bank

Figure 66: Sensitivity of coal price on methanol cost – Inner Mongolia "self-owned coal mines" vs Eastern China "purchased coal"

Case 3 : Inner Mongolia / self-owned coal mines			Case 4 : Eastern China / purchased natural gas		
Change in coal price	Methanol cost (USD / ton)	Compare with current methanol cost	Change in coal price	Methanol cost (USD / ton)	Compare with current methanol cost
-10%	232	-2.0%	-10%	251	-4.6%
-5%	234	-1.0%	-5%	257	-2.3%
0%	237	0.0%	0%	263	0.0%
+5%	239	1.0%	+5%	269	2.3%
+10%	242	2.0%	+10%	275	4.6%
+15%	244	3.0%	+15%	281	6.9%
+20%	246	4.0%	+20%	287	9.2%
+30%	251	6.1%	+30%	299	13.8%
+50%	261	10.1%	+50%	323	22.9%

Source: Deutsche Bank

Figure 67: Sensitivity of coal price on methanol cost – Inner Mongolia "self-owned coal mines" vs Eastern China "purchased natural gas"

Case 5 : Inner Mongolia / self-owned coal mines			Case 6 : Eastern China / purchased natural gas		
Change in coal price	Methanol cost (USD / ton)	Compare with current methanol cost	Change in coal price	Methanol cost (USD / ton)	Compare with current methanol cost
-10%	238	-2.2%	-10%	464	-8.1%
-5%	241	-1.1%	-5%	485	-4.1%
0%	244	0.0%	0%	505	0.0%
+5%	247	1.1%	+5%	526	4.1%
+10%	249	2.2%	+10%	546	8.1%
+15%	252	3.4%	+15%	567	12.2%
+20%	255	4.5%	+20%	587	16.2%
+30%	260	6.7%	+30%	628	24.4%
+50%	271	11.2%	+50%	710	40.6%

Source: Deutsche Bank

Figure 68: CTM cost model - Inner Mongolia "self-owned coal mines" vs. "purchased coal"

	Case 1 Inner Mongolia Self-owned coal mines	Case 2 Inner Mongolia Purchased coal	
Coal cost			
Coal used for feedstock			
Coal price (ex-plant)	207	258	RMB/ton coal
Coal price (ex-plant)	34	42	USD/ton coal
Coal consumption per ton methanol	1.40	1.40	ton coal/ton methanol
Coal feedstock cost per ton methanol	***289***	***362***	***RMB/ton methanol***
Coal feedstock cost per ton methanol	***48***	***59***	***USD/ton methanol***
Coal transportation			
Transportation cost per ton coal	N/A	20	RMB/ton coal
Transportation cost of coal per ton methanol	N/A	***28***	***RMB/ton methanol***
Electricity			
Usage per ton methanol	500	500	Kwh/ton methanol
Electricity tariff	0.35	0.35	RMB/Kwh
Total electricity cost per ton methanol	***175***	***175***	***RMB/ton methanol***
Other OPEX			
Depreciation	***178***	***178***	***RMB/ton methanol***
Labor and management overhead	***50***	***50***	***RMB/ton methanol***
Water price	3.50	3.50	RMB/ton water
Water usage	15	15	ton water/ton methanol
Water cost	***53***	***53***	***RMB/ton methanol***
Effluent treatment charges	0.95	0.95	RMB/ton water
Effluent amount	30	30	ton effluent/ton methanol
Effluent treatment cost	***29***	***29***	***RMB/ton methanol***
Steam usage	1.20	1.20	ton steam/ton methanol
Steam price	2.00	2.00	RMB/ton steam
Steam cost	***2.40***	***2.40***	***RMB/ton methanol***
R&M and insurance	***40***	***40***	***RMB/ton methanol***
Other production supplies	***50***	***50***	***RMB/ton methanol***
(e.g. Catalyst replacement and consumables)			
Transportation fee of methanol product			
Distance	1,889	1,889	km
Transportation cost	0.30	0.30	RMB/ton km
Methanol transportation: Inner Mongolia to Jiangsu	***567***	***567***	***RMB/ton***
Total production cost per ton methanol	***1,433***	***1,533***	***RMB/ton methanol***
	237	***253***	***USD/ton methanol***

Source: NDRC, CEIC, Deutsche Bank

Figure 69: CTM cost model - Inner Mongolia “self-owned coal mines” vs. E. China “purchased coal”

	Case 3 Inner Mongolia Self-owned coal mines	Case 4 Eastern China Purchased coal	
Coal cost			
Coal used for feedstock			
Coal price (ex-plant)	207	530	RMB/ton coal
Coal price (ex-plant)	34	88	USD/ton coal
Coal consumption per ton methanol	1.40	1.40	ton coal/ton methanol
Coal feedstock cost per ton methanol	***290***	***742***	***RMB/ton methanol***
Coal feedstock cost per ton methanol	***48***	***121***	***USD/ton methanol***
Coal transportation			
Transportation cost per ton coal	N/A	60	RMB/ton coal
Transportation cost of coal per ton methanol (intra-province : Jiangsu)	N/A	***84***	***RMB/ton methanol***
Electricity			
Usage per ton methanol	500	500	Kwh/ton methanol
Electricity tariff	0.35	0.65	RMB/Kwh
Total electricity cost per ton methanol	***175***	***325***	***RMB/ton methanol***
Other OPEX			
Depreciation	***178***	***178***	***RMB/ton methanol***
Labor and management overhead	***50***	***60***	***RMB/ton methanol***
Water price	3.50	3.50	RMB/ton water
Water usage	15	15	ton water/ton methanol
Water cost	***53***	***53***	***RMB/ton methanol***
Effluent treatment charges	0.95	1.30	RMB/ton water
Effluent amount	30	30	ton effluent/ton methanol
Effluent treatment cost	***29***	***39***	***RMB/ton methanol***
Steam usage	1.20	1.20	ton steam/ton methanol
Steam price	2.00	2.50	RMB/ton steam
Steam cost	***2.40***	***3.00***	***RMB/ton methanol***
R&M and insurance	***40***	***48***	***RMB/ton methanol***
Other production supplies	***50***	***60***	***RMB/ton methanol***
(e.g. Catalyst replacement and consumables)			
Transportation fee of methanol product			
Distance	1,889	0	km
Transportation cost	0.30	0.30	RMB/ton km
Methanol transportation: Inner Mongolia to Jiangsu	***567***	***0***	
			RMB/ton
Total production cost per ton methanol	***1,433***	***1,592***	***RMB/ton methanol***
	237	***263***	***USD/ton methanol***

Source: NDRC, CEIC, Deutsche Bank

Figure 70: CTM / GTM cost models - Inner Mongolia “self-owned coal mines” vs. E. China “purchased natural gas”

	Case 5 Inner Mongolia Self-owned coal mines	Case 6 Eastern China Purchased natural gas	
Coal cost			
Coal/Natural Gas used for feedstock			
Coal / NG price	237	2.42	RMB/ton coal (m3 NG)
Coal / NG price	39	0.40	USD/ton coal (m3 NG)
Coal / NG consumption per ton methanol	1.40	1,025	ton coal (m3 NG)/ton methanol
Coal / NG feedstock cost per ton methanol	***332***	***2,481***	***RMB/ton methanol***
Coal / NG feedstock cost per ton methanol	***55***	***410***	***USD/ton methanol***
Coal transportation			
Transportation cost per ton coal	N/A	N/A	RMB/ton coal
Transportation cost of coal per ton methanol	N/A	N/A	RMB/ton methanol
Electricity			
Usage per ton methanol	500	80	Kwh/ton methanol
Electricity tariff	0.35	0.65	RMB/Kwh
Total electricity cost per ton methanol	***175***	***52***	***RMB/ton methanol***
Other OPEX			
Depreciation	***178***	***258***	***RMB/ton methanol***
Labor and management overhead	***50***	***60***	***RMB/ton methanol***
Water price	3.50	3.50	RMB/ton water
Water usage	15	15	ton water/ton methanol
Water cost	***53***	***53***	***RMB/ton methanol***
Effluent treatment charges	0.95	1.30	RMB/ton water
Effluent amount	30	30	ton effluent/ton methanol
Effluent treatment cost	***29***	***39***	***RMB/ton methanol***
Steam usage	1.20	1.20	ton steam/ton methanol
Steam price	2.00	2.50	RMB/ton steam
Steam cost	***2.40***	***3.00***	***RMB/ton methanol***
R&M and insurance	***40***	***48***	***RMB/ton methanol***
Other production supplies	***50***	***63***	***RMB/ton methanol***
(e.g. Catalyst replacement and consumables)			
Transportation fee of methanol product			
Distance	1,889	0	km
Transportation cost	0.30	0.30	RMB/ton km
Methanol transportation: Inner Mongolia to Jiangsu	***567***	***0***	***RMB/ton***
Total production cost per ton methanol	***1,475***	***3,056***	***RMB/ton methanol***
	244	***505***	***USD/ton methanol***

Source: NDRC, CEIC, Deutsche Bank

Figure 71: CTM / GTM cost models - Inner Mongolia “self-owned coal mines” vs. N. America purchased natural gas”

	Case 7 Inner Mongolia Self-owned coal mines	Case 8 The United States Purchased natural gas	
Coal cost			
Coal/Natural Gas used for feedstock			
Coal / NG price	250	1.13	RMB/ton coal (m3 NG)
Coal / NG price	41	5.00	USD/ton coal (mmBtu)
Coal / NG consumption per ton methanol	1.40	30	ton coal (mmBtu NG)/ton methanol
Coal / NG feedstock cost per ton methanol	***350***	***923***	***RMB/ton methanol***
Coal / NG feedstock cost per ton methanol	***58***	***150***	***USD/ton methanol***
Coal transportation			
Transportation cost per ton coal	N/A	N/A	RMB/ton coal
Transportation cost of coal per ton methanol	N/A	N/A	RMB/ton methanol
Electricity			
Usage per ton methanol	500	80	Kwh/ton methanol
Electricity tariff	0.35	0.36	RMB/Kwh
Total electricity cost per ton methanol	***175***	***29***	***RMB/ton methanol***
Other OPEX			
Depreciation	***178***	***214***	***RMB/ton methanol***
Labor and management overhead	***50***	***60***	***RMB/ton methanol***
Water price	3.50	3.50	RMB/ton water
Water usage	15	15	ton water/ton methanol
Water cost	***53***	***53***	***RMB/ton methanol***
Effluent treatment charges	0.95	2.00	RMB/ton water
Effluent amount	30	30	ton effluent/ton methanol
Effluent treatment cost	***29***	***60***	***RMB/ton methanol***
Steam usage	1.20	1.20	ton steam/ton methanol
Steam price	2.00	2.00	RMB/ton steam
Steam cost	***2.40***	***2.40***	***RMB/ton methanol***
R&M and insurance	***40***	***48***	***RMB/ton methanol***
Other production supplies	***50***	***63***	***RMB/ton methanol***
(e.g. Catalyst replacement and consumables)			
Transportation fee of methanol product			
Distance	1,889	0	km
Transportation cost	0.30	0.00	RMB/ton km
Methanol transportation: Inner Mongolia to Jiangsu	***567***	***0***	***RMB/ton***
Total production cost per ton methanol	***1,493***	***1,451***	***RMB/ton methanol***
	247	***240***	***USD/ton methanol***

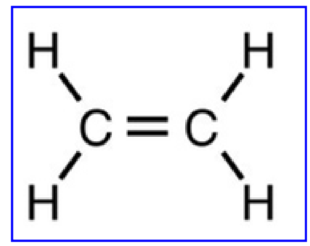
Source: NDRC, CEIC, Deutsche Bank

Coal to olefins

We have analyzed above the transformation of coal to syngas; and syngas to methanol – with integrated cost models. We will now consider the process of transforming methanol into "olefins", which for all practical purses means transforming methanol into ethylene and propylene.

Olefins can be defined as any unsaturated hydrocarbon containing one or more pairs of carbon atoms linked by a double bond. A "double bond" is a bond where two electron pairs are shared between two atoms. In layman's terms, a double bond enables a stronger linkage between the two carbon atoms but it also makes the compound more reactive in that each carbon atom is unsaturated (ie - looking to align with additional hydrogen atoms). The two most important olefins are ethylene and propylene as they form the backbone of the petrochemicals market. The highly reactive double bond makes the olefin molecule ideal for conversion to many polymers such as: polyethylene, polypropylene, polystyrene, ethylene dichloride, ethylene oxide and others.

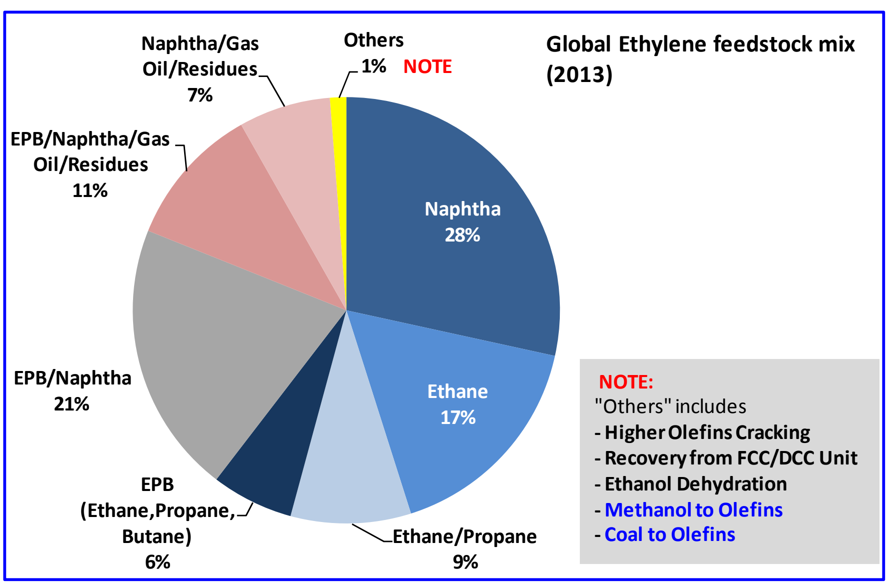
Figure 72: Ethylene – double bond between two carbon atoms



Source: Deutsche Bank

Olefins are produced worldwide from a wide array of feedstocks including ethane, liquefied petroleum gases (LPG / Propane & Butane), gas oil / diesel and naphtha. Today, c.67% of global olefins production comes from naphtha / naphtha mix feedstock(s) while c.32% comes from ethane and mixtures of ethane, propane and butane or LPG (Figure 73).

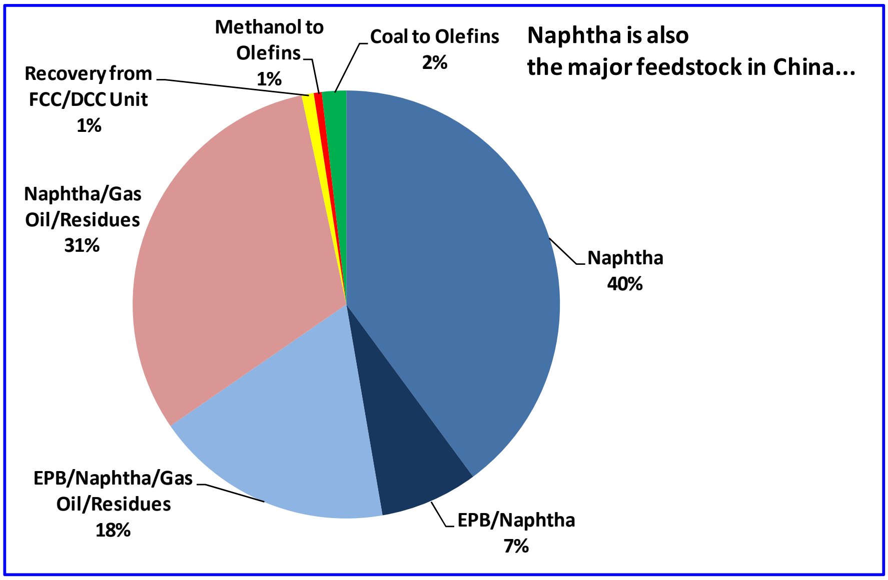
Figure 73: Global Ethylene feedstock mix (2013)



Source: IHS , Deutsche Bank

China accounts for 100% of the world's dedicated coal-to-olefins production; yet, olefins produced in China using coal / syngas / methanol as feedstock continues to represent only about 3% of China's olefins capacity (Figure 74) or less than 1% of global olefins capacity (Figure 73-74). China began industrialized olefins production using coal / syngas / methanol as feedstock in 4Q09 (Shenhua Baotou – CTO facility).

Figure 74: China Ethylene feedstock mix (2013)



Source: IHS, Deutsche Bank

According to IHS, ethylene capacity in China at year-end 2013 was 17.8 million tons or 11.6% of the world's total capacity (Appendix 6-10). China's feedstock of choice for ethylene production (Figure 74) is naphtha / naphtha mix (c.40% / c.97%). Ethylene production in China is skewed to SOE's Sinopec (386.HK) and PetroChina (857.HK). Together, these two SOE own / operate roughly 58% and 22% of China's ethylene capacity. China's CTO/ MTO capacity is relatively small with 5 facilities in operation and total olefin capacity of 2.36 mln tons/ year. Ignoring both international and / or domestic MTO pilot programs:

1. Only China has commercial CTO/ MTO facilities in operation (2.36 mln tpa); no other country in the world has producing CTO/ MTO facilities;

2. China's CTO/ MTO operating capacity represents ~1.5% of year-end 2013 global ethylene capacity (153.2 mln tpa);

3. China has another 20.3 mln tpa of NDRC Approved (6.9 mln tpa) and/ or "Pre-approved"(13.4 mln tpa) CTO/ MTO capacity (Appendix 1-2);

4. China's Approved (6.9 mln tpa) and Pre-approved (13.4 mln tpa) MTO/ CTO capacity represents another 13.2% of 2013 global ethylene capacity – which is meaningful if it were all to come on-line in at once. Bottom line ethylene grows at 1-1.5% of global GDP growth. With global GDP growth of 3-3.5% pa, the world should add 4-6k Tpa / year of ethylene capacity.

5. Of China's total Approved (6.9 mln tpa) and Pre-approved / Possible (13.4 mln tpa) CTO / MTO capacity, we believe a total of approximately 5.9 mln tpa of MTO (Figure 51) and 5.1 mln tpa of CTO (Figure 75) will be operating in China by year-end 2018.

6. By year-end 2018, China's CTO / MTO operating capacity could represent as much as 5.9% of global ethylene capacity.

Figure 75: Estimates of China's CTO capacity & growth 2013-2018e.

		China Capacity additions (mtpa)						Cummulated China expected capacity (mtpa)					
		In operation	2014e	2015e	2016e	2017e	2018e	In operation	2014e	2015e	2016e	2017e	2018e
Coal to Olefin ("CTO")													
Case 1													
Already commenced production	*Assumes 100% realized*	0.60						0.60	0.60	0.60	0.60	0.60	0.60
Received NDRC approval	*Assumes 100% realized*				1.20	1.20		0.00	0.00	0.00	1.20	2.40	2.40
Potential Note 1	*Assumes 100% realized*				1.20	4.05	4.85	0.00	0.00	0.00	1.20	5.25	10.10
	Total	***0.60***	***0.00***	***0.00***	***2.40***	***5.25***	***4.85***	***0.60***	***0.60***	***0.60***	***3.00***	***8.25***	***13.10***
								Case 1 : CTO CAGR (2013-2018e) :					**85.3%**
								Case 1: Methanol CAGR due to CTO (2013-2018e)					**85.3%**
Case 2													
Already commenced production	*Assume 100% realized*	0.60						0.60	0.60	0.60	0.60	0.60	0.60
Received NDRC approval	*Assume 80% realized*				0.96	0.96		0.00	0.00	0.00	0.96	1.92	1.92
Potential	*Assume 50% realized*				0.60	2.03	2.43	0.00	0.00	0.00	0.60	2.63	5.05
	Total	***0.60***	***0.00***	***0.00***	***1.56***	***2.99***	***2.43***	***0.60***	***0.60***	***0.60***	***2.16***	***5.15***	***7.57***
								Case 2 : CTO CAGR (2013-2018e) :					**66.0%**
								Case 2: Methanol CAGR due to CTO (2013-2018e):					**66.0%**
Case 3 (DB Estimate)													
Already commenced production	*Assume 100% realized*	0.60						0.60	0.60	0.60	0.60	0.60	0.60
Received NDRC approval	*Assume 70% realized*				0.84	0.84		0.00	0.00	0.00	0.84	1.68	1.68
Potential	*Assume 28% realized*				1.08	1.19	0.55	0.00	0.00	0.00	1.08	2.27	2.82
	Total	***0.60***	***0.00***	***0.00***	***1.92***	***2.03***	***0.55***	***0.60***	***0.60***	***0.60***	***2.52***	***4.55***	***5.10***
								Case 3 : CTO CAGR (2013-2018e) :					**53.4%**
								Case 3: Methanol CAGR due to CTO (2013-2018e):					**53.4%**

NOTES
1) For full list of methanol-to-olefins (MTO) and coal-to-olefins (CTO) projects, please refer to Appendix 3 and 4 respectively.
2) For Case 1, we assume the CTO capacity without completion date to be evenly distributed across 2017-18e.

Source: NDRC; Company data; Deutsche Bank

Ethylene

Ethylene is a colorless and flammable gas with a faint "sweet and musky" odor. The chemical formula for ethylene is C_2H_2. Globally, ethylene is used in producing 1) polyethylene (60%), 2) ethylene oxide (15%), 3) ethylene dichloride and ethylbenzene (16%) and 4) other chemical products (9%).

Polyethylene (PE) is a light, durable and elastic plastic material. PE is the most widely used plastic in the world and is used principally in the production of food and drink containers, plastic bags, and packaging materials.

Ethylene oxide (EO) is a colorless and flammable (C_2H_4O). It is principally used in the production of ethylene glycols (MEG). MEG is a major chemical feedstock / intermediate product for the production of PET, which in its own right is a feedstock for making containers and synthetic fibers. EO is also used in the production of solvents, textile, detergents and personal care products.

Ethylene Dichloride (EDC) is a colorless liquid with chloroform-like odor ($C_2H_4C_{12}$). It is principally used in the production of polyvinyl chloride (PVC). PVC is used for making pipes, electric cables and construction materials.

Ethylbenzene is a colorless and flammable liquid with a gasoline-like odor (C_8H_{10}). It is used as a chemical intermediate in the manufacture of polystyrene – an inexpensive plastic material for making food and drink containers with high insulation ability.

Propylene

Propylene is a colorless gas with a weak and unpleasant smell. Propylene is the second most important chemical building block after ethylene. The chemical formula for propylene is C_3H_6 and globally it is used in producing 1) polypropylene (60%), 2) Propylene oxide (7%) and 3) other chemical products.

Polypropylene (PP) is a light, elastic plastic material which is resistant to many chemical solvents and acid, but not as sturdy as polyethylene (PE). PP is principally used in the production of packaging materials, plastic parts, reusable containers and automotive components containers.

Propylene oxide is a colorless and volatile liquid (C_3H_6O). It is used as an intermediate in the manufacture of polyurethane for decoration purposes.

Producing ethylene & propylene

Olefin feedstocks

In most parts of the world ethylene and propylene are produced via the cracking of naphtha and / or ethane under steam and pressure ("steam-cracking"). The steam cracking of naphtha and / or ethane are well established, globally accepted processes for producing industrial olefins.

High cost oil / high cost naphtha

Notwithstanding, the cost of converting naphtha into ethylene and propylene is relatively high which stems from the current high price (globally) of crude oil. Unlike crude oil / naphtha, ethane (a component of natural gas liquids) is priced regionally (not globally) and driven by regional natural gas supply-demand factors as well as government specific / company specific strategic goals.

Natural gas – high cost China; low cost N. America, Middle East and parts of Africa

Natural gas in China is expensive (US$ 8-12/ mcf) and the price is influenced by natural gas imports from faraway places like Turkmenistan and Australia (LNG). Natural gas in North America is relatively cheap (US$ 4-5/ mcf) due to recent discoveries of abundant shale gas; whereas natural gas in the Middle East and Africa can arguably be said to have a cost of US$ 0.0/ mcf in that it is "associated gas" – associated with the extraction of crude oil from reservoirs.

Strategic and economic

China's drive to produce olefins from coal / syngas / methanol is an attempt to use a lower cost hydrocarbon (coal) relative to oil and / or China natural gas. We are not sure if China's drive to produce olefins from coal is based purely on economics or if it is also based on the fact that China has an abundance of coal and limited supplies of crude oil and natural gas - strategic rational.

China leading the way – pushing the envelope at least

Regardless, China is trying to utilize its abundantly inexpensive coal reserves to produce high-value olefin products that it would otherwise produce from imported oil and / or natural gas. However, unlike the "steam cracking" of naphtha / ethane to produce olefins; and unlike the "gasification" of coal to produce syngas; and unlike the "synthesis" of methanol from syngas; the synthesis of olefins from methanol remains commercially under-developed. If China were to be successful in developing a commercial coal-to-olefins industry, it would be a first world-wide.

SAPO – which means frog in Spanish

Methanol is not "steam-cracked" to produce olefins. The process of converting methanol to olefins involves a complex sieve-catalyst (SAPO-34). The SAPO-34 catalyst was originally discovered by the Union Carbide Corporation in 1982 and consists of silicon, aluminum, phosphate and oxygen.

Limited MTO worldwide

Despite on-going efforts to commercialize methanol to olefins (MTO), there seems to be only 3 demonstration plants outside of China; 3 demonstration plants inside of China; and 5 commercial operating plants inside of China.

Outside of China there are three pilot MTO facilities: 1) a UOP pilot plant that was constructed in 1988, location undisclosed and we suspect the plant is no longer operating; 2) an INEOS pilot plant constructed in 1995 and located in Norway; and 3) a TOTAL pilot plant constructed in 2009 and located in Belgium. The methanol input capacity for these pilot projects was 1 kilogram per day; 1 ton per day and 10 tons per day respectively. The conversion rate of current MTO plants is ~3 tons of methanol to 1 ton of olefins.

Dalian Institute of Chemical Physics seems to play a big role in China's CTO/ MTO developments

Inside of China, the Dalian Institute of Chemical Physics (DICP) has built three pilot MTO projects: 1) in 1993 located in Dalian, 2) in 1995 located in Shanghai; and 3) in 2006 located in Shaanxi province. The early 1993 MTO pilot facility had methanol input capacity of 0.8 ton per day; the 2006 pilot facility had methanol input capacity of 82 tons per day (10k tpa of olefin output). In addition to these three DICP pilot projects, China currently has five CTO-MTO facilities in operation: 1) the Shenhua Baotou CTO project; 2) the Shenhua Ningxia MTP project; 3) the Datang Duolun MTO project; 4) the Sinopec Zhongyuan "S-MTO" project; and 5) the Ningbo Heyuan MTO project.

Figure 76: China's CTO-MTO projects currently in operations

Project Name	Shareholder(s) of project vehicle	Location	Process technology	Olefin capacity (mln tpa)	Notes
Shenhua Baotou CTO Project (Phase I)	China Shenhua Energy (1088 HK): 100%	Inner Mongolia	DMTO by DICP	0.60	Vertical integrated
Shenhua Ningxia MTP Project (Phase I)	Shenhua Group : 51% Ningxia provincial government : 49%	Ningxia	MTP by Lurgi	0.50	Vertical integrated
Datang Duolun MTP Project	Datang International Power (991 HK) : 60% China Datang Group : 40%	Inner Mongolia	MTP by Lurgi	0.46	Vertical integrated
Sinopec Zhongyuan SMTO project	Sinopec (386 HK) : 93.51% Henan provincial government : 6.49%	Henan	S-MTO by Sinopec	0.20	Vertical integrated
Ningbo Heyuan MTO project	Ningbo Heyuan Chemical : 100%	Zhejiang	DMTO by DICP	0.60	Not vertical integrated
				2.36	

Source: IHS; ICIS; Company specific data; Deutsche Bank

In the following sections of the report, we look at:

- The synthesis of olefins from methanol;
- The technology used in China and other parts of the world to synthesize olefins from methanol; and
- The "SAPO-34" catalyst.

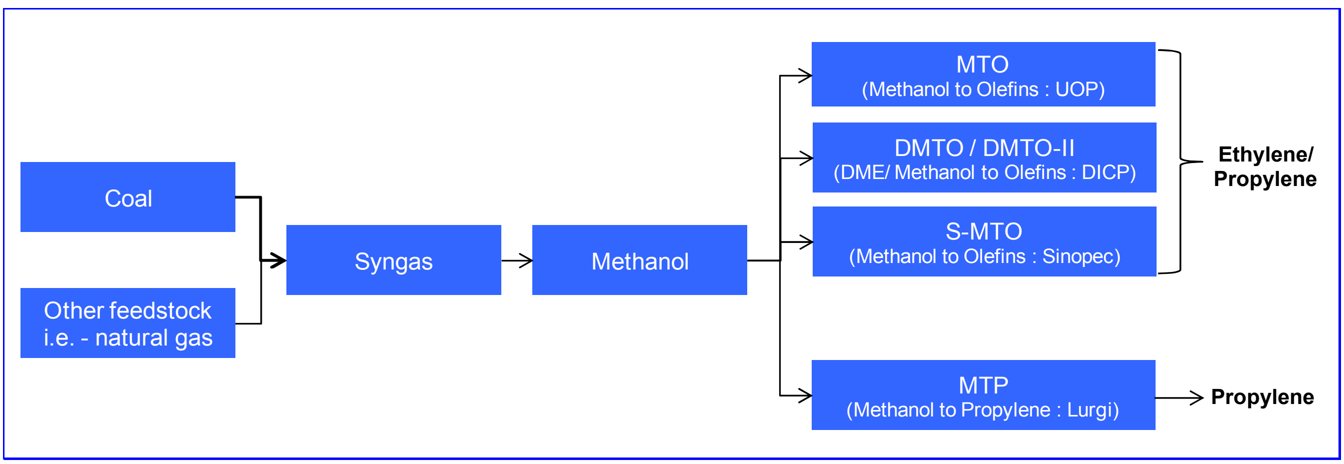
In concluding our CTO/ MTO remarks, we take a look at:

- The environmental issues of water use / conservation and CO_2 emissions that continue to be debated by the authorities and continue to plague / delay project approvals in China's "Coal-to" industry.

Converting methanol to olefins:

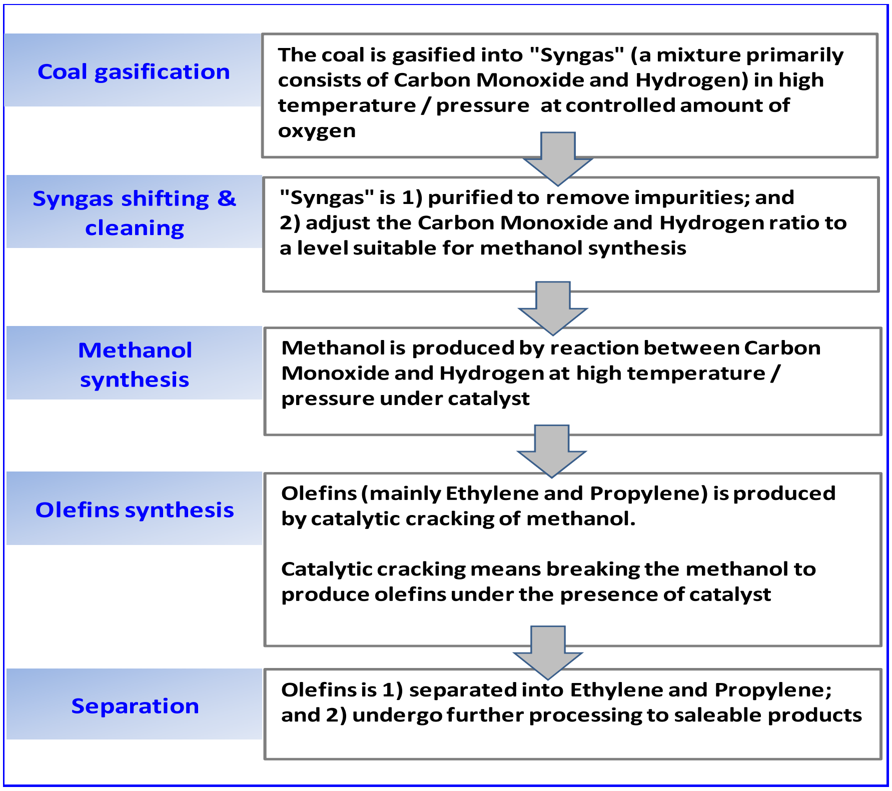
Figure 77 and Figure 78 present high-level views of the steps involved in the conversion of coal to syngas to methanol to olefins (MTO):

Figure 77: Overview – Coal-to-Olefins



Source: Deutsche Bank

Figure 78: General steps for coal to olefins process



Source: Deutsche Bank

Olefins synthesis and catalyst re-generation:

Methanol, recycled water and un-reacted methanol are fed into a fluidized-bed catalytic reactor. “Fluidized” means that the catalyst particles can move freely inside the reactor and not locked-down in a single, specific location. The reactor is also equipped with a catalyst regenerator and a recycle reactor (Figure 79). The optimal operating conditions for an MTO fluidized-bed catalytic reactor are 350°C and 0.2MPa of pressure.

The effluent of the methanol fluidized-bed catalytic reactor is a mixture of ethylene (C_2H_4), propylene (C_3H_6) – collectively referred to as olefins; methanol (CH_3OH); water (H_2O); carbon dioxide (CO_2); and other hydro-carbons such as ethane (C_2H_6); propane (C_3H_8); butane (C_4H_{10}) and heavier ($+C_4$) chains of carbon and hydrogen. The water and un-reacted methanol are cooled, condensed to a liquid and re-cycled back to the fluidized-bed catalytic reactor for olefins synthesis once again. Spent catalyst from the fluidized-bed catalytic reactor is routed to the catalyst regenerator in which the accumulated coke is burned off the catalyst with the application of hot air. The coke-free regenerated catalyst is then fed back into the fluidized-bed catalytic reactor to serve as the catalyst for methanol to olefins synthesis again and again.

Olefins separation

The cooled reactor effluent leaving the recycle reactor (Figure 79) is further processed to 1) remove carbon dioxide; and thereafter 2) compressed at high pressure to a liquid state for the purpose of further separation by distillation. At the start of separation process, the reactor effluent (a mixture of ethylene, propylene, methane, propane, butane and other hydrocarbons) is passed over a series of separation units, including de-ethanizer, de-methanizer and de-propanizer to remove ethane, methane-rich flue gas and propane, respectively.

The effluent leaving the de-ethanizer consists of two hydrocarbon streams: a "lighter hydrocarbon stream" and a "heavier hydrocarbon stream". The "lighter hydrocarbon stream" contains a mixture of ethylene (C_2H_4), methane (CH_4) and small amount of ethane (C_2H_6) that has not been removed by the de-ethanizer. The "heavier hydrocarbon stream" contains a mixture of propylene (C_3H_6), propane (C_3H_8), butane (C_4H_{10}) and other heavier hydrocarbons. These two streams will be processed separately to obtain the MTO target products of ethylene and propylene.

The "lighter hydrocarbon stream" is fed into the de-methanizer. The de-methanizer is used to remove methane which is used as a fuel source to power the plant operation. After the methane is removed, the resulting effluent of ethylene (C_2H_4) and ethane (C_2H_6) is fed into a C2 splitter to separate the two products.

The "heavier hydrocarbon stream" is fed to the de-propanizer. The de-propanizer is used to remove propane before further processing. Two hydrocarbon streams are emitted from de-propanizer. The first stream, being a mixture of propylene (C_3H_6) and propane (C_3H_8) is 1) fed into an oxygen removal unit, and thereafter 2) fed into a C3 splitter to separate propylene and propane. The second stream, being a mixture of butane and other heavier hydrocarbons, is sent to the de-butanizer for separation of butane (C_4H_{10}) and other heavier hydrocarbons.

It is worth noting that the configuration of the MTO equipment / facility is not always uniform across production facilities. We have thus summarized the process and equipment (Figure 79) as a reference point only.

De-Ethanizer: A de-ethanizer is used to remove ethane. The reaction effluent leaving de-ethanizer consists of two hydrocarbon streams, with a lighter stream containing ethylene (and other light hydrocarbons) and a heavier stream containing propylene (and other heavy hydrocarbons).

De-methanizer: A de-methanizer is similar to the de-ethanizer, except that it is used to remove methane.

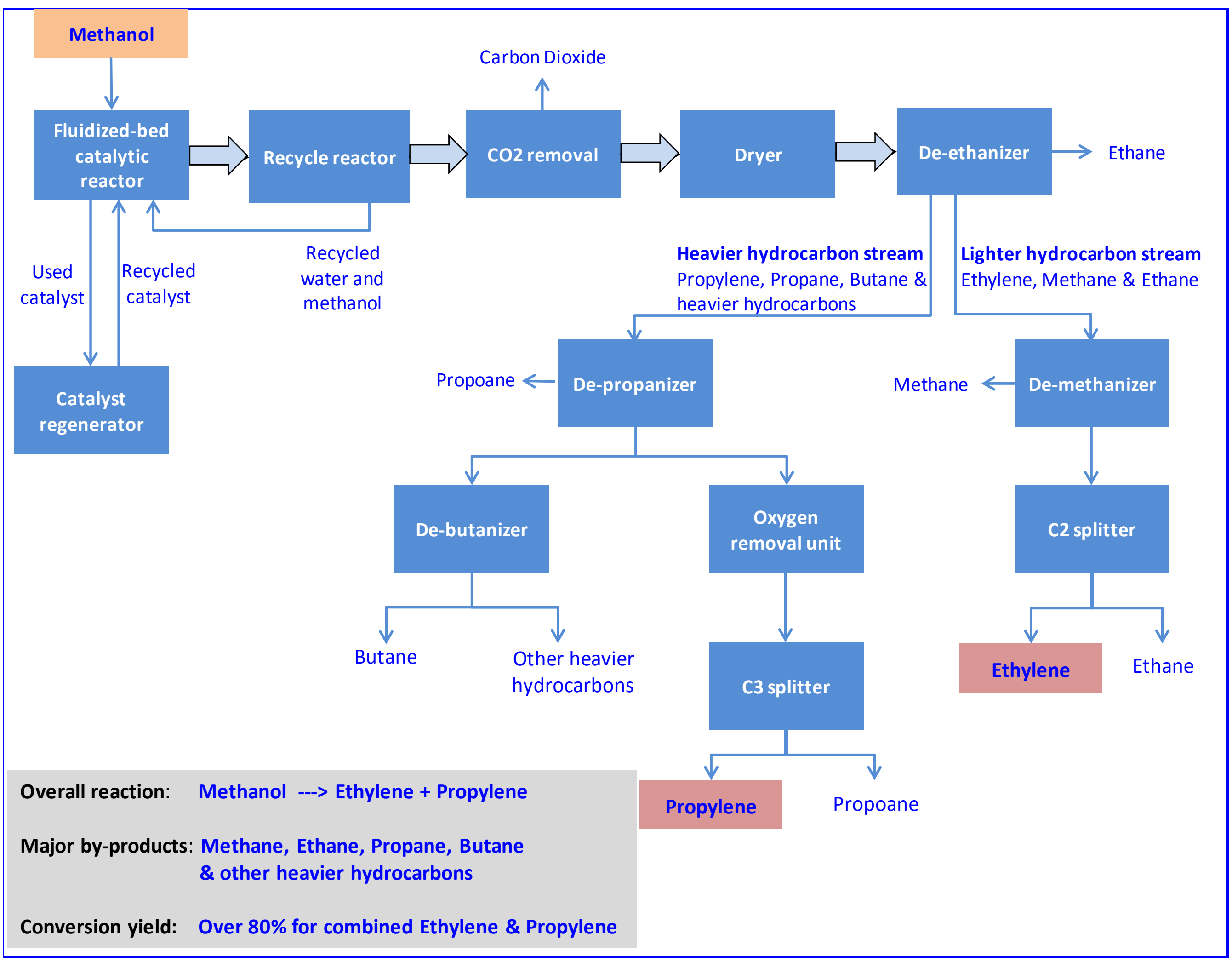
De-propanizer: A de-propanize is also similar to de-ethanizer, except that it is used to remove propane.

De-butanizer: A de-butanizer is used to separate butane and other heavier hydrocarbons.

C_2 / C_3 splitters: C_2 / C_3 splitters are used to separate ethylene / ethane and propylene / propane by distillation. Distillation is achieved by utilizing the different of boiling points between different substances.

Both crude methanol (17-20% water by mass) and pure methanol (0.1% water by mass) can be used as feedstock to produce olefins (MTO). The CTO producer can eliminate costs by using crude methanol as feedstock for olefins production and do away with the need to capex a methanol refinery. However the CTM producer has the option to sell to markets that require the premium quality / price of pure methanol (fuel blending; fuel cells as hydrogen carrier and waste water treatment) and / or to markets that can use the lower quality / lower cost crude methanol (feedstock for MTO, DME, plasticizers and emulsifiers). We suspect that the CTO producer's ability to use crude methanol says a lot about limited crossover of stand-alone CTM into stand alone MTO facilities. Economics are favorable on CTO relative to non-dedicated CTM into a dedicated MTO facility.

Figure 79: Process of methanol to olefins (MTO)



Source: US Department of Energy, Deutsche Bank

MTO technology(s) found in China

World-wide there are four methanol-to-olefin technologies, of which all four are being used currently in China:

1. D-MTO / D-MTO-II,
2. S-MTO,
3. MTO by UOP; and
4. MTP by Lurgi

There is a 5th MTO technology called "F-MTP" which was developed by Tsinghua University in conjunction with China National Chemical Engineering Group beginning in 1999. However, according to current research notes, "F-MTP" technology has yet to be commercially tested.

"D-MTO / D-MTO-II" and "S-MTO" are technologies developed in China by Chinese companies / institutes. The D-MTO / D-MTO-II technology has the largest market share in China (64% and 70% in terms of number of units and capacity, respectively). The "Market share" participations noted below include methanol-to-olefin projects both in operation and in the planning stage. We discuss the characteristics and reaction mechanisms associated with each of these different technologies in the following sections.

Figure 80: Market share in China – Methanol-to-olefin technology

Technology	No. of units	Olefins capacity (mln ton per year)	Market share	Origin
D-MTO / D-MTO-II	**18**	**10.0**	**69%**	**Domestic**
S-MTO	4	2.0	14%	Domestic
UOP MTO	3	1.2	8%	Overseas
Lurgi MTP	2	0.9	7%	Overseas
Others	1	0.2	1%	
	28	**14.4**	100%	

Note: The units include projects in operation and at planning stage.

Source: Dalian Institute of chemical Physics, Deutsche Bank

D-MTO / D-MTO-II

D-MTO is a 1st generation methanol-to-olefins technology which was discovered (1980s) by the Dalian Institute of Chemical Physics (DICP) and later developed, tested and financed with help from Sinopec Group and the Shaanxi Coal and Chemical Industry Group. The technology was first tested on a commercial scale (Shenhua Baotou) in June 2010. The 2nd generation technology (D-MTO-II) is an upgraded version of D-MTO and has the capacity to recycle C_4 and higher carbon chains back through the reactor (Figure 82). The D-MTO process required 2.97 tons of methanol to produce 1 ton of olefins; the D-MTO-II process requires 2.67 tons of methanol to produce 1 ton of olefins.

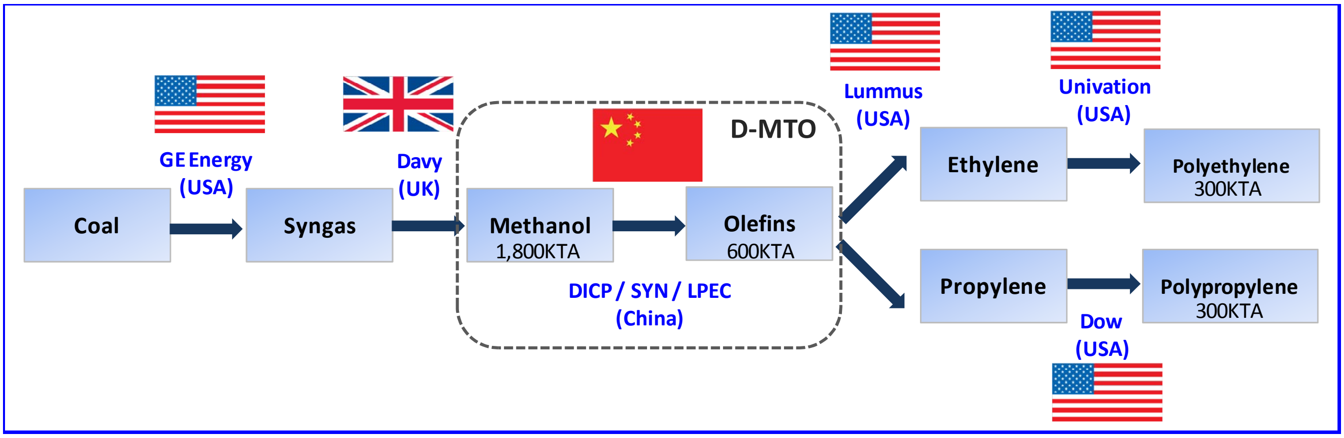
The Shenhua Baotou CTO project uses coal to produce methanol and methanol to produce olefins via D-MTO technology. Butene / butylene, propane, ethane, heavier hydrocarbons (+C_4) and sulfur are by-products of the D-MTO / MTO process. The key feature of D-MTO technology is the ability to separate target products (ethylene/ propylene) from a mixture of hydrocarbons that may include some unwanted heavier hydrocarbons.

The Shenhua Baotou 600,000 ton/year project is the world's first commercial CTO project and the world's first CTO project using D-MTO technology. As per the Chinese Social Sciences Net (CSSN.cn) the 2012 utilization rate for Shenhua Baotau (CTO) was 90%. In Dec 2013, the Shenhua Baotou project was transferred from Shenhua Group (Parent) to China Shenhua Energy Company Ltd (1088 HK; Buy). On 25-April, China Shenhua Energy Company reported 1Q14 olefin sales (polyethylene and polypropylene) of 170k tons which would equate to an annualized utilization rate on the Baotou CTO facility of approximately 113%.

We note that the Shenhua Ningxia MTO project (0.5 mln tpa propylene / polypropylene) remains under the Shenhua Group (Parent) company rather than under China Shenhua Energy Company Ltd (1088 HK; Buy). We also assume that China Shenhua Energy (1088 HK) in its 1Q14 results announcement reported PE and PP production (170k tons) only for its Baotou CTO project rather than for both its Baotou project and its Parent's MTO Ningxia project.

Figure 81 shows the technology providers for the Shenhua Baotou CTO project from start to finish: 1) GE technology (GE US; Buy) is used for the coal to syngas conversion; 2) Johnson Matthey Davy (JMAT LN; Buy) technology is used for the syngas to methanol conversion; 3) DICP/ SYN / LPEC technology is used for the methanol to olefins conversion (LEPC is Luoyang Petrochemical Engineering Corporation a subsidiary of the Sinopec Group – Parent company); 4) Lummus technology is used to separate the ethylene and propylene streams; while 5) Univation technology is used to convert ethylene to polyethylene; and 6) Dow Chemical (DOW UN; Hold) technology is used to convert propylene to polypropylene.

Figure 81: Shenhua Baotou CTO technology processes



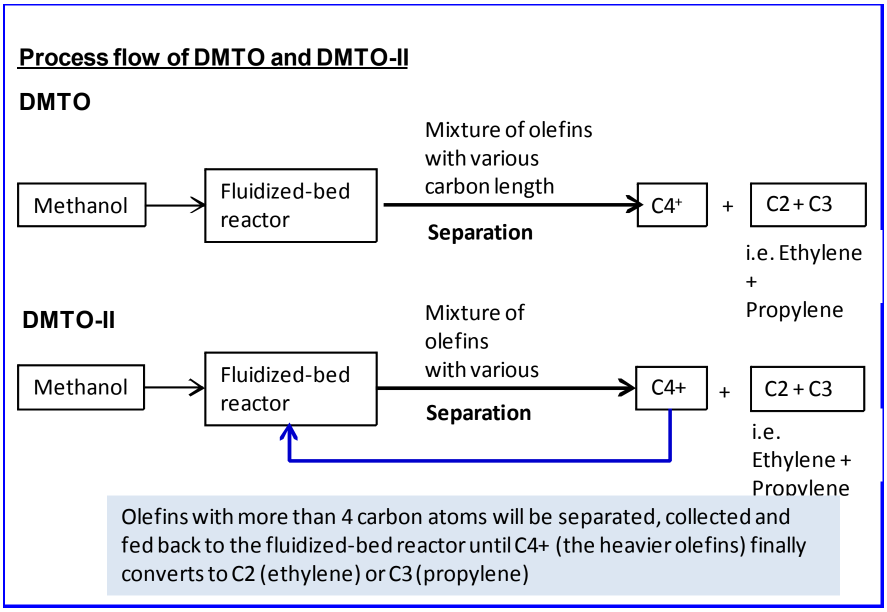
Source: Dalian Institute of Chemical Physics (DICP); Deutsche Bank

***Reaction condition and feedstock consumption**:* The reaction under D-MTO/ D-MTO-II technology is an acid catalyzed reaction with a 100% methanol conversion rate. This reaction occurs at high temperature and medium pressure (400-500°C and 0.1-0.3MPa) and is exothermic (gives off heat).

Equipment: The D-MTO/ D-MTO-II system(s) consist of a fluidized catalytic reactor, a catalyst regenerator, a unit for separating ethylene (C_2) / propylene (C_3) and heavier hydrocarbons ($+C_4$), and peripheral equipment (e.g. utilities, air compression units). SYN Energy Technology Company Ltd, a subsidiary of Dalian Institute of Chemical Physics (DICP) and the holder of the D-MTO/ D-MTO-II intellectual property rights, confirmed to us that all D-MTO/ D-MTO-II equipment can be fully manufactured in China with the exception of certain metering equipment.

Catalyst: D-MTO/ D-MTO-II use the same dedicated catalyst for the reaction. In addition, the one catalyst can be used for two separate catalyst-reactions: 1) converting methanol to ethylene and propylene; and 2) converting heavier olefins ($+C_4$) to ethylene and propylene. The developer of the catalyst (DICP) estimates that the catalyst consumption per ton methanol is less than 0.25 kg.

Figure 82: Methanol to Olefin technology (DMTO vs DMTO-II)



Source: Dalian Institute of chemical Physics, Deutsche Bank

According to the chief scientist of the D-MTO project, the "D" in D-MTO stands for two things 1) the city of Dalian in Liaoning province, where the project was developed by DICP, and / or 2) "D" as an abbreviation for DME or "Di-Methol Ether" (CH_3OCH_3). In essence, both methanol and DME can be used as feedstock to produce olefins in the D-MTO and / or D-MTO-II process.

In China, DME is used as 1) a substitute and / or filler for LPG; 2) a blender into the gasoline and / or diesel pool; and 3) an aerosol propellant. DME is produced by the de-hydration (removal of water) of methanol.

The core D-MTO process technology is the SAPO-34 catalyst (See section below "Catalyst for MTO – SAPO 34")

S-MTO

Sinopec has also developed its own methanol-to-olefins process called "S-MTO" (Figure 83) or "Sinopec-MTO". In 2007, Sinopec built a pilot project at Yanshan Petrochemical Co. for testing the S-MTO technology. Sinopec built the first large-scale (200k tpa) S-MTO plant in Henan province (central China) which was put into commercial operation in October 2011. This S-MTO plant is under Sinopec Zhongyuan Petrochemical Corp. Ltd. which is 93.5% owned by Sinopec Corp (386.HK) and 6.49% by the government of Henan Province.

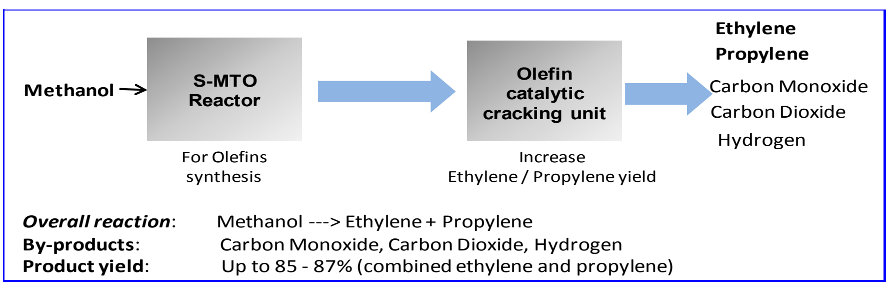
In December 2013, the Zhong Tian He Chuang Energy Corporation (a JV owned 38.75%, 38.75%, 12.5% and 10% by Sinopec Corp (386 HK), China Coal Energy Company (1898 HK; Sell), Shanghai Shenergy (600642 CH) and Inner Mongolia Manshi Coal Group), contracted Sinopec Engineering Group (2386 HK; Buy) to build a large CTO facility in Inner Mongolia using S-MTO technology. The capacity of this project has been declared at 3.6 million tpa of olefin with a provisional handover date by October 2015.

The NDRC has granted Sinopec Group "preliminary approval" to build two 600K tpa MTO plants using S-MTO technology. The two facilities will be built in Guizhou and Henan. Sinopec Group (parent company) has yet to provide a work schedule and / or intended completion date for the two projects. Sinopec Group did not comment as to whether these assets would be passed to Sinopec Corp (386 HK) at any time in the future.

S-MTO technology uses "SAPO-34" as a catalyst which is able to alter the product mix (yield) of ethylene vs. propylene. The ratio of ethylene and propylene can be adjusted from 0.6 to 1.3. A product ratio of ethylene and propylene of 1.3 suggests a product yield of ethylene to propylene of 57% and 43% (57 / 43 = 1.3) respectively.

If Olefin Catalytic Cracking ("OCC") is used simultaneously with S-MTO, the overall yield of ethylene and propylene can be increased from 81% to 85-87% (Figure 83). OCC is a process to break down the heavier olefins into lighter olefins (ethylene and propylene) with the use of catalyst. The by-products of OCC include hydrogen, carbon monoxide and carbon dioxide.

Figure 83: Basic process flow of S-MTO



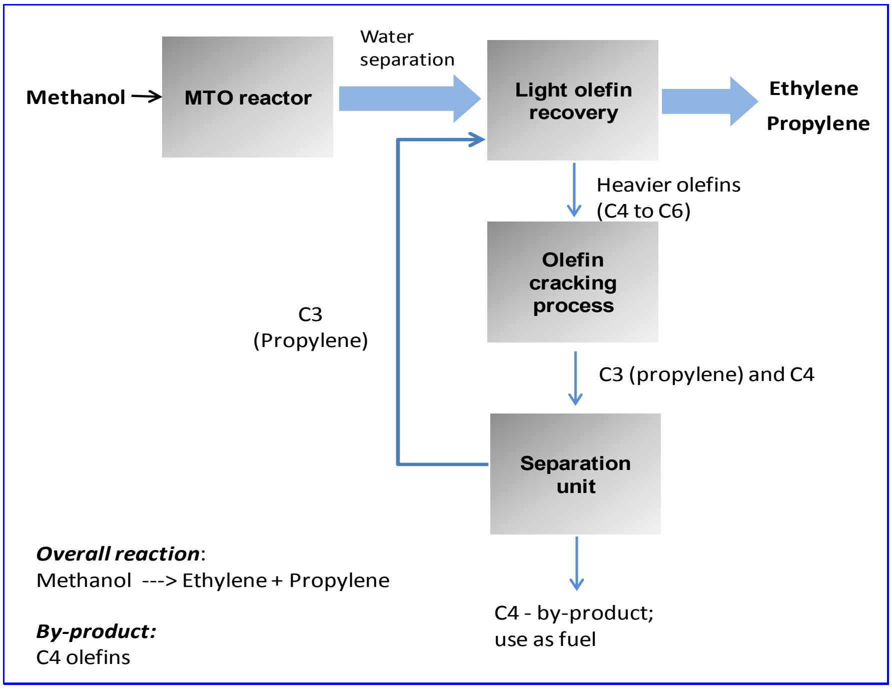
Source: Deutsche Bank

(There is limited information on S-MTO technology as developed by Sinopec. Nothing in terms of reaction condition, basic process flow, performance, and / or equipment configuration has been shared with public markets.)

Methanol to Olefins ("MTO") by UOP

The methanol-to-olefins by UOP process takes place through a complex network of chemical reactions. "Selectivity" is a measure of the amount of one product produced relative to others when the possibility to form multiple products exists: ethylene & propylene in our case. Selectivity depends on temperature.

Figure 84: Basic process flow of MTO by UOP



Source: Deutsche Bank

Methanol is pre-heated to gaseous phase and introduced into the MTO reactor for olefins synthesis (Figure 84). The reactor operates at vapor phase at temperature of 340 – 540°C and pressure of 0.1- 0.3 MPa. Olefins synthesis is speed up by catalyst SAPO-34, which is circulating inside the reactor.

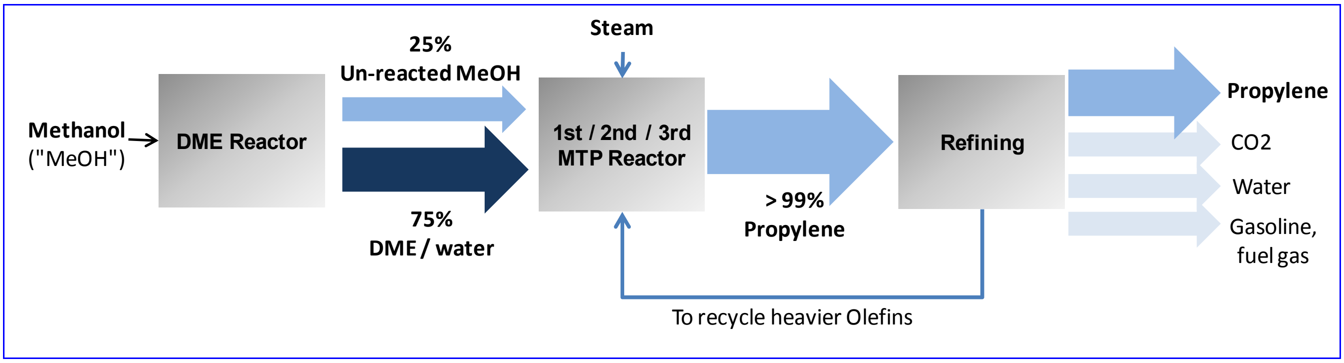
During the olefins synthesis, coke is accumulated on catalyst's surface and requires removal to restore the catalyst's ability to function properly. This is achieved by routing the catalyst into a catalyst regenerating system in which the coke is removed by combustion with air. After the coke has been removed, the catalyst will be circulated back to MTO reactor.

The reactor effluent (i.e. - ethylene, propylene, heavier olefins and water) is then cooled. Water is separated from the product gas stream. The effluent is then fed into a light olefin recovery unit which separates ethylene (C_2) & propylene (C_3) while the heavier olefins C_4 to C_6 (olefins with 4 to 6 carbon atoms at each olefins molecule) are sent to be cracked into either C_3 (propylene) or C_4 (butadiene) olefins. The propylene is recycled for light olefin recovery while the C_4 is used as fuel for the MTO process or other processes.

Methanol-to-propylene ("MTP") by Lurgi:

MTP by Lurgi is a technology that converts methanol to propylene under relatively mild operating conditions (430-450°C and 0.35MPa).

Figure 85: Process flow – Methanol to propylene ("MTP")



Source: Deutsche Bank

Methanol is first pre-heated to 260°C before fed into the DME reactor (Figure 85). Under the presence of catalyst, 75% of the methanol feed is converted to DME and water. The remaining 25% of reactor effluent is un-reacted methanol. The reaction mixture is then heated to 470°C and fed into the first MTP reactor with steam (0.3 – 0.8 kg steam per kg reaction mixture). The first MTP reactor converts more than 99% of the methanol / DME mix into propylene. The reaction mixture is then fed into a second and third MTP reactor to further increase the propylene yield.

The gaseous reaction mixture (rich in propylene) leaving the third MTP reactor is cooled to separate propylene (product), organic liquids and water. Propylene is further compressed to remove trace amount of impurities (carbon dioxide, water and DME). Organic liquids will be refined to olefins, gasoline and fuel gas. Any olefins that are heavier than propylene will be recycled to MTP reactors to increase the propylene yield.

The Catalyst for methanol-to-olefins (SAPO-34)

The SAPO-34 catalyst was developed by the Union Carbide Corporation (acquired by Dow Chemical 2001) in 1982 and consists of silicon, aluminum, phosphate and oxygen. SAPO-34 is used to synthesize olefins from methanol.

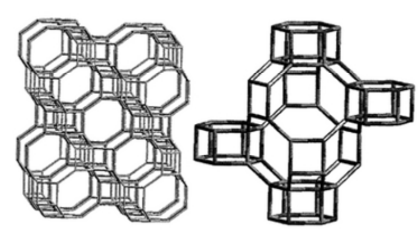
Physical outlook and basic working principle

SAPO-34 is an eight-ring crystalline substance with numerous extremely small holes / pores of 0.38nm (Figure 86). 1 nm equals to 1/1,000,000,000 of 1 meter. SAPO-34 catalyst works by using small pore molecular sieves to alter the structure of the methanol feedstock and convert it to olefin molecules.

Preparation method

SAPO-34 is synthesized with the assistance by Tri-ethylamine. Tri-ethylamine is commonly used in the process of organic synthesis (i.e. to assist the production of carbon-containing molecules). SAPO-34 catalyst is prepared by the conversion of a dry gel containing Aluminum Oxide, Phosphate Oxide, Tri-

Figure 86: Structure of SAPO-34



Source: Freepatent Online; Deutsche Bank ethylamine and water in a ratio of 1.0 : 1.0 : 0.6 : 3.0 : 50. The gel is then transferred to a stainless steel autoclave for further processing. "Autoclave" is a device used to sterilize equipment / substance (i.e. to kill bacteria. viruses, fungi and spores). The SAPO-34 catalyst is obtained after crystallization at 200^{o}C and calcinations of the gel at 550^{o}C for 4 hours. Calcination is a thermal treatment process carried out in the presence of air / oxygen for decomposition or removal volatile substances.

Modification on "SAPO-34" to improve its catalytic performance

In order to increase the product selectivity and avoid side reactions, metal such as Nickel, Magnesium, Calcium and Strontium are added to the pores / molecular sieve to adjust the size of pores and increase the catalyst's mechanical strength.

Financials

We have conducted a cost analysis for coal-to-olefins (Figure 87 to Figure 93). We have considered two cases: Case 1 is a plant located in Inner Mongolia with coal feedstock from its self-owned coal mine; and Case 2 is a "MTO" plant located at Eastern China (Jiangsu province) that uses imported pure methanol (as opposed to crude methanol) for olefins production.

We would see that olefin from Inner Mongolia has a cost advantage of around US$905 / ton compared with Case 2 (MTO at Eastern China). But it is worth noting that the cost of coal-to-olefins in Inner Mongolia depends heavily on low cost coal feedstock. On the other hand, olefin cost in Case 2 depends heavily on imported methanol, which is probably gas-based methanol from Middle East. We would point out that the cost comparison is mainly a competition of feedstock which accounts for 25 – 30% of the total production cost.

Figure 87: Key Assumptions for Olefins cost analysis

Key Assumptions for Olefins cost analysis:

1. **Assumes 3 tons of methanol used to produce 1 ton of olefins (ethylene and / or propylene)**
2. **Assumes that 1.4 tons of bituminous coal is used to produce 1 ton of methanol**
3. **Assumes DMTO-II technology is used in Case 1 and Case 2**
4. **Assumes that the coal cost from self-owned mines is 20% less than coal purchased from third parties**
5. **Assumes 3.47 tons of naphtha used to produce 1 ton of olefins (ethylene and / or propylene)**
6. **Assumes the olefins production capacity of CTO and MTO to be 600k TPA & Naphtha-to-olefins to be 4m TPA**
7. **Assumes the total investment of CTO and MTO projects to be 15.0 billion Rmb and 9.0 billion Rmb (60% of CTO); and Naphtha-to-olefins to be 19.2 billion Rmb**
8. **Assumes the useful life of plant & machinery to be 15 years and the depreciation expenses spread evenly over the olefins products**
9. **Assumes the target market is in Eastern China, in close proximity to the olefins plant in Case 2 and Case 3**

Source: Deutsche Bank

Figure 88: Sensitivity test - Coal and Methanol cost on Olefins

Case 1 : Inner Mongolia / self-owned coal mines		
Change in coal price	Methanol cost *(USD / ton)*	Compare with current methanol cost
-10%	626	-2.2%
-5%	633	-1.1%
0%	640	0.0%
+5%	647	1.1%
+10%	654	2.2%
+15%	662	3.4%
+20%	669	4.5%
+30%	683	6.7%
+50%	712	11.2%

Case 2 : Eastern China / imported methanol		
Change in methanol price	Methanol cost *(USD / ton)*	Compare with current methanol cost
-10%	1421	-8.0%
-5%	1483	-4.0%
0%	1545	0.0%
+5%	1607	4.0%
+10%	1669	8.0%
+15%	1731	12.0%
+20%	1793	16.1%
+30%	1917	24.1%
+50%	2164	40.1%

Source: Deutsche Bank

Figure 89: Sensitivity test - Coal and Naphtha cost on Olefins

Case 1 : Inner Mongolia / self-owned coal mines		
Change in coal price	Methanol cost *(USD / ton)*	Compare with current methanol cost
-10%	626	-2.2%
-5%	633	-1.1%
0%	640	0.0%
+5%	647	1.1%
+10%	654	2.2%
+15%	662	3.4%
+20%	669	4.5%
+30%	683	6.7%
+50%	712	11.2%

Case 3 : Eastern China / naphtha		
Change in methanol price	Methanol cost *(USD / ton)*	Compare with current methanol cost
-10%	845	-28.6%
-5%	1015	-14.3%
0%	1185	0.0%
+5%	1354	14.3%
+10%	1524	28.6%
+15%	1694	43.0%
+20%	1863	57.3%
+30%	2203	85.9%
+50%	2881	143.2%

Source: Deutsche Bank

Figure 90: CTO / MTO cost models – Inner Mongolia "self-owned coal mines" vs. E. China "imported methanol"

	Case 1 Inner Mongolia Self-owned coal mines	Case 2 Eastern China Imported methanol	
Feedstock cost			
Coal used for feedstock			
Coal price (ex-plant)	207	0	RMB/ton coal
Coal price (ex-plant)	34	0	USD/ton coal
Coal consumption per ton methanol	1.40	0.00	ton coal/ton methanol
Coal feedstock cost per ton methanol	***290***	***0***	***RMB/ton methanol***
	48	***0***	***USD/ton methanol***
Total coal consumption per ton methanol	1.40	0.00	ton coal/ton methanol
Total coal cost per ton methanol	290		RMB/ton methanol
	48		USD/ton methanol
Methanol consumption per ton olefins	3.00	3.00	ton methanol/ton olefins
Methanol purchase cost		2,500	RMB/ton methanol
		413	USD/ton methanol
Total feedstock cost per ton olefins	***869***	***7,500***	***RMB/ton olefins***
	144	***1,240***	***USD/ton olefins***
Electricity			
Electricity (from coal to methanol)			
Usage per ton methanol	500	0	Kwh/ton methanol
Electricity tariff	0.35	0	RMB/Kwh
Electricity cost per ton methanol	175	0	RMB/ton methanol
Electricity cost per ton olefins	***525***	***0***	***RMB/ton olefins***
Electricity (from methanol to olefins)			
Usage per ton olefins	450	650	Kwh/ton olefins
Electricity tariff	0.35	0.65	RMB/Kwh
Electricity cost per ton olefins	***158***	***421***	***RMB/ton olefins***
Total electricity cost per ton olefins	***683***	***421***	***RMB/ton olefins***
Depreciation and Labor			
Depreciation	***500***	***300***	***RMB/ton olefins***
Labor and management overhead	***100***	***50***	***RMB/ton olefins***

Source: www.sxcoal.com, NDRC, CEIC, Deutsche Bank

Figure 91: CTO/ MTO cost models – Inner Mongolia "self-owned coal mines" vs. E. China "imported methanol" (Con't)

	Case 1 Inner Mongolia Self-owned coal mines	Case 2 Eastern China Imported methanol	
Water cost			
Water (from coal to methanol)			
Water price	3.50	0.00	RMB/ton water
Water usage	15	0	ton water/ton methanol
Water cost per ton methanol	53	0	RMB/ton methanol
Water cost per ton olefins	***158***	*0*	***RMB/ton olefins***
Water (from methanol to olefins)			
Water price	3.50	2.60	RMB/ton water
Water usage	15	15	ton water/ton olefins
Water cost per ton olefins	***53***	***39***	***RMB/ton olefins***
Total water cost per ton olefins	***210***	***39***	***RMB/ton olefins***
Effluent treatment cost			
Effluent treatment (from coal to methanol)			
Treatment price	0.95	0.00	RMB/ton effluent
Treatment volume	30	0	ton effluent/ton methanol
Treatment cost per ton methanol	29	0	RMB/ton methanol
Treatment cost per ton olefins	***86***	*0*	***RMB/ton olefins***
Effluent treatment (from methanol to olefins)			
Treatment price	0.95	1.30	RMB/ton effluent
Treatment volume	30	30	ton effluent/ton methanol
Treatment cost per ton olefins	***29***	***39***	***RMB/ton olefins***
Total effluent treatment cost per ton olefins	***114***	***39***	*RMB/ton olefins*
Others			
R&M and insurance	***80***	***96***	***RMB/ton olefins***
Other production supplies	***750***	***900***	***RMB/ton olefins***
Transportation cost for olefins product			
Distance	1,889	0	km
Transportation cost	0.30	0	RMB/ton km
Transportation cost per ton olefins	***567***	*0*	***RMB/ton olefins***
Total production cost per ton olefins	***3,873***	***9,345***	***RMB/ton olefins***
	640	***1,545***	***USD/ton olefins***

Source: www.sxcoal.com, NDRC, CEIC, Deutsche Bank

Figure 92: CTO / Naphtha-to-olefins cost models – Inner Mongolia "self-owned coal mines" vs. E. China "naphtha"

	Case 1 Inner Mongolia Self-owned coal mines	Case 3 Eastern China Naphtha	
Feedstock cost			
Coal used for feedstock			
Coal price (ex-plant)	207	0	RMB/ton coal
Coal price (ex-plant)	34	0	USD/ton coal
Coal consumption per ton methanol	1.40	0	ton coal/ton methanol
Coal feedstock cost per ton methanol	***290***	*0*	***RMB/ton methanol***
	48	*0*	***USD/ton methanol***
Methanol consumption per ton olefins	3.00		ton methanol/ton olefins
Naphtha used for feedstock			
Naphtha price (ex-plant)	0	666	RMB/bbl naphtha
Naphtha price (ex-plant)	0	110	USD/bbl naphtha
Naphtha consumption per ton olefins	0	30.8	bbl naphtha/ton olefins
Total feedstock cost per ton olefins	***869***	***20,529***	***RMB/ton olefins***
	144	***3,393***	***USD/ton olefins***
Credit: by-products sales			
Propylene (0.581 tons / ton olefins)	0	4,519	RMB/ton olefins
Crude C4s (0.381 tons / ton olefins)	0	2,287	RMB/ton olefins
Pygas (0.803 tons / ton olefins)	0	4,640	RMB/ton olefins
Hydrogen (0.048 tons / ton olefins)	0	569	RMB/ton olefins
Fuel (25.543 tons / ton olefins)	0	2,269	RMB/ton olefins
Pyrolysis fuel oil (0.168 tons / ton olefins)	0	629	RMB/ton olefins
	0	**14,913**	***RMB/ton olefins***
Electricity			
Electricity (from coal to methanol)			
Usage per ton methanol	500	0	Kwh/ton methanol
Electricity tariff	0.35	0	RMB/Kwh
Electricity cost per ton methanol	175	0	RMB/ton methanol
Sub-total	***525***	0	***RMB/ton olefins***
Electricity (from methanol to olefins)			
Usage per ton olefins	450	0	Kwh/ton olefins
Electricity tariff	0.35	0.00	RMB/Kwh
Sub-total	***158***	0	***RMB/ton olefins***
Electricity (from naphtha to olefins)			
Usage per ton olefins	0	213	Kwh/ton olefins
Electricity tariff	0.00	0.65	RMB/Kwh
Sub-total	0	***138***	***RMB/ton olefins***
Total electricity cost per ton olefins	***683***	***138***	***RMB/ton olefins***
Depreciation and Labor			
Depreciation	***500***	***320***	***RMB/ton olefins***
Labor and management overhead	***100***	***50***	***RMB/ton olefins***

Source: China Petroleum and Chemical Industry Federation, CEIC, Deutsche Bank

Figure 93: CTO / Naphtha-to-olefins cost models – Inner Mongolia "self-owned coal mines" vs. E. China "naphtha" (Con't)

	Case 1 Inner Mongolia Self-owned coal mines	Case 3 Eastern China Naphtha	
Water cost			
Water (from coal to methanol)			
Water price	3.50	0.00	RMB/ton water
Water usage	15	0	ton water/ton methanol
Water cost per ton methanol	53	0	RMB/ton methanol
Sub-total	***158***	0	***RMB/ton olefins***
Water (from methanol to olefins)			
Water price	3.50	0.00	RMB/ton water
Water usage	15	0	ton water/ton olefins
Sub-total	***53***	0	***RMB/ton olefins***
Water (from naphtha to olefins)			
Water price	0.00	2.60	RMB/ton water
Water usage	0	12	ton water/ton olefins
Sub-total	0	***31***	***RMB/ton olefins***
Total water cost per ton olefins	***210***	***31***	***RMB/ton olefins***
Effluent treatment cost			
Effluent treatment (from coal to methanol)			
Treatment price	0.95	0.00	RMB/ton effluent
Treatment volume	30	0	ton effluent/ton methanol
Treatment cost per ton methanol	29	0	RMB/ton methanol
Sub-total	***86***	0	***RMB/ton olefins***
Effluent treatment (from methanol to olefins)			
Treatment price	0.95	0.00	RMB/ton effluent
Treatment volume	30	0	ton effluent/ton methanol
Sub-total	***29***	0	***RMB/ton olefins***
Effluent treatment (from naphtha to olefins)			
Treatment price	0.00	1.30	
Treatment volume	0	12	
Sub-total	0	***16***	
Total effluent treatment cost per ton olefins	***114***	***16***	*RMB/ton olefins*
Others			
R&M and insurance	***80***	***96***	***RMB/ton olefins***
Other production supplies & utilities	***750***	***900***	***RMB/ton olefins***
Transportation cost for olefins product			
Distance	1,889	0	km
Transportation cost	0.30	0	RMB/ton km
Transportation cost per ton olefins	***567***	*0*	***RMB/ton olefins***
Total production cost per ton olefins	***3,873***	***7,167***	***RMB/ton olefins***
	640	***1,185***	***USD/ton olefins***

Source: China Petroleum and Chemical Industry Federation, CEIC, Deutsche Bank

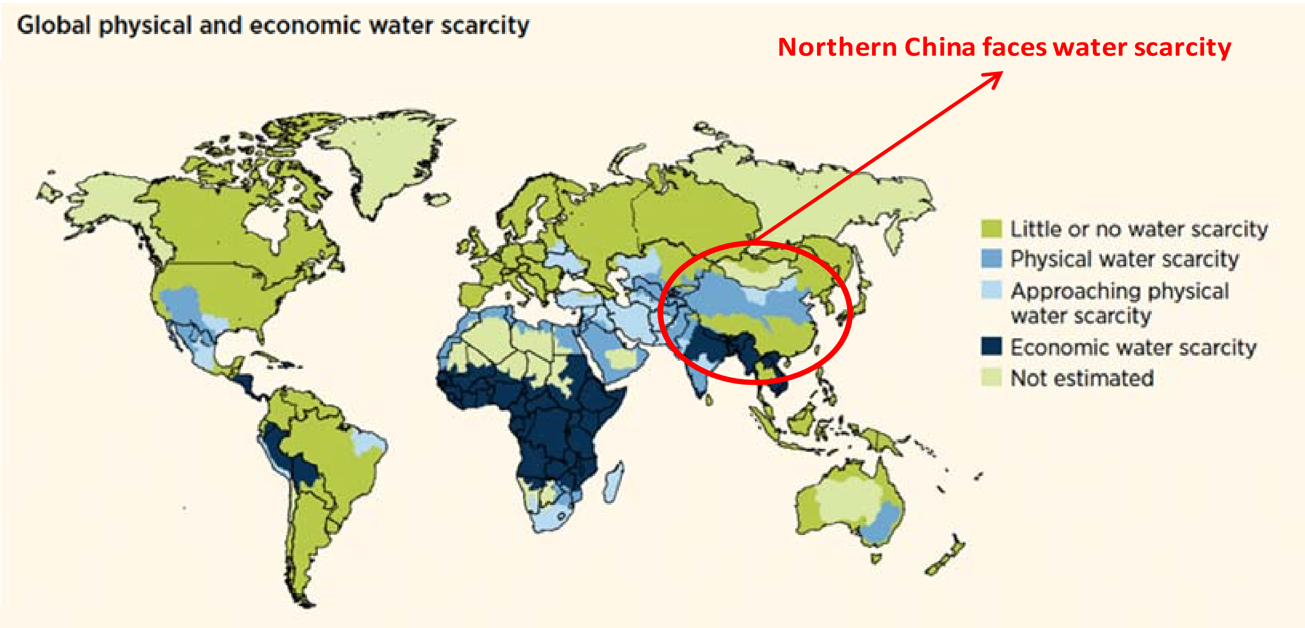
Figure 94: CTO / (US) natural gas liquids to olefins cost models

	Case 1 Inner Mongolia Self-owned coal mines		Case 4 North America Natural Gas Liquids	
Feedstock Cost				
Coal / Natural gas price	34	USD/ton coal	5.0	USD/mmbtu
Coal / Natural gas usage	4.2	ton coal/ton olefins	45.5	mmbtu/ton olefins
Coal / Natural gas cost	***144***	***USD/ton olefins***	***227***	***USD/ton olefins***
Electricity				
Electricity tariff	116.8	USD/MWH	46.8	USD/MWH
Electricity usage	0.95	MWH	0.15	MWH
Total electricity cost	***111***	***USD/ton olefins***	***7***	***USD/ton olefins***
Fuel				
Fuel price	0.0	USD/mmbtu	5.0	USD/mmbtu
Fuel consumption	0.00	mmbtu	22.1	mmbtu
Total fuel cost	***0***	***USD/ton olefins***	***110***	***USD/ton olefins***
Water usage				
Water price	3.500	RMB/ton	0.065	USD/M gallons
Water usage	60.0	ton/ton olefins	61.5	Gallon
Total water cost	***34***	***USD/ton olefins***	***4***	***USD/ton olefins***
Catalyst				
Total catalyst cost	***5***	***USD/ton olefins***	***5***	***USD/ton olefins***
Credit by-product sales				
Propylene (0.04 tons / ton olefins)	0	USD/ton olefins	52	USD/ton olefins
Crude C4s (0.04 tons / ton olefins)	0	USD/ton olefins	44	USD/ton olefins
Pygas (0.02 tons / ton olefins)	0	USD/ton olefins	23	USD/ton olefins
Hydrogen (0.08 tons / ton olefins)	0	USD/ton olefins	41	USD/ton olefins
Fuel (6.12 mmBtu / ton olefins)	0	USD/ton olefins	31	USD/ton olefins
Total co-product sales	***0***	***USD/ton olefins***	***190***	***USD/ton olefins***
Other cost				
Labour, Maintanence, Insurance	172	USD/ton olefins	77	USD/ton olefins
Depreciation	81	USD/ton olefins	97	USD/ton olefins
Total - other cost	***253***	***USD/ton olefins***	***174***	***USD/ton olefins***
Transportation cost for olefins product				
Distance	1,889.0	km	0.0	km
Transportation cost	0.05	USD/ton km	0.0	USD/ton km
Transportation cost per ton olefins	***92***	***USD/ton olefins***	***0***	***USD/ton olefins***
Production cost per ton olefins	***640***	***USD/ton olefins***	***338***	***USD/ton olefins***

Source: Deutsche Bank

Water & Pollution

Figure 95: Global water scarcity



Source: United Nations, Deutsche Bank

Water scarcity in China (Figure 95)

According to China's Ministry of Water Resources, the country has roughly 2,100 cubic meters of water per capita (2013), which is only 28% of the global average of 7,500 cubic meters per capita.

Figure 96: UN definitions of water availability / impact

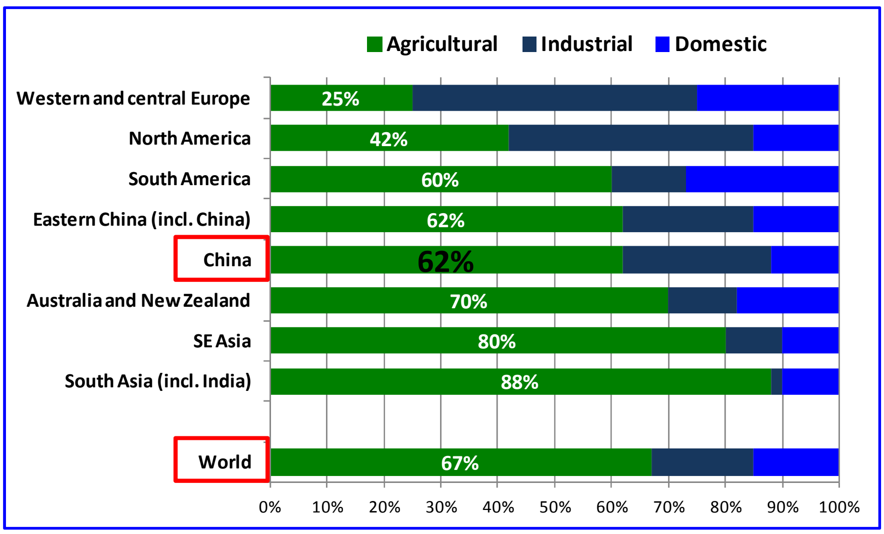
Water availability	What it means...
Above 1,700 m^3 per capita per year	Shortage will be rare
1,000 - 1,700 m^3 per capita per year	May experience periodic / regular water stress
500 - 1,000 m^3 per capita per year	Water scarity affects health, economic development and human well being
Below 500 m^3 per capita per year	Water availability is a primary constraint of life

Source: United Nations; Deutsche Bank

Water usage in China

According to the United Nations water for irrigation and food production accounts for c.67% of global freshwater withdrawal while industrial and residential represents c.18% and c.15% of usage. In China, c.62% of water is used in agricultural while industrial and residential account for 26% and 12% respectively. China's distribution of water use is quite similar to that mapped to global water use (Figure 97).

Figure 97: Water usage by sector by region (2012)



Source: FAO AQUASTAT, United Nations, Deutsche Bank

China's water resource location vs. usage

Water resources are unevenly distributed in China – extremely scarce in the North and abundant in the South. The water resource in China's mountainous southwest area can reach 25,000 cubic meters per capita per year (3.3x global average) while in China's Northern regions the water resource can be as low as 500 cubic meters per capita per year (8% of global average).

China's coal resource and the majority of its CTO facilities are located in the north-central and north-western provinces of Xinjiang, Inner Mongolia, Shaanxi and Shanxi (Figure 12 & 13). China's coal and the majority of its CTO projects are located in the water-scarce areas of China (Figure 100). This geographical mismatch makes water scarcity a critical issue for China's burgeoning coal to industry.

Water use comparisons by product

According to Pucheng Clean Energy Chemical Company Ltd. (a subsidiary of Shaanxi Coal & Chemical Industry Group Company), the amount of water consumed per ton olefin production ("MTO" - propylene & ethylene) is 50 to 60 tons of water per 1 ton of olefins, where as the MTP process consumes 36 to 45 tons of water to 1 ton of propylene (Figure 98). The water consumption required by Coal-to-Chemicals (MTO and / or MTP) is materially higher than the amount of water required in the Coal-to-Liquids ("coal to oil" = gasoline / diesel) process which is 15-17 tons of water per 1 ton of gasoline/ diesel produced. Materials published by The Pucheng Clean Energy Chemical Company regarding water use all specify the use of "fresh water" rather than brackish and / or sea water.

For coal to olefins (CTO), the amount of water consumed per ton of olefin production is effectively the sum of water consumed in the "Coal to Methanol" (CTM) process plus water consumed in the "Methanol to Olefins" (MTO) process. Converting Coal to Methanol requires 12-15 tons of water per ton of methanol; it takes 3 tons of methanol to produce 1 ton of olefins. An additional 50 to 60 tons of water is required to convert 1 ton of methanol into olefins (MTO). In sum, the full conversion of coal-to-methanol-to-olefins requires approximately 86 to 105 tons water for each ton of olefin production.

Calculation (for reference):

Low range: CTM (12 x 3) + MTO 50 = 86 ton water / ton olefins (CTO)

High range: CTM (15x 3) + MTO 60 = 105 ton water / ton olefins (CTO)

Figure 98: Comparison of feedstock / utilities consumption on different coal-to-chemicals projects

	Coal consumption *(ton of coal / ton of chemical)*	Water consumption *(ton of water / ton of chemical)*	Electricity usage *(KWh / ton of chemical)*	Carbon emission *(ton of CO_2 / ton of chemical)*
Methanol to Olefins *(MTO)*	**7 - 8**	**50 - 60**	**1,500 - 2,000**	**10 - 12**
Methanol to Propylene *(MTP)*	**8 - 9**	**36 - 45**	**2,000 - 2,500**	**10 - 12**
Coal to Liquids *(principally diesel and gasoline; Indirect coal liquefaction)*	**4 - 5**	**15 - 17**	**300 - 400**	**7 - 10**
Coal to Synthetic Natural Gas	**3.5 / 1000m^3**	**6 - 10 / 1000m^3**	**200 - 300 / 1000m^3**	**> 10 / 1000m^3**
Coal to Methanol	**2 - 3**	**12 - 15**	**300 - 400**	**3 - 4**

Source: Company data, Deutsche Bank

Inner Mongolia Yitai Coal Co., Ltd. (900948 CH), one of the largest non-state owned coal mining groups in China, provided another set of water consumption data. Yitai estimates that only 20 tons of water is needed produce 1 ton of olefins (CTO). The Shenhua Group, with nearly half of China's MTO / CTO capacity in operation (1.06 out of 2.36 mpta) (Figure 76), has yet to disclose water consumption data from either of its operating facilities.

For "Coal to Liquids" ("Coal to Oil" / gasoline &/ or diesel) and "Coal to Syngas" projects, there is also a large variation in data regarding required water usage. Water consumption for converting coal to synthetic gas ranges from 3.5 to 6.0 tons of water per 1,000 cubic meters of syngas, while 9 to 17 tons of water is needed per ton of oil product (gasoline/ diesel) (Figure 102).

We suspect that the wide range of values for water consumption per ton (or per 1,000 cubic meter) of coal-to-product is most probably due to 1) the fact that we are only in the initial stages of this industry in China and world-wide; 2) water reporting standards in China are probably not specified / unified across the industry; and 3) it probably does not behoove any of the Chinese corporate(s) operating in the space to actually make this information public.

Figure 99: China's Coal-to-liquid (gasoline / diesel) in operation

Project	Capacity (mln tons)	Company	Location
Direct Liquefaction			
Shenhua Baotou CTL Project (1st production line of Phase I)	1.08	**Shenhua Group : 100%**	**Inner Mongolia**
Indirect Liquefaction			
Lu'an coal-to-oil project	0.21	**Lu'an Group : 100%**	**Shanxi**
Shenhua Ordos CTL Project	0.18	**Shenhua Group : 100%**	**Inner Mongolia**
Yitai CTL Project (Phase I)	0.16	**Yitai Coal (3948 HK) : 51%** **I-Mongolia Mining Industry Group : 39.5%** **I-Mongolia Yitai Group : 9.5%**	**Inner Mongolia**
	0.55		
Methanol to Gasoline			
Jinmei MTG project	0.10	**Jinmei Group : 100%**	**Shanxi**
Total CTL capacity in operation	1.73		

Source: Asiachem; ICIS; NDRC; Company data;, Deutsche Bank

Emissions

China is making an effort to reduce industrial emissions by eliminating excess low-efficient capacity of high emission industries. China's biggest air polluters according to National Resources Defense Council statistics are:

Figure 100: Percentage contribution by industry to China's air pollution

Combined heat and power generation	**21.0%**
Thermal power generation	**20.8%**
Cement manufacturing	**10.0%**
Iron & steel smelting industry	**9.3%**
Chemical industry	**6.1%**
Non-ferrous metallurgy	**5.9%**
Paper manufacruring	**3.5%**
Coking industry	**3.3%**
Sugar industry	**2.9%**
Oil refinery and processing	**2.2%**
Heat production	**2.1%**
Others	**13.0%**
	100.0%

Source: National Resources Defense Council, Deutsche Bank

The above table dovetails well with recent comments from our consulting partner Wood Mackenzie with regards to government initiatives to replace heat and power generators with natural gas generators. We think the government will fall short of its objectives, but it's a good start ("Asia Natural Gas – On the road with Wood Mackenzie" dated 12-May 2014.)

Major air pollutants in China are SOx, NOx, CO_2, CO, PM10 and 2.5 (Figure 101).

Figure 101: Emission of China by sectors (2010)

	Power plants	Industrial use	Transportation	Residential / commercial	Total
SO_2	9,199	15,254	374	2,888	**27,715**
NOx	9,629	9,541	7,042	2,604	**28,816**
CO_2	3,253	4,635	834	1,454	**10,176**
CO	1,400	90,058	32,676	63,765	**187,899**
PM10	1,233	10,254	709	4,794	**16,990**
PM2.5	717	6,394	672	4,429	**12,212**

* All pollutants are in kt except CO_2 (in million ton)

Source: "Emissions of anthropogenic atmospheric pollutants and CO2" by researchers of Harvard University and Nanjiang University, Deutsche Bank

Provinces that contribute most to China's air pollution (Appendix 17 & 18) and the principal contributors to the pollution are:

- Shandong province: refining, chemicals and general industry;
- Hebei province: steel and iron production / coal in adjacent provinces;

- Henan province: vehicles / residential activities;
- Jiangsu province: steel and textiles;
- Guangdong: teapot refineries and general industrialization;
- Sichuan: vehicles / residential activities;
- Shanxi & Inner Mongolia: coal production and coal transport.

Hebei province is a center for China's pollution problems. The principal reasons for this are 1) Hebei province is located (i) near the coal-rich provinces of Inner Mongolia, Shanxi and Henan, (ii) near China's principal coal receiving port (Qinhuangdao), and (iii) the province serves as a thoroughfare for China's principal coal transport (Daqin railway); 2) Hebei is the capital of China's steel and iron manufacturing activities; and 3) Hebei boarders the greater Beijing city area: to reduce air pollutants in Beijing the government has relocated state-owned heavy industry away from Beijing and into Hebei province.

CTO emissions:

Coal to Olefin (CTO) projects produce an abundance of CO_2 emissions. The data in Figure 102 has been provided by the Shenhua Group and represents CO_2 emissions from a "typical 600k tpa CTO project". Given the fact that there are very few of such projects in operation, we are not sure what "typical" actually means – but, we will ignore that issue.

From the chart below, we note that the production of 1 ton of olefins and / or propylene from roughly 3.0 tons of methanol (MTO/ MTP) will emit 10.07 tons of carbon dioxide (Figure 102). To be more precise, the Shenhua literature states that a typical 600k Tpa MTO/ MTP project will produce 6.0 to 7.2 mln tpa of CO_2 effluent.

Extending this analysis to a coal-to-olefins (CTO) project we note in Figure 102 that 3 to 4 tons of CO2 is emitted for each ton of coal converted to methanol. As such, we estimate that "a typical" 600k Tpa CTO project, operating at 100% utilization will produce 11.4 to 14.4 million tons of CO_2 per year.

Calculation for reference:

Lower range = (10 + 3 x 3) x 600,000 = 11.4 million tons CO2

Upper range = (12 + 4 x 3) x 600,000 = 14.4 million tons CO2

A standard (600k Tpa) CTO project cited in center Beijing would increase CO_2 pollutants in the capital city by 14.3%. To be fair: 1) a standard CTO project cited in central Hebei province would increase CO_2 pollutants in the province by 1.8%; whereas 2) a standard CTO project cited in central Tibet (China) would increase CO_2 pollutants in the province by 350%. (Appendix 17-18).

During the CTO synthesis process, CO_2 is emitted principally during the coal gasification (c.36.4%) process and the Syngas purification (c.60.3%) process (Figure 102). Since the emission of CO_2 in the CTO process is highly concentrated in only two processes, "**C**arbon dioxide **C**apture and **S**torage"

(CCS) is technically feasible for CTO / MTO projects. CCS is the process of capturing emitted CO_2 from various industrial processes. However, CCS is still not an active part of China's current "coal-to" projects.

Figure 102: CTO – 600k tpa CO2 emission at different stage of Olefins synthesis

Emission Source	% Contribution to each ton of CO_2 emitted (%)	Concentration of CO_2 emitted NOTE 1 (%)	CO_2 emission for each ton of olefins (ton CO_2 / ton olefins)	CO_2 emission for whole plant NOTE 2 (mln ton CO_2 / year)
Syngas Purification	60.3%	88.1%	6.07	3.64
Coal Gasification	36.4%	6.0%	3.67	2.20
Sulfur Recovery	1.0%	28.1%	0.10	0.06
Other processes	2.3%	21.0%	0.23	0.14
	100.0%		10.07	6.04

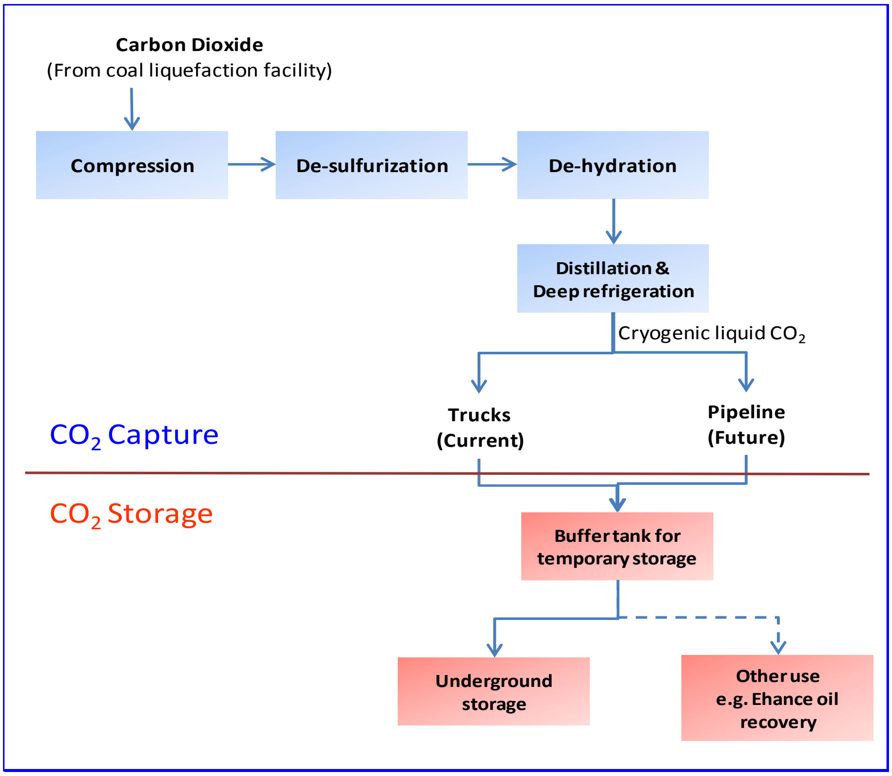
NOTES:
1) This refers to number of CO2 particles in 100 gaseous particles of effluent stream
2) Assume 100% operating rate

Source: Company data, Deutsche Bank

China has one small pilot CCS facility in operation (Shenhua Baotou CTL) and two more in the planning phase: 1) Shenhua is planning a large scale CCS facility at its Ningxia coal-to-liquids project due on line "after 2018e"; while 2) China Huaneng Group and China Power Investment Corporation are studying / "planning" CCS from power plant flue gas in Beijing, Tianjin, Shanghai and Chongqing.

The Shenhua Baotou-CTL CCS facility has a capacity of 100,000 tons of CO_2 per year, was built in 2010 by the Shenhua Group for its coal to liquids (gasoline / diesel) project in Inner Mongolia. The sequestration facility is built near the liquefaction plant; the CO_2 storage site is located 11 km to the west of the liquefaction plant. In Shenhua's CCS process (Figure 103), the major processes include:

Figure 103: Steps on Carbon Capture and Storage ("CCS")



Source: Deutsche Bank

- **CO_2 capture**

CO_2 from the coal gasifier is compressed, de-sulfurised, de-hydrated, distillated and refrigerated. Refrigerated (cryogenic) liquid CO_2 is then trucked to temporary (above ground) storage units and thereafter trucked / pumped into long-term underground storage areas.

- **CO_2 storage**

Cryogenic liquid CO_2 is transported by trucks to storage site, where CO_2 is unloaded to a buffer tank for temporary storage. When the amount of CO_2 inside buffer tank reaches certain level, the storage pump will inject cryogenic liquid CO_2 into injection well for storage.

According to Xinhua (the state news agency of China):

1) Current CCS cost in China is c.280 Rmb / ton CO_2 (c.45 USD / ton). This amount includes depreciation charge, staff and utilities cost. CO_2 capture and storage costs are 200 Rmb / ton CO_2 and 80 Rmb / ton CO_2 respectively.

2) Shenhua Group estimated that the CCS cost can be lowered from to 25 USD / ton from 45 USD / ton if CCS is implemented in large scale.

3) Shenhua Group also stated that liquid CO_2 will be transported by pipelines instead of trucks in the future (no exact time schedule is provided) so that the cost can be further reduced.

Emission from Syngas production process

Figure 104: Emission at Syngas production stage

Emission Source	Emission details	Control Procedures
Coal pre-treatment		
Storage, handling and crushing	Consist of coal dust at transfer points esp those exposed to wind erosion. Significant source	Water sprays and polymer coatings can be installed at storage site. Water sprays and enclosures vented to baghouses can be installed at crushing
Drying	Consist of coal dust, combustion products from heater and organics volatilized from coal. Significant source	Electrostatic precipitators and baghouse can be installed for dust control. Low drying temperature can reduce organics formation
Coal Gasification		
Feeding - Vent gas	The gas exiting coal gasifier may contain hazardous species such as Hydrogen Sulfide, Sulfur Oxides, Ammonia, Methane, tars and particulates. The size and composition depends on the type of gasifiers	May implement desulfurization for Sulfur Dioxide control. Combustion modifications can be used for reducing particulates, Carbon Monoxide, Nitrogen Oxides and hydrocarbons
Ash dust	Ash dust may be released from all gasifiers that are not slagging or agglomerating ash units	The emissions have not been sufficiently characterized to recommend necessary controls

Source: U.S. Energy Information Administration, Deutsche Bank

Listed companies / DB rating as mentioned in FITT report

Air Liquide SA (AI FP; Buy), through its subsidiaries, produces, markets, and sells industrial and healthcare gases worldwide. These gases include liquid nitrogen, argon, carbon dioxide, and oxygen. The Company also produces welding equipment, diving equipment, and technical-medical equipment. Air Liquide sells its products throughout Europe, the United States, Canada, Africa, and Asia.

Air Products and Chemicals, Inc. (APD UN; Buy) produces industrial atmospheric and specialty gases, and performance materials and equipment. The Company's products include oxygen, nitrogen, argon, helium, specialty surfactants and amines, polyurethane, epoxy curatives and resins. Air Products and Chemicals, Inc. products are used in the beverage, health and semiconductors fields.

China BlueChemical Ltd. (3983 HK) manufactures nitrogen fertilizers. The Company produces ammonia and urea.

China Coal Energy Company Ltd (1898 HK; Hold) mines and markets thermal coal and coking coal. The Company also manufactures coal mining equipment and offers coal mine design services.

China Energy Ltd. (CEGY SP) produces Dimethyl Ether (DME) and Methanol. The Company sells to fuel distributors, chemical producers, and traders.

China Petroleum and Chemical Corporation (386 HK) refines, produces and trades petroleum and petrochemical products such as gasoline, diesel, jet fuel, kerosene, ethylene, synthetic fibers, synthetic rubber, synthetic resins, and chemical fertilizers. Also, The company explores for and produces crude oil and natural gas in China.

China Sanjiang Fine Chemicals Co Ltd. (2198 HK) manufactures and supplies consumer chemicals and their ingredients. The Company's main product is ethylene oxide and AEO surfactants which are the core components for household cleansing and cosmetic products.

China Shenhua Energy Company Limited (1088 HK; Buy) is an integrated coal-based energy company focusing on the coal and power businesses in China. The Company also owns and operates an integrated coal transportation network consisting of dedicated rail lines and port facilities.

CNOOC Limited (883 HK; Hold), through its subsidiaries, explores, develops, produces and sells crude oil and natural gas. The Group's core operation areas are Bohai, Western South China Sea, Eastern South China Sea and East China Sea in offshore China. Internationally, the Group has oil and gas assets in Asia, Africa, North America, South America and Oceania.

Datang International Power Generation Company Limited (991 HK; Buy) develops and operates power plants, sells electricity, repairs and maintains power equipment, and provides power-related technical services.

Dongfang Electric Corporation Limited (1072 HK; Buy) manufactures and sells hydro and steam power generators and AC/DC electric motors. The Company also provides repair, upgrade, maintenance, and other services.

GD Power Development Co., Ltd. (600795 CH) generates and distributes electric power and heat throughout China. The Company also invests in new energy development and environmental protection projects.

General Electric Company (GE US; Buy) is a globally diversified technology and financial services company. The Company's products and services include aircraft engines, power generation, water processing, and household appliances to medical imaging, business and consumer financing and industrial products.

Guanghui Energy Co., Ltd. (600256 CH) is principally engaged in energy development, automotive services and real estate property leasing. The Company is in the business of coal mining and related coal chemical manufacturing. The Company is also engaged in the processing and distributing of granite materials and trading of general merchandise such as plastic doors and windows.

Hangzhou Hangyang Co., Ltd. (002430 CH) manufactures and sells air separation equipment, industrial gas products and petrochemical equipment. The Company's products are medium & large sets of air separation equipment, small-scale air separation equipment, liquefied nitrogen wash cold box, liquefied natural gas separation equipment, and liquefied petroleum gas storage & distribution devices.

Inner Mongolia Yitai Coal Co., Ltd. (900948 CH) operates in coal mining, processing, and distribution. Through its subsidiaries, the Company also operates in hotel management, licorice planting, pharmaceutical manufacturing, and manages roadways.

Inner Mongolia Yuan Xing Energy Co., Ltd. (000683 CH) manufactures and markets natural alkali chemicals. The Company's products include methanol, dimethyl formamide, synthetic ammonia, urea, formaldehyde, dimethyl ether, soda ash, bicarbonate, and other related chemicals.

Jiangsu SOPO Chemical Co., Ltd. (600746 CH) manufactures baking soda, caustic soda, and bleach products. The Company, through its subsidiaries, distributes electricity and supplies steam.

Johnson Matthey PLC (JMAT LN; Buy) is a specialty chemicals company which manufactures catalysts, pharmaceutical materials, and pollution control systems. The Company also refines platinum, gold and silver, and produces color and coating materials for the glass, ceramics, tile, plastics, paint, ink, and construction industries. Johnson Matthey has operations around the world.

KBR, Inc. (KBR US) is a global engineering, construction, and services company supporting the energy, petrochemicals, government services, and civil infrastructure sectors. The Company offers a wide range of services through two business segments, Energy and Chemicals (E&C) and Government and Infrastructure (G&I).

Kingboard Chemical Holdings Limited (148 HK), through its subsidiaries, manufactures laminates, copper foil, glass fabric, glass yarn, bleached kraft paper, printed circuit boards, and chemicals.

LCY Chemical Corporation (1704 TT) manufactures chemicals. The Company produces formaldehyde, acetaldehyde, ethyl acetate, methanol, acetone, methyl isobutyl ketone, liquefied petroleum gas and synthetic resins.

Linde AG (LIN GY; Buy) is a gases and engineering company. The Gases Division offers a wide range of industrial and medical gases mainly used in energy sector, steel production, chemical processing, as well as in food processing. The Engineering Division develops olefin plants, natural gas plants and air separation plants, as well as hydrogen and synthesis gas plants.

Methanex Corporation (MX CN) produces and markets methanol. The methanol is used to make industrial and consumer products including windshield washer fluid, plywood floors, paint, sealants and synthetic fibers.

Methanol Chemicals Co (CHEMANOL AB) produces methanol derivatives. The Company's products include aqueous and urea formaldehydes, formaldehyde derivatives, super plasticizers and various amino resins.

Mitsubishi Corporation (8058 JP) is a general trading company. The Company has business groups such as New Business Initiatives, IT & Electronics, Fuels, Metals, Machinery, Chemicals, Living Essentials, and Professional Services. Mitsubishi diversifies by satellite communications through a joint venture.

MITSUBISHI GAS CHEMICAL COMPANY, INC. (4182 JP) produces chemical products such as xylene and methanol. The Company also manufactures engineering plastics and specialty chemicals.

MITSUI & CO., LTD. (8031 JP) is a general trading company. The Company has operating groups including Iron and Steel, Non-Ferrous Metals, Machinery, Chemicals, Foods, Energy, Textiles, and General Merchandise. Mitsui also operates real estate and overseas development projects.

Nylex (Malaysia) Berhad (NYL MK) manufactures and sells vinyl-coated fabrics, calendared film and sheeting, and other plastic products such as geotextiles and prefabricated sub-soil drainage systems. The Company, through its subsidiaries, manufactures electrical engineering products, roofing products, glass wool insulation products, bulk containers, and golf bags.

PetroChina Company Limited (857 HK; Buy) explores, develops, and produces crude oil and natural gas. The Company also refines, transports, and distributes crude oil, petroleum products, chemicals, and natural gas.

Petronas Chemicals Group Bhd. (PCHEM MK; Hold) produces a diversified range of petrochemical products such as olefins, polymers, fertilizers, methanol, and other basic chemicals and derivative products.

Praxair, Inc. (PX UN; Buy) supplies gas to industries primarily located in North and South America. The Company produces, sells, and distributes atmospheric gases including oxygen, nitrogen, argon, and rare gases, as well as process gases including carbon dioxide, helium, hydrogen, electronics gases, and acetylene. Praxair also supplies metallic and ceramic coatings and powders.

PTT Global Chemical PCL (PTTGC TB; Hold) is a fully integrated petrochemical and chemical company. The Company's products are derived from its main product, Olefins, namely ethylene and propylene.

Royal Dutch Shell PLC (RDSA LN; Hold), through subsidiaries, explores for, produces, and refines petroleum. The Company produces fuels, chemicals, and lubricants. Shell owns and operates gasoline filling stations worldwide.

Saudi Basic Industries Corporation (SABIC AB; Buy) manufactures chemicals and steel. The Company produces methanol, ethylene, propylene, benzene, toluene, xylene, industrial gases, thermoplastic resins, polyester, melamine, urea fertilizers, and long and flat hot and cold rolled steel products.

Saudi International Petrochemical Co (SIPCHEM AB) is a petrochemical company. The Company produces methanol and butanediol.

Shenergy Company Limited (600642 CH) develops, constructs, and invests in electric power and other energy related projects. The Company distributes electric power, heat, and gas.

Siemens AG (SIE GY, Buy) is an engineering and manufacturing company. The Company focuses on four major business sectors including infrastructure and cities, healthcare, industry and energy. Siemens AG also provides engineering solutions in automation and control, power, transportation, and medical.

Sinopec Engineering (Group) Co., Ltd. (2386 HK; Buy) provides petrochemical engineering and construction services.

Sojitz Corporation (2768 JP) is a trading company. The Company has business divisions such as Machinery & Aerospace, Energy & Mineral Resources, Chemicals & Plastics, Real Estate Development & Forest Products, Consumer Lifestyle Business, and New Business Development Group. Sojitz was formed through the integration of Nichimen and Nissho Iwai.

The Dow Chemical Company (DOW UN; Hold) is a diversified chemical company that provides chemical, plastic, and agricultural products and services to various essential consumer markets. The Company serves customers in countries around the world in markets such as food, transportation, health and medicine, personal care, and construction.

Wison Engineering Services Co Ltd (2236 HK) is a chemical engineering, procurement and construction management (or EPC) service provider in China.

Yangquan Coal Industry Group Co Ltd. (600348 CH) produces, processes, and sells coal. The Company also generates electricity and heat. Yangquan Coal sells its products domestically and exports to other countries.

Yingde Gases Group Co., Ltd. (2168 HK; Buy) manufactures industrial gases. The Company produces and delivers oxygen, nitrogen, argon, hydrogen, and other gases to its customers throughout China.

APPENDIX 1: China's Coal-to-Olefins (CTO) projects in China

Project	Company Name	Location	Output (mln tpa)	Status	Coal consumption (mln tpa)	Est delivery date	Capex (RMBbn)
Producing:							
Shenhua Baotou coal-to-olefin (D-MTO) project phase I	Shenhua (1088 HK) : 100%	Inner Mongolia	0.60	In operation	4.6	2011	16
			0.60				
NDRC Approved:							
China Coal coal-to-olefin project	China Coal Group : 100%	Shaanxi	0.60	Received NDRC approval		2016/2017	NA
Sinopec Zhong Tian He Chuang coal-to-olefin project	Sinopec (386 HK) : 38.75%; China Coal Energy (1898 HK) : 38.75%; Shanghai Shenergy (600642 CH) : 12.5%; Inner Mongolia Manshi Coal Group : 10%	Inner Mongolia	1.20	Received NDRC approval		2016	NA
Huahong Huijin coal-to-olefin project	Huahong Huijin Corp : 100%	Gansu	0.60	Received NDRC approval		2016/2017	NA
			2.40				
Possible Projects							
CPI Western Inner Mongolia coal-to-olefin project	Chian Power Investment Corporation : 100%	Inner Mongolia	0.80	Preliminary work	4.7	2017	NA
Guodian Pingmei Nileke olefin project	Guodian(600795 CH), Pingzhuang Coal, Nileke NOTE 1	Xinjiang	0.60	Preliminary work	3.5	NA	NA
Fanhai Group coal-to-olefin project	Fanhai Group : 100%	Inner Mongolia	1.20	Preliminary work	7.9	NA	NA
Zhejiang Tiansheng Group coal-to-olefin project	Zhejiang Tiansheng Holding Group : 100%	Inner Mongolia	0.60	Preliminary work	3.5	NA	NA
Xinweng Xinjiang Yinan coal-to-olefin project	Xinwen Mining Co : 100%	Xinjiang	0.60	Preliminary work	3.5	NA	NA
Qinghua coal-to-olefin project	Qinghua Group : 100%	Xinjiang	2.00	Preliminary work	11.8	NA	NA
Chizhou coal-to-olefin project	NOTE 2	Anhui	0.60	Preliminary work	3.5	NA	NA
Panjiang coal-to-olefin project	Panjiang Group : 100%	Guizhou	0.60	Preliminary work	3.5	NA	NA
Shenhua coal-to-olefin (DMTO) project phase II	Shenhua Group : 100%	Inner Mongolia	0.70	Preliminary work		NA	NA
Shenhua/Dow coal-to-olefin project	Shenhua Group : 100%	Shaanxi	1.20	Preliminary work		2016	NA
			10.10				
	Total (Producing + NDRC Approved + Possible Projects)		13.10				

NOTES
1) No information on shareholding structure has been disclosed
2) No information on project owner(s) has been disclosed

Source: Asiachem, ICIS, NDRC, Company specific websites, Deutsche Bank

APPENDIX 2: China's Methanol-to-Olefins (MTO) projects:

Project	Company Name	Location	Output (mln tpa)	Status	Methanol consumption (mln tpa)	Est delivery date	Capex (RMBbn)
Producing:							
Shenhua Ningxia MTP project (Phase I)	Shenhua Group : 51% Ningxia provincial government : 49%	Ningxia	0.50	In operation	1.50	2010	17.0
Datang Duolun MTP project	Datang International Power (991 HK) : 60% China Datang Group : 40%	Inner Mongolia	0.46	In operation	1.38	2011	NA
Sinopec Zhongyuan S-MTO project	Sinopec (386 HK) : 93.51% Henan provincial government : 6.49%	Henan	0.20	In operation	0.60	2011	NA
Ningbo Heyuan MTO project	Ningbo Heyuan Chemical : 100%	Zhejiang	0.60	In operation	1.80	2013	NA
			1.76				
NDRC Approved:							
Wison MTO project	Wison (2236 HK) : 100%	Nanjin	0.30	Trial Operation	0.90	2014	NA
Gansu Huating olefin MTP project	Gansu Huating : 100%	Gansu	0.20	Approved by NDRC	0.60	2014	NA
Zhejiang XingXing MTO project	Sanjiang Fine Chemical (2198 HK) : 75% Zhejiang Xingxing : 25%	Zhejiang	0.60	Approved by NDRC	2.07	2014	NA
Shandong Yangmei Hengtong MTO project	Yangquan Coal Mining (600348 CH) : 100%	Linyi	0.30	Approved by NDRC	0.89	2014	NA
China Coal Mengda MTO project	China Coal Energy (1898 HK) : 75% Yuanxing Energy (000683 CH) : 25%	Inner Mongolia	0.60	Approved by NDRC	1.80	2015	NA
Gansu Huijin MTO project	Huahing Huijin : 100%	Gansu	0.70	Approved by NDRC	2.10	NA	NA
Xuzhou Haitian MTP project	Xuzhou Haitian Chemicals : 100%	Jiangsu	0.60	Approved by NDRC	1.80	NA	NA
Sinopec Guizhou S-MTO project	Sinopec (386 HK): 50%; remaining parties : 50%	Guizhou	0.60	Approved by NDRC	1.80	NA	NA
Sinopec Henan S-MTO project	Sinopec (386 HK): 50%; remaining parties : 50%	Henan	0.60	Approved by NDRC	1.80	NA	NA
Sinopec Anhui S-MTO project	Sinopec (386 HK): 50%; remaining parties : 50%	Anhui	0.60	Approved by NDRC	1.80	NA	NA
			4.50				
Possible projects							
Shanxi Coking MTO project	Shanxi Coking Co Ltd (600740 CH) : 100%	Shanxi	0.60	Preliminary work	1.80	2014	NA
Jiutai MTO project	Jiutai Group : 100%	Inner Mongolia	0.60	Preliminary work	1.80	2014	NA
Qinghai Damei Coal MTO project	Western Mining : 100%	Xining	0.60	Preliminary work	1.80	2016	NA
Shenhua Ningxia MTP project (Phase II)	Shenhua Group : 51% Ningxia provincial government : 49%	Ningxia	0.50	Preliminary work	1.50	NA	NA
Guanghui MTO project	Guanghui Group (600256 CH) : 100%	Xinjiang	1.00	Project has been suspended	3.00	2015	NA
			3.30				
	Total (Producing + NDRC Approved + Possible Projects)		9.56				

Source: Asiachem, ICIS, NDRC, company website, Deutsche Bank

APPENDIX 3: China's Coal-to-syngas projects

Project	Company Name	Location	Output (bcm)	Status	Coal consumption (mln tpa)	Est delivery date	Capex (RMBbn)
Producing:							
Qinghua coal-to-gas project phase I	Xinjiang Qinghua	Xinjiang	1.38	In operation		2013	9
Datang coal-to-gas project	Datang (991 HK)	Inner Mongolia	4.00	NDRC's preliminary approval	12.0	2014	23
			5.38				
NDRC Preliminary Approval:							
Qinghua coal-to-gas project phase II/III	Xinjiang Qinghua	Xinjiang	4.13	NDRC's preliminary approval		2014-17	19
Datang coal-to-gas project	Datang (991 HK)	Liaoning	4.00	NDRC's preliminary approval		2014	25
Huineng coal-to-gas project	Huineng	Inner Mongolia	1.60	NDRC's preliminary approval		NA	30
CPI coal-to-gas project	CPI	Xinjiang	6.00	NDRC's preliminary approval		2017/18	48
Shandong Xinwen coal-to-gas project	Shandong Xinwen Mining Corp	Xinjiang	4.00	NDRC's preliminary approval		2017/18	27
Guodian coal-to-gas project	Guodian (600795 CH)	Inner Montolia	4.00	NDRC's preliminary approval		2017/18	33
CNOOC coal-to-gas project	CNOOC Group	Shanxi	4.00	NDRC's preliminary approval	15.0	2017/18	25
Inner Mongolia Xinmeng Energy coal-to-gas project	Xinmeng Energy Corp	Inner Mongolia	4.00	NDRC's preliminary approval		2017/18	24
Beijing Enterprise coal-to-gas project	Beijing Enterprise (392 HK)	Inner Mongolia	4.00	NDRC's preliminary approval		2017/18	27
Hebei Construction Inv. coal-to-gas project	Hebei Construction Investment	Inner Mongolia	4.00	NDRC's preliminary approval		2017/18	27
CNOOC New Energy coal-to-gas project	CNOOC Group	Inner Mongolia	4.00	NDRC's preliminary approval		2017/18	27
Xinjiang Zhundong Coal Ingegrated project	Sinopec Group, Huaneng, Guanghui (600256 CH)	Xinjiang	30.00	NDRC's preliminary approval		2017/18	183
			73.73				
Possible projects							
Wanneng Guotou Xinji coal-to-gas project	Wanneng Group, Guotou Xinji	Anhui	4.00	Under construction	13.0	NA	NA
Huadian coal-to-gas project	Huadian Group	Inner Mongolia	4.00	Preliminary work	13.0	NA	NA
Huadian Xinjiang coal-to-gas project	Huadian Xinjiang Elec. Co Ltd	Xinjiang	6.00	Preliminary work	19.5	NA	NA
Guodian Pingmei Nileke coal-to-gas project	Guodian (600795 CH), Pingzhuang Coal, Nileke	Xinjiang	4.00	Preliminary work	13.0	NA	NA
CPI coal-to-gas project	China Power Investment	Xinjiang	6.00	Preliminary work	19.5	NA	NA
Shenhua coal-to-gas project	Shenhua Group	Inner Mongolia	2.00	Preliminary work	7.5	NA	14
China Coal coal-to-gas project	China Coal Group (1898 HK)	Inner Mongolia	2.00	Preliminary work	6.5	NA	NA
China Coal Xinjiang coal-to-gas project	China Coal Xinjiang Co Ltd	Xinjiang	4.00	Preliminary work	13.0	NA	NA
Yankuang Xinjiang Nenghua coal-to-gas project	Yankuang Xinjiang Nenghua Co Ltd	Xinjiang	4.00	Preliminary work	13.0	NA	NA
Kailuan Energy coal-to-gas project	Kailuan Energy Inv. Corp	Xinjiang	4.00	Preliminary work	13.0	NA	NA
Changji Shengxin coal-to-gas project	Changji Shengxin Co Ltd	Xinjiang	1.60	Preliminary work	5.2	NA	NA
Tebian Elec Xinjiang Energy Huaidong coal-to-gas	Tebian Diangong Xinjiang Energy	Xinjiang	4.00	Preliminary work	13.0	NA	NA
Xinjiang Huahong Mining coal-to-gas project	Xinjiang Huahong Mining	Xinjiang	2.00	Preliminary work	6.5	NA	NA
Xukuang Xinjiang coal-to-gas project	Xukuang Xinjiang Corp	Xinjiang	4.00	Preliminary work	13.0	NA	NA
Hami Ziguang Mining coal-to-gas project	Hami Ziguang Corp	Xinjiang	0.80	Preliminary work	2.6	NA	NA
Lu'an Xinjiang coal-to-gas project	Lu'an Xinjiang Coal Chemicals	Xinjiang	4.00	Preliminary work	13.0	NA	NA
Shendong Tianlong coal-to-gas project	Shendong Tianlong Group Co Ltd	Xinjiang	1.30	Preliminary work	4.2	NA	NA
Sinopec Guizhou coal-to-gas project	Sinopec Guizhou	Guizhou	4.00	Preliminary work	13.0	NA	NA
			61.70				
	Total (Producing + NDRC Approved + Possible Projects)		140.80				

Source: Asiachem, ICIS, NDRC, company website , Deutsche Bank

APPENDIX 4: Global Methanol capacity – Part 1

(Thousand tons)	2008	2009	2010	2011	2012	2013	2014e	2015e	2016e	2017e	2018e
NORTH AMERICA											
Canada	----	----	----	313	470	495	560	560	560	1,310	1,310
Mexico	180	180	180	180	180	180	180	180	180	180	180
United States	980	980	980	860	1,235	1,675	2,584	3,795	7,230	12,370	12,370
Total - North America	**1,160**	**1,160**	**1,160**	**1,353**	**1,885**	**2,350**	**3,324**	**4,535**	**7,970**	**13,860**	**13,860**
Natural Gas	965	965	965	1,158	1,690	2,155	3,129	4,340	7,775	12,385	12,385
Coal	195	195	195	195	195	195	195	195	195	195	195
Petcoke	----	----	----	----	----	----	----	----	----	1,280	1,280
	1,160	**1,160**	**1,160**	**1,353**	**1,885**	**2,350**	**3,324**	**4,535**	**7,970**	**13,860**	**13,860**
SOUTH AMERICA											
Argentina	450	450	450	450	450	450	450	450	450	450	450
Brazil	303	303	303	303	303	353	353	353	353	1,074	1,074
Chile	2,918	2,918	2,078	1,088	1,088	1,088	840	840	840	840	840
Trinidad	6,650	6,650	6,722	6,722	6,722	6,722	6,722	6,722	6,722	7,472	7,722
Venezuela	1,540	1,700	2,050	2,550	2,550	2,550	2,550	2,550	2,550	2,550	2,550
Total - South America	**11,861**	**12,021**	**11,603**	**11,113**	**11,113**	**11,163**	**10,915**	**10,915**	**10,915**	**12,386**	**12,636**
Natural gas	11,861	12,021	11,603	11,113	11,113	11,163	10,915	10,915	10,915	12,386	12,636
	11,861	**12,021**	**11,603**	**11,113**	**11,113**	**11,163**	**10,915**	**10,915**	**10,915**	**12,386**	**12,636**
WEST EUROPE											
Germany	1,805	1,805	1,675	1,675	1,675	1,675	1,675	1,675	1,675	1,675	1,675
Netherlands	500	365	400	500	500	500	500	500	500	500	500
Norway	900	900	900	900	900	900	900	900	900	900	900
Total - West Europe	**3,205**	**3,070**	**2,975**	**3,075**	**3,075**	**3,075**	**3,075**	**3,075**	**3,075**	**3,075**	**3,075**
Natural gas	1,860	1,560	1,430	1,430	1,430	1,430	1,430	1,430	1,430	1,430	1,430
Heavy liquids	1,345	1,345	1,345	1,345	1,345	1,345	1,345	1,345	1,345	1,345	1,345
Bio-feedstock	----	165	200	300	300	300	300	300	300	300	300
	3,205	**3,070**	**2,975**	**3,075**	**3,075**	**3,075**	**3,075**	**3,075**	**3,075**	**3,075**	**3,075**
CENTRAL EUROPE											
Former Yugoslavia	365	365	365	200	200	200	200	200	200	200	200
Romania	440	440	440	200	200	200	200	200	200	200	200
Total - Central Europe	**805**	**805**	**805**	**400**	**400**	**400**	**400**	**400**	**400**	**400**	**400**
Natural gas	805	805	805	400	400	400	400	400	400	400	400
	805	**805**	**805**	**400**	**400**	**400**	**400**	**400**	**400**	**400**	**400**
CIS & BALTIC STATES											
Other CIS & Baltic States	376	376	302	302	302	302	862	862	862	862	862
Russia	3,888	3,728	3,768	3,878	3,858	3,858	3,908	3,958	4,008	4,188	6,368
Total - CIS & Baltic States	**4,264**	**4,104**	**4,070**	**4,180**	**4,160**	**4,160**	**4,770**	**4,820**	**4,870**	**5,050**	**7,230**
Natural gas	4,179	4,019	3,985	4,095	4,075	4,075	4,685	4,735	4,785	4,965	7,145
Heavy oil	85	85	85	85	85	85	85	85	85	85	85
	4,264	**4,104**	**4,070**	**4,180**	**4,160**	**4,160**	**4,770**	**4,820**	**4,870**	**5,050**	**7,230**

Source: IHS; Deutsche Bank

APPENDIX 5: Global methanol capacity – Part 2

(Thousand tons)	2008	2009	2010	2011	2012	2013	2014e	2015e	2016e	2017e	2018e
MIDDLE EAST											
Bahrain	425	425	450	450	450	450	450	450	450	450	450
Iran	3,394	4,244	5,044	5,044	5,044	5,044	5,044	5,044	5,044	5,044	5,044
Israel	----	----	----	----	----	----	----	----	----	----	----
Oman	1,050	1,050	1,700	2,350	2,350	2,350	2,350	2,350	2,350	2,350	2,350
Qatar	990	990	990	990	990	990	1,030	1,070	1,070	1,070	1,070
Saudi Arabia	6,200	7,180	7,280	7,280	7,280	7,280	7,280	7,280	7,280	7,280	7,280
Total - Middle East	**12,059**	**13,889**	**15,464**	**16,114**	**16,114**	**16,114**	**16,154**	**16,194**	**16,194**	**16,194**	**16,194**
Natural gas	12,059	13,889	15,464	16,114	16,114	16,114	16,154	16,194	16,194	16,194	16,194
Heavy oil	----	----	----	----	----	----	----	----	----	----	----
	12,059	**13,889**	**15,464**	**16,114**	**16,114**	**16,114**	**16,154**	**16,194**	**16,194**	**16,194**	**16,194**
AFRICA											
Algeria	110	110	110	110	110	110	110	110	110	110	110
Egypt	24	----	----	945	1,260	1,260	1,260	1,260	1,260	1,260	1,260
Libya	660	660	660	660	660	660	660	660	660	660	660
Nigeria	----	----	----	----	----	----	----	----	----	----	450
Other Africa	1,150	1,150	1,150	1,150	1,150	1,150	1,150	1,150	1,150	1,150	1,650
South Africa	140	140	140	140	140	140	140	140	140	140	140
Total - Africa	**2,084**	**2,060**	**2,060**	**3,005**	**3,320**	**3,320**	**3,320**	**3,320**	**3,320**	**3,320**	**4,270**
Natural gas	2,084	2,060	2,060	3,005	3,320	3,320	3,320	3,320	3,320	3,320	4,270
	2,084	**2,060**	**2,060**	**3,005**	**3,320**	**3,320**	**3,320**	**3,320**	**3,320**	**3,320**	**4,270**
INDIAN SUBCONTINENT											
India	**416**	**502**	**502**	**502**	**502**	**597**	**667**	**667**	**832**	**832**	**832**
Natural gas	416	502	502	502	502	597	667	667	832	832	832
NORTHEAST ASIA											
China	**20,019**	**26,357**	**33,039**	**37,925**	**42,419**	**49,389**	**54,634**	**58,959**	**58,959**	**58,959**	**58,959**
Natural gas	5,832	6,568	7,535	8,380	9,740	10,900	10,900	11,700	11,700	11,700	11,700
Heavy oil	120	120	120	250	250	250	250	250	250	250	250
Coal	12,037	15,963	19,809	23,109	25,159	29,859	34,829	37,079	37,079	37,079	37,079
Coking gas	2,030	3,706	5,575	6,186	7,270	8,380	8,655	9,930	9,930	9,930	9,930
	20,019	**26,357**	**33,039**	**37,925**	**42,419**	**49,389**	**54,634**	**58,959**	**58,959**	**58,959**	**58,959**
SOUTHEAST ASIA											
Australia	100	100	100	100	100	100	100	100	100	100	100
Indonesia	1,040	760	710	710	710	710	710	710	710	710	710
Malaysia	920	2,520	2,520	2,520	2,520	2,520	2,520	2,520	2,520	2,520	2,520
Myanmar	150	150	150	150	150	150	150	150	150	150	150
New Zealand	611	850	850	850	1,175	1,717	2,200	2,200	2,200	2,200	2,200
Other Southeast Asia	----	----	600	850	850	850	850	850	850	850	850
Total - SE Asia	**2,821**	**4,380**	**4,930**	**5,180**	**5,505**	**6,047**	**6,530**	**6,530**	**6,530**	**6,530**	**6,530**
Natural gas	2,821	4,380	4,930	5,180	5,505	6,047	6,530	6,530	6,530	6,530	6,530
	2,821	**4,380**	**4,930**	**5,180**	**5,505**	**6,047**	**6,530**	**6,530**	**6,530**	**6,530**	**6,530**
WORLD											
Natural gas	42,882	46,769	49,279	51,377	53,889	56,201	58,130	60,231	63,881	70,142	73,522
Heavy oil	1,550	1,550	1,550	1,680	1,680	1,680	1,680	1,680	1,680	1,680	1,680
Coal	12,232	16,158	20,004	23,304	25,354	30,054	35,024	37,274	37,274	37,274	37,274
Coking gas	2,030	3,706	5,575	6,186	7,270	8,380	8,655	9,930	9,930	9,930	9,930
Bio-feedstock	----	165	200	300	300	300	300	300	300	300	300
Petcoke	----	----	----	----	----	----	----	----	----	1,280	1,280
TOTAL - World	**58,694**	**68,348**	**76,608**	**82,847**	**88,493**	**96,615**	**103,789**	**109,415**	**113,065**	**120,606**	**123,986**

Source: IHS; Deutsche Bank

APPENDIX 6: Global ethylene capacity – Part 1

Unit: Thousand tons	2008	2009	2010	2011	2012	2013	2014e	2015e	2016e	2017e	2018e
NORTH AMERICA											
Canada	5,138	5,048	5,048	5,048	5,048	5,048	5,048	5,048	5,048	5,216	5,216
Mexico	1,382	1,382	1,382	1,382	1,382	1,382	1,382	1,632	2,382	2,382	2,382
United States	28,615	27,005	26,555	26,934	26,958	27,579	28,292	29,288	29,380	32,255	35,118
TOTAL - North America	35,135	33,435	32,985	33,364	33,388	34,009	34,722	35,968	36,810	39,853	42,716
Ethane	8,191	8,191	8,191	8,191	8,191	8,205	8,235	8,565	9,315	12,190	15,053
Ethane/Propane	5,329	4,498	4,337	4,580	4,580	5,012	5,141	5,270	5,270	5,270	5,270
EPB (Ethane,Propane,Butane)	1,689	1,609	1,578	1,714	1,726	1,726	1,726	1,766	1,808	1,808	1,808
EPB/Naphtha	10,216	10,248	10,248	10,248	10,490	11,355	11,909	12,179	12,229	12,229	12,229
Naphtha	907	920	920	920	690	----	----	----	----	----	----
EPB/Naphtha/Gas Oil/Residues	7,914	7,536	7,518	7,518	7,518	7,518	7,518	7,995	7,995	8,163	8,163
Naphtha/Gas Oil/Residues	544	136	----	----	----	----	----	----	----	----	----
Recovery from FCC/DCC Unit	345	297	193	193	193	193	193	193	193	193	193
	35,135	33,435	32,985	33,364	33,388	34,009	34,722	35,968	36,810	39,853	42,716
SOUTH AMERICA											
Argentina	752	752	752	752	752	752	752	752	752	752	752
Brazil	3,657	3,770	3,820	3,970	3,970	3,970	3,970	3,970	3,970	3,970	3,970
Chile	49	49	49	49	49	49	49	49	49	49	49
Colombia	100	100	100	100	100	100	100	100	100	100	100
Venezuela	600	600	600	600	600	600	600	600	600	600	600
TOTAL - South America	**5,158**	**5,271**	**5,321**	**5,471**	**5,471**	**5,471**	**5,471**	**5,471**	**5,471**	**5,471**	**5,471**
Ethane	700	700	700	700	700	700	700	700	700	700	700
Ethane/Propane	1,140	1,140	1,140	1,140	1,140	1,140	1,140	1,140	1,140	1,140	1,140
EPB (Ethane,Propane,Butane)	30	30	30	30	30	30	30	30	30	30	30
EPB/Naphtha	71	71	71	71	71	71	71	71	71	71	71
Naphtha	3,050	3,097	3,097	3,097	3,097	3,097	3,097	3,097	3,097	3,097	3,097
Ethanol Dehydration	----	----	50	200	200	200	200	200	200	200	200
Recovery from FCC/DCC Unit	167	233	233	233	233	233	233	233	233	233	233
	5,158	**5,271**	**5,321**	**5,471**	**5,471**	**5,471**	**5,471**	**5,471**	**5,471**	**5,471**	**5,471**

Source: IHS; Deutsche Bank

APPENDIX 7: Global ethylene capacity – Part 2

	2008	2009	2010	2011	2012	2013	2014e	2015e	2016e	2017e	2018e
WEST EUROPE											
Austria	500	500	500	500	500	500	500	500	500	500	500
Belgium	2,460	2,460	2,460	2,460	2,460	2,326	2,230	2,230	2,230	2,230	2,230
Finland	380	380	380	380	380	380	380	380	380	380	380
France	3,320	3,080	3,080	3,080	3,080	3,080	3,080	2,995	2,740	2,740	2,740
Germany	5,818	5,943	5,943	5,878	5,683	5,683	5,683	5,683	5,683	5,683	5,683
Italy	2,048	1,925	1,925	1,800	1,675	1,601	1,380	1,380	1,380	1,380	1,380
Netherlands	3,975	3,975	3,975	3,975	3,975	3,975	3,975	3,975	3,975	3,975	3,975
Norway	575	575	575	575	575	575	575	575	575	575	575
Portugal	410	410	410	410	410	410	410	410	410	410	410
Spain	1,560	1,560	1,601	1,622	1,622	1,622	1,622	1,622	1,622	1,622	1,622
Sweden	610	610	610	610	610	610	610	610	610	610	610
Switzerland	30	30	30	30	30	30	30	30	30	30	30
United Kingdom	2,920	2,920	2,880	2,800	2,800	2,800	2,528	2,470	2,470	2,470	2,470
TOTAL - West Europe	**24,606**	**24,368**	**24,369**	**24,120**	**23,800**	**23,592**	**23,003**	**22,860**	**22,605**	**22,605**	**22,605**
Ethane	830	830	830	830	830	830	830	830	830	830	830
EPB (Ethane,Propane,Butane)	1,915	1,915	1,915	1,915	1,915	1,915	1,915	1,915	1,915	1,915	1,915
EPB/Naphtha	9,716	9,718	9,718	9,718	9,718	9,584	9,216	9,158	9,158	9,158	9,158
Naphtha	6,375	6,135	6,135	6,135	6,135	6,135	6,135	6,050	5,795	5,795	5,795
EPB/Naphtha/Gas Oil/Residues	3,550	3,550	3,551	3,492	3,492	3,492	3,492	3,492	3,492	3,492	3,492
Naphtha/Gas Oil/Residues	2,175	2,175	2,175	1,985	1,665	1,591	1,370	1,370	1,370	1,370	1,370
Recovery from FCC/DCC Unit	45	45	45	45	45	45	45	45	45	45	45
	24,606	**24,368**	**24,369**	**24,120**	**23,800**	**23,592**	**23,003**	**22,860**	**22,605**	**22,605**	**22,605**
CENTRAL EUROPE											
Bulgaria	150	150	----	----	----	----	----	----	----	----	----
Czech Republic & Slovakia	764	764	764	764	764	764	764	764	764	764	764
Former Yugoslavia	290	290	290	290	200	200	200	200	200	200	200
Hungary	620	660	660	660	660	660	660	660	660	660	660
Poland	700	700	700	700	700	700	700	700	700	700	700
Romania	200	----	----	----	----	----	----	----	----	----	----
TOTAL - Central Europe	**2,724**	**2,564**	**2,414**	**2,414**	**2,324**	**2,324**	**2,324**	**2,324**	**2,324**	**2,324**	**2,324**
Ethane	90	90	90	90	----	----	----	----	----	----	----
EPB/Naphtha	----	----	----	----	----	----	----	----	----	----	----
Naphtha	550	350	200	200	200	200	200	200	200	200	200
EPB/Naphtha/Gas Oil/Residues	1,464	1,464	1,464	1,464	1,464	1,464	1,464	1,464	1,464	1,464	1,464
Naphtha/Gas Oil/Residues	620	660	660	660	660	660	660	660	660	660	660
	2,724	**2,564**	**2,414**	**2,414**	**2,324**	**2,324**	**2,324**	**2,324**	**2,324**	**2,324**	**2,324**

Source: IHS; Deutsche Bank

APPENDIX 8: Global ethylene capacity – Part 3

	2008	2009	2010	2011	2012	2013	2014e	2015e	2016e	2017e	2018e
CIS & BALTIC STATES											
Other CIS & Baltic States	835	585	835	885	885	885	885	885	1,285	1,285	2,085
Russia	2,861	2,861	2,861	3,031	3,092	3,132	3,412	3,652	3,652	3,652	3,802
TOTAL - CIS & Baltic States	**3,696**	**3,446**	**3,696**	**3,916**	**3,977**	**4,017**	**4,297**	**4,537**	**4,937**	**4,937**	**5,887**
Ethane	475	475	475	375	415	415	625	835	835	835	1,635
Ethane/Propane	----	----	----	----	----	----	----	----	400	400	400
EPB (Ethane,Propane,Butane)	95	95	95	423	465	465	465	465	465	465	465
EPB/Naphtha	1,111	1,111	1,111	1,053	1,032	1,072	1,142	1,172	1,172	1,172	1,172
Naphtha	1,620	1,620	1,620	1,620	1,620	1,620	1,620	1,620	1,620	1,620	1,770
EPB/Naphtha/Gas Oil/Residues	395	145	395	445	445	445	445	445	445	445	445
Other	----	----	----	----	----	----	----	----	----	----	----
	3,696	**3,446**	**3,696**	**3,916**	**3,977**	**4,017**	**4,297**	**4,537**	**4,937**	**4,937**	**5,887**
MIDDLE EAST											
Iran	4,538	4,868	5,202	5,368	5,368	6,368	6,368	6,868	7,826	7,826	7,826
Iraq	150	150	150	150	150	150	150	150	150	150	150
Israel	245	245	245	245	245	245	245	245	245	245	245
Kuwait	1,026	1,770	1,770	1,770	1,770	1,770	1,770	1,770	1,770	1,770	1,770
Oman	----	----	----	----	----	----	----	----	----	----	----
Qatar	1,220	1,220	2,195	2,520	2,520	2,520	2,520	2,520	2,520	2,520	4,520
Saudi Arabia	8,795	11,400	13,908	14,570	15,585	15,790	15,790	15,790	17,290	17,290	17,290
Turkey	520	520	520	520	520	520	520	520	520	520	520
United Arab Emirates	600	600	1,300	2,000	2,000	2,000	2,750	3,500	3,500	3,500	3,500
TOTAL - Middle East	**17,094**	**20,773**	**25,290**	**27,143**	**28,158**	**29,363**	**30,113**	**31,363**	**33,821**	**33,821**	**35,821**
SEthane	8,301	9,045	11,054	12,245	12,245	13,245	13,995	15,245	15,745	15,745	15,745
Ethane/Propane	1,250	3,155	5,000	5,000	6,015	6,220	6,220	6,220	6,220	6,220	7,520
EPB (Ethane,Propane,Butane)	2,360	2,910	3,573	4,235	4,235	4,235	4,235	4,235	4,235	4,235	4,935
EPB/Naphtha	4,485	4,815	4,815	4,815	4,815	4,815	4,815	4,815	6,773	6,773	6,773
Naphtha	698	848	848	848	848	848	848	848	848	848	848
Recovery from FCC/DCC Unit	----	----	----	----	----	----	----	----	----	----	----
	17,094	**20,773**	**25,290**	**27,143**	**28,158**	**29,363**	**30,113**	**31,363**	**33,821**	**33,821**	**35,821**

Source: IHS; Deutsche Bank

APPENDIX 9: Global ethylene capacity – Part 4

	2008	2009	2010	2011	2012	2013	2014e	2015e	2016e	2017e	2018e
AFRICA											
Algeria	200	200	200	200	200	200	200	200	200	200	200
Egypt	300	300	300	300	300	300	300	300	530	760	760
Libya	330	330	330	330	330	330	330	330	330	330	330
Nigeria	300	300	300	300	300	300	300	300	300	300	300
South Africa	720	720	720	720	720	730	768	768	768	768	768
TOTAL - Africa	**1,850**	**1,850**	**1,850**	**1,850**	**1,850**	**1,860**	**1,898**	**1,898**	**2,128**	**2,358**	**2,358**
Ethane	620	620	620	620	620	620	620	620	850	1,080	1,080
EPB (Ethane,Propane,Butane)	300	300	300	300	300	300	300	300	300	300	300
Naphtha	330	330	330	330	330	330	330	330	330	330	330
Methanol to Olefins	----	----	----	----	----	----	----	----	----	----	----
Higher Olefins Cracking	200	200	200	200	200	200	200	200	200	200	200
Other	400	400	400	400	400	410	448	448	448	448	448
	1,850	**1,850**	**1,850**	**1,850**	**1,850**	**1,860**	**1,898**	**1,898**	**2,128**	**2,358**	**2,358**
INDIAN SUBCONTINENT											
India	3,085	3,013	3,826	4,080	4,080	4,080	4,963	5,850	6,525	7,200	7,200
Ethane/Propane	1,360	1,360	1,405	1,420	1,420	1,420	1,533	1,870	1,870	1,870	1,870
EPB/Naphtha	----	----	----	----	----	----	770	1,320	1,320	1,320	1,320
Naphtha	1,560	1,560	2,328	2,567	2,567	2,567	2,567	2,567	2,567	2,567	2,567
Ethanol Dehydration	165	93	93	93	93	93	93	93	93	93	93
Recovery from FCC/DCC Unit	----	----	----	----	----	----	----	----	675	1,350	1,350
TOTAL - Indian Subcontinent	**3,085**	**3,013**	**3,826**	**4,080**	**4,080**	**4,080**	**4,963**	**5,850**	**6,525**	**7,200**	**7,200**
NORTHEAST ASIA											
China	10,280	11,093	14,993	15,636	16,347	17,805	19,513	21,808	24,578	28,258	29,483
Japan	7,824	7,824	7,824	7,734	7,689	7,689	7,421	7,260	6,789	6,734	6,734
North Korea	60	60	60	60	60	60	60	60	60	60	60
South Korea	7,288	7,390	7,498	7,633	8,076	8,180	8,203	8,320	8,320	8,320	8,520
Taiwan	4,050	4,050	4,050	4,050	3,916	4,120	4,420	4,420	3,920	3,920	3,920
TOTAL - Northeast Asia	**29,502**	**30,417**	**34,425**	**35,113**	**36,088**	**37,854**	**39,617**	**41,868**	**43,667**	**47,292**	**48,717**
EPB/Naphtha	2,495	2,495	2,945	2,855	2,810	2,810	2,542	2,485	2,677	2,740	2,740
Naphtha	19,872	20,391	22,932	23,448	23,776	24,409	25,507	25,520	24,857	24,739	24,739
EPB/Naphtha/Gas Oil/Residues	1,710	2,043	2,710	2,710	2,960	3,310	3,310	3,310	3,310	3,310	3,310
Naphtha/Gas Oil/Residues	5,425	5,425	5,575	5,625	5,992	6,525	7,108	7,375	7,275	8,858	9,275
Recovery from FCC/DCC Unit	----	63	150	150	150	150	150	375	450	450	650
Methanol to Olefins	----	----	----	25	100	350	500	1,158	2,045	2,045	2,045
Coal to Olefins	----	----	113	300	300	300	500	1,645	3,053	5,150	5,958
	29,502	**30,417**	**34,425**	**35,113**	**36,088**	**37,854**	**39,617**	**41,868**	**43,667**	**47,292**	**48,717**

Source: IHS; Deutsche Bank

APPENDIX 10: Global ethylene capacity – Part 5

	2008	2009	2010	2011	2012	2013	2014e	2015e	2016e	2017e	2018e
SOUTHEAST ASIA											
Australia	504	504	472	472	472	472	472	472	472	472	472
Indonesia	600	600	600	600	600	600	600	600	860	860	860
Malaysia	1,723	1,723	1,723	1,723	1,723	1,723	1,787	1,850	1,850	1,850	1,850
Philippines	----	----	----	----	----	----	267	320	320	320	320
Singapore	1,955	1,955	2,622	2,755	2,755	3,422	3,805	3,955	3,955	3,955	3,955
Thailand	2,428	2,528	4,120	4,428	4,428	4,428	4,428	4,428	4,428	4,428	4,428
TOTAL - Southeast Asia	**7,210**	**7,310**	**9,537**	**9,978**	**9,978**	**10,645**	**11,359**	**11,625**	**11,885**	**11,885**	**11,885**
Ethane	922	1,224	2,109	2,192	2,192	2,192	2,192	2,192	2,192	2,192	2,192
Ethane/Propane	600	600	600	600	600	600	600	600	600	600	600
EPB (Ethane,Propane,Butane)	543	543	543	543	543	543	543	543	543	543	543
EPB/Naphtha	1,797	1,595	1,595	1,595	1,595	1,595	1,595	1,595	1,595	1,595	1,595
Naphtha	2,123	2,123	2,798	3,023	3,023	3,023	3,354	3,470	3,730	3,730	3,730
Naphtha/Gas Oil/Residues	1,225	1,225	1,892	2,025	2,025	2,692	3,075	3,225	3,225	3,225	3,225
	7,210	**7,310**	**9,537**	**9,978**	**9,978**	**10,645**	**11,359**	**11,625**	**11,885**	**11,885**	**11,885**
WORLD											
Ethane	20,129	21,175	24,069	25,243	25,193	26,207	27,197	28,987	30,467	33,572	37,235
Ethane/Propane	9,679	10,752	12,482	12,740	13,755	14,392	14,634	15,100	15,500	15,500	16,800
EPB (Ethane,Propane,Butane)	6,932	7,402	8,034	9,160	9,214	9,214	9,214	9,254	9,296	9,296	9,996
EPB/Naphtha	29,891	30,053	30,503	30,355	30,531	31,302	32,060	32,795	34,995	35,058	35,058
Naphtha	37,085	37,374	41,208	42,188	42,286	42,229	43,658	43,702	43,044	42,926	43,076
EPB/Naphtha/Gas Oil/Residues	15,033	14,738	15,638	15,629	15,879	16,229	16,229	16,706	16,706	16,874	16,874
Naphtha/Gas Oil/Residues	9,989	9,621	10,302	10,295	10,342	11,468	12,213	12,630	12,530	14,113	14,530
Ethanol Dehydration	165	93	143	293	293	293	293	293	293	293	293
Recovery from FCC/DCC Unit	557	638	621	621	621	621	621	846	1,596	2,271	2,471
Methanol to Olefins	----	----	----	25	100	350	500	1,158	2,045	2,045	2,045
Higher Olefins Cracking	200	200	200	200	200	200	200	200	200	200	200
Coal to Olefins	----	----	113	300	300	300	500	1,645	3,053	5,150	5,958
Other	400	400	400	400	400	410	448	448	448	448	448
TOTAL - World	**130,060**	**132,446**	**143,713**	**147,449**	**149,114**	**153,215**	**157,767**	**163,764**	**170,173**	**177,746**	**184,984**

Source: IHS; Deutsche Bank

APPENDIX 11: Global propylene capacity – Part 1

(in thousand tons)	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
NORTH AMERICA										
Canada	946	928	1,003	1,003	883	823	823	823	823	823
Mexico	861	921	921	921	1,266	1,381	1,385	1,397	1,413	1,413
United States	17,554	18,232	18,159	18,422	18,698	17,641	17,416	17,761	17,879	18,277
	19,361	**20,081**	**20,083**	**20,346**	**20,847**	**19,845**	**19,624**	**19,981**	**20,115**	**20,513**
Steam Cracker-Chem. grade	4,404	4,852	4,935	5,031	5,064	4,178	4,124	4,136	4,152	4,381
Steam Cracker-Poly. grade	5,405	5,500	5,419	5,435	5,282	5,064	4,627	4,702	4,702	4,702
Refinery-Chem. grade	2,858	2,898	2,898	2,898	3,243	3,358	3,358	3,358	3,358	3,358
Refinery-Poly. grade	5,906	6,043	6,043	6,194	6,470	6,457	6,457	6,457	6,457	6,626
Metathesis	788	788	788	788	788	788	788	788	788	788
C3 Dehydro-Poly. grade	0	0	0	0	0	0	270	540	658	658
	19,361	**20,081**	**20,083**	**20,346**	**20,847**	**19,845**	**19,624**	**19,981**	**20,115**	**20,513**
SOUTH AMERICA										
Argentina	320	332	376	396	396	396	396	396	396	396
Brazil	1,888	1,940	2,036	2,096	2,636	2,846	2,846	2,846	2,846	2,846
Chile	130	130	130	130	130	130	130	130	130	130
Colombia	0	0	0	100	150	150	150	150	150	150
Venezuela	395	395	395	395	395	395	400	420	420	420
	2,733	**2,797**	**2,937**	**3,117**	**3,707**	**3,917**	**3,922**	**3,942**	**3,942**	**3,942**
Steam Cracker-Chem. grade	457	457	457	457	469	469	469	469	469	469
Steam Cracker-Poly. grade	1,296	1,312	1,404	1,404	1,470	1,500	1,500	1,500	1,500	1,500
Refinery-Chem. grade	80	116	120	120	120	120	120	120	120	120
Refinery-Poly. grade	900	912	956	1,136	1,648	1,828	1,833	1,853	1,853	1,853
	2,733	**2,797**	**2,937**	**3,117**	**3,707**	**3,917**	**3,922**	**3,942**	**3,942**	**3,942**

Source: IHS, Deutsche Bank

APPENDIX 12: Global propylene capacity – Part 2

(in thousand tons)	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
CENTRAL EUROPE										
Austria	300	315	365	365	365	365	365	365	365	365
Bulgaria	125	125	125	125	125	125	55	60	65	65
Czech Republic & Slovakia	480	525	595	595	621	621	621	621	621	621
Former Yugoslavia	85	85	85	85	85	85	85	85	85	85
Greece	120	120	120	120	120	120	120	120	120	120
Hungary	275	385	385	385	385	403	403	403	403	403
Poland	310	355	485	485	485	485	485	485	485	485
Romania	205	205	225	225	225	130	130	130	90	90
Turkey	200	232	240	240	240	240	240	240	240	240
	2,100	**2,347**	**2,625**	**2,625**	**2,651**	**2,574**	**2,504**	**2,509**	**2,474**	**2,474**
Steam Cracker-Chem. grade	280	280	280	280	280	185	185	185	185	185
Steam Cracker-Poly. grade	1,145	1,347	1,545	1,545	1,571	1,589	1,519	1,519	1,519	1,519
Refinery-Chem. grade	220	220	175	175	175	175	175	180	185	185
Refinery-Poly. grade	455	500	625	625	625	625	625	625	585	585
	2,100	**2,347**	**2,625**	**2,625**	**2,651**	**2,574**	**2,504**	**2,509**	**2,474**	**2,474**
WEST EUROPE										
Belgium	1,835	1,870	1,870	1,870	2,055	2,055	2,055	2,055	2,055	1,973
Finland	200	200	203	223	223	223	223	223	223	223
France	2,721	2,721	2,721	2,721	2,721	2,571	2,496	2,481	2,411	2,411
German Federal Republic	4,042	4,042	4,042	4,115	4,571	4,614	4,639	4,627	4,514	4,514
Italy	1,635	1,635	1,635	1,635	1,593	1,550	1,550	1,485	1,420	1,382
Netherlands	2,318	2,318	2,318	2,380	2,380	2,380	2,380	2,380	2,380	2,380
Norway	105	105	105	105	105	105	105	105	105	105
Portugal	185	185	188	200	200	200	200	200	200	200
Spain	1,295	1,368	1,400	1,400	1,400	1,400	1,433	1,450	1,450	1,450
Sweden	350	350	350	350	350	350	350	350	350	350
United Kingdom	1,231	1,221	1,221	1,221	1,221	1,221	1,188	1,121	1,121	1,121
	15,917	**16,015**	**16,053**	**16,220**	**16,819**	**16,669**	**16,619**	**16,477**	**16,229**	**16,109**
Steam Cracker-Chem. grade	5,767	5,987	5,990	6,007	6,039	5,889	5,856	5,687	5,509	5,427
Steam Cracker-Poly. grade	6,084	5,922	5,957	6,052	6,274	6,274	6,307	6,324	6,324	6,286
Refinery-Chem. grade	2,236	2,236	2,236	2,156	2,166	2,166	2,166	2,166	2,096	2,096
Refinery-Poly. grade	1,240	1,230	1,230	1,345	1,460	1,460	1,410	1,420	1,420	1,420
Metathesis	0	0	0	20	240	240	240	240	240	240
C3 Dehydro-Poly. grade	590	640	640	640	640	640	640	640	640	640
	15,917	**16,015**	**16,053**	**16,220**	**16,819**	**16,669**	**16,619**	**16,477**	**16,229**	**16,109**

Source: IHS, Deutsche Bank

APPENDIX 13: Global propylene capacity – Part 3

(in thousand tons)	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
CIS & BALTIC STATES										
Other Fmr. Soviet Union	0	0	0	0	0	0	0	0	0	0
Russia	1,462	1,417	1,441	1,454	1,502	1,502	1,477	1,627	1,627	1,958
	1,462	**1,417**	**1,441**	**1,454**	**1,502**	**1,502**	**1,477**	**1,627**	**1,627**	**1,958**
Steam Cracker-Chem. grade	1,037	992	1,002	1,015	1,063	1,063	1,063	1,063	1,063	1,082
Steam Cracker-Poly. grade	125	125	139	139	139	139	139	139	139	139
Refinery-Chem. grade	0	0	0	0	0	0	0	150	150	150
Refinery-Poly. grade	300	300	300	300	300	300	275	275	275	460
	1,462	**1,417**	**1,441**	**1,454**	**1,502**	**1,502**	**1,477**	**1,627**	**1,627**	**1,831**
MIDDLE EAST										
Iran	321	411	576	746	975	1,051	1,051	1,051	1,051	1,051
Israel	240	240	250	390	450	450	450	450	450	450
Kuwait	143	143	143	143	164	185	185	185	185	214
Saudi Arabia	1,455	1,565	1,630	1,670	2,448	4,427	5,465	5,795	6,166	6,340
United Arab Emirates	0	0	0	0	0	0	213	802	802	802
	2,159	**2,359**	**2,599**	**2,949**	**4,037**	**6,113**	**7,364**	**8,283**	**8,654**	**8,857**
Steam Cracker-Chem. grade	155	155	160	175	175	175	175	175	175	175
HS FCC	0	0	0	0	0	533	800	800	800	800
Steam Cracker-Poly. grade	1,464	1,554	1,784	1,994	2,447	3,108	3,791	4,146	4,350	4,420
Refinery-Poly. grade	200	200	205	220	220	220	220	220	220	320
Metathesis	0	0	0	110	212	420	608	1,172	1,339	1,372
C3 Dehydro-Poly. grade	340	450	450	450	983	1,658	1,770	1,770	1,770	1,770
	2,159	**2,359**	**2,599**	**2,949**	**4,037**	**6,113**	**7,364**	**8,283**	**8,654**	**8,857**

Source: IHS, Deutsche Bank

APPENDIX 14: Global propylene capacity – Part 4

(in thousand tons)	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
NORTHEAST ASIA										
China	6,630	7,543	8,636	9,478	9,844	10,558	12,909	14,691	16,239	17,930
Japan	5,919	6,175	6,413	6,484	6,553	6,599	6,687	6,506	6,495	6,495
Korea (North)	30	30	30	30	30	30	30	30	30	30
Korea (South)	3,926	4,012	4,342	4,844	5,416	5,746	5,801	5,956	6,307	6,713
Malaysia	916	916	950	962	1,070	1,092	1,092	1,092	1,092	1,092
Taiwan	2,099	2,099	2,243	2,881	3,303	3,303	3,303	3,303	3,279	3,808
	19,520	**20,775**	**22,614**	**24,679**	**26,216**	**27,328**	**29,822**	**31,578**	**33,442**	**36,068**
Steam Cracker-Chem. grade	3,031	3,133	3,183	3,261	3,288	3,288	3,701	3,771	3,726	3,723
HS FCC	464	464	464	464	464	529	613	613	646	713
Coal to Olefins	0	0	0	0	0	0	113	300	300	300
Coal to Propylene	0	0	0	0	0	0	0	333	875	1,000
Steam Cracker-Poly. grade	9,156	9,901	10,754	12,053	12,726	13,152	14,644	14,790	15,281	16,049
Refinery-Chem. grade	944	984	984	984	984	1,014	1,080	1,554	1,797	1,797
Refinery-Poly. grade	5,100	5,273	5,860	6,256	6,785	7,204	7,261	7,727	8,252	9,496
Metathesis	30	225	545	816	1,124	1,296	1,546	1,546	1,546	1,546
C3 Dehydro-Poly. grade	795	795	795	795	795	795	795	795	795	945
Olefin Cracking	0	0	29	50	50	50	69	124	124	124
	19,520	**20,775**	**22,614**	**24,679**	**26,216**	**27,328**	**29,822**	**31,553**	**33,342**	**35,693**
SOUTHEAST ASIA										
Indonesia	505	525	548	573	595	595	595	595	595	745
Singapore	1,225	1,225	1,352	1,466	1,466	1,466	1,841	1,916	1,916	2,249
Thailand	1,181	1,282	1,303	1,319	1,358	1,383	2,102	2,516	2,549	2,616
	2,911	**3,032**	**3,203**	**3,358**	**3,419**	**3,444**	**4,538**	**5,027**	**5,060**	**5,610**
HS FCC	180	180	180	120	120	120	120	120	120	120
Steam Cracker-Poly. grade	2,136	2,237	2,268	2,363	2,424	2,449	3,266	3,422	3,422	3,755
Refinery-Poly. grade	495	515	538	575	575	575	575	575	575	575
Metathesis	0	0	117	200	200	200	425	500	533	750
C3 Dehydro-Poly. grade	100	100	100	100	100	100	152	410	410	410
	2,911	**3,032**	**3,203**	**3,358**	**3,419**	**3,444**	**4,538**	**5,027**	**5,060**	**5,610**

Source: IHS, Deutsche Bank

APPENDIX 15: Global propylene capacity – Part 5

(in thousand tons)	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
AUSTRALIASIA										
Australia	**400**	**387**	**350**	**350**	**380**	**380**	**380**	**380**	**360**	**300**
Steam Cracker-Chem. grade	50	37	0	0	0	0	0	0	0	0
Steam Cracker-Poly. grade	60	60	60	60	90	90	90	90	90	90
Refinery-Poly. grade	290	290	290	290	290	290	290	290	270	210
	400	**387**	**350**	**350**	**380**	**380**	**380**	**380**	**360**	**300**
AFRICA										
Egypt	26	26	26	26	26	26	26	401	426	426
Libya	170	170	170	170	170	170	170	170	170	170
Nigeria	135	135	135	135	135	135	135	135	135	135
South Africa	690	690	790	910	1,030	1,030	1,030	1,030	1,030	1,030
	1,021	**1,021**	**1,121**	**1,241**	**1,361**	**1,361**	**1,361**	**1,736**	**1,761**	**1,761**
Steam Cracker-Chem. grade	26	26	26	26	26	26	26	26	26	26
Other	650	650	750	750	750	750	750	750	750	750
Steam Cracker-Poly. grade	245	245	245	245	245	245	245	245	245	245
Refinery-Poly. grade	100	100	100	100	100	100	100	100	100	100
C3 Dehydro-Poly. grade	0	0	0	0	0	0	0	375	400	400
	1,021	**1,021**	**1,121**	**1,121**	**1,121**	**1,121**	**1,121**	**1,496**	**1,521**	**1,521**
INDIAN SUBCONTINENT										
India	**1,834**	**1,894**	**2,337**	**2,484**	**2,484**	**3,159**	**3,939**	**4,114**	**4,114**	**4,187**
Steam Cracker-Chem. grade	503	503	531	578	578	578	578	578	578	578
HS FCC	0	0	0	0	0	675	900	900	900	900
Steam Cracker-Poly. grade	346	406	386	386	386	386	941	1,116	1,116	1,116
Refinery-Chem. grade	82	82	157	157	157	157	157	157	157	157
Refinery-Poly. grade	903	903	1,263	1,363	1,363	1,363	1,363	1,363	1,363	1,436
	1,834	**1,894**	**2,337**	**2,484**	**2,484**	**3,159**	**3,939**	**4,114**	**4,114**	**4,187**

Source: IHS, Deutsche Bank

APPENDIX 16: Global propylene capacity – Part 6

(in thousand tons)	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
WORLD										
Steam Cracker-Chem. grade	16,015	16,727	16,869	17,135	17,286	16,039	16,482	16,417	16,211	16,374
HS FCC	644	644	644	584	712	1,997	2,573	2,573	2,606	2,673
Coal to Olefins	0	0	0	0	0	0	113	300	300	300
Coal to Propylene	0	0	0	0	0	0	0	333	875	1,000
Other	650	650	750	750	750	750	750	750	750	750
Steam Cracker-Poly. grade	27,462	28,609	29,961	31,676	33,054	33,996	37,069	37,993	38,688	39,821
Refinery-Chem. grade	6,420	6,536	6,570	6,490	6,845	6,990	7,056	7,685	7,863	7,863
Refinery-Poly. grade	16,079	16,456	17,713	18,934	20,366	21,083	21,124	21,620	22,085	23,796
Metathesis	818	1,013	1,450	1,934	2,564	2,944	3,607	4,246	4,446	4,696
C3 Dehydro-Poly. grade	1,825	1,985	1,985	1,985	2,518	3,193	3,627	4,530	4,673	4,951
Olefin Cracking	0	0	29	170	290	290	309	364	364	364
TOTAL - World	**69,913**	**72,620**	**75,970**	**79,657**	**84,385**	**87,280**	**92,710**	**96,836**	**98,961**	**102,962**

Source: IHS, Deutsche Bank

APPENDIX 17 : Statistics of major pollutants by provinces in China

	Region	SO_2 (Kilo tons)	NOx (Kilo tons)	CO_2 (Mln tons)	CO (Kilo tons)	PM2.5 (Kilo tons)	PM10 (Kilo tons)
Beijing	North-Central	187	312	98	2,267	83	118
Tianjin	North-Central	351	594	186	3,003	137	181
Hebei	North-Central	1,942	2,009	782	16,730	1,021	1,395
Shanxi	North-Central	1,660	1,243	443	6,639	473	656
Inner Mongolia	North-Central	1,304	1,248	470	5,273	534	697
Liaoning	Northeast	1,188	1,339	456	9,421	525	724
Jilin	Northeast	356	586	212	4,168	298	410
Heilongjiang	Northeast	309	764	260	5,258	356	460
Shanghai	East	691	914	194	4,020	154	212
Jiangsu	East	1,341	1,889	710	11,500	749	1,019
Zhejiang	East	909	1,335	413	5,263	299	446
Anhui	East	803	1,184	402	9,702	617	782
Fujian	East	486	766	249	3,414	219	321
Jiangxi	East	633	576	225	4,643	288	442
Shandong	East	3,199	2,610	905	17,234	1,182	1,704
Henan	South-central	1,402	1,874	683	12,418	859	1,237
Hubei	South-central	1,241	1,107	412	8,869	539	741
Hunan	South-central	1,036	963	336	7,423	571	769
Guangdong	South-central	1,112	1,836	607	8,834	492	737
Guangxi	South-central	738	710	269	7,384	483	618
Hainan	South-central	38	127	38	674	38	50
Chongqing	Southwest	1,148	487	179	3,088	214	303
Sichuan	Southwest	1,813	1,083	409	10,276	573	768
Guizhou	Southwest	1,075	752	259	3,896	305	409
Yunnan	Southwest	616	735	232	4,440	404	550
Tibet	Southwest	1	23	4	136	7	8
Shaanxi	Northwest	926	703	276	4,794	289	400
Gansu	Northwest	409	380	149	2,708	200	256
Qinghai	Northwest	36	93	38	534	61	78
Ningxia	Northwest	303	277	103	842	94	136
Xinjiang	Northwest	460	458	176	3,047	230	306
Total		27,713	28,977	10,175	187,898	12,294	16,933

Source: :"Emissions of anthropogenic atmospheric pollutants and CO2" by researchers of Harvard University and Nanjiang University, Deutsche Bank

APPENDIX 18 : Statistics of major pollutants by provinces in China (by %)

		SO_2	NOx	CO_2	CO	PM2.5	PM10	∑
Beijing	North-Central	0.7%	1.1%	1.0%	1.2%	0.7%	0.7%	5.3%
Tianjin	North-Central	1.3%	2.0%	1.8%	1.6%	1.1%	1.1%	8.9%
Hebei	North-Central	7.0%	6.9%	7.7%	8.9%	8.3%	8.2%	47.1%
Shanxi	North-Central	6.0%	4.3%	4.4%	3.5%	3.8%	3.9%	25.9%
Inner Mongolia	North-Central	4.7%	4.3%	4.6%	2.8%	4.3%	4.1%	24.9%
Liaoning	Northeast	4.3%	4.6%	4.5%	5.0%	4.3%	4.3%	26.9%
Jilin	Northeast	1.3%	2.0%	2.1%	2.2%	2.4%	2.4%	12.5%
Heilongjiang	Northeast	1.1%	2.6%	2.6%	2.8%	2.9%	2.7%	14.7%
Shanghai	East	2.5%	3.2%	1.9%	2.1%	1.3%	1.3%	12.2%
Jiangsu	East	4.8%	6.5%	7.0%	6.1%	6.1%	6.0%	36.6%
Zhejiang	East	3.3%	4.6%	4.1%	2.8%	2.4%	2.6%	19.8%
Anhui	East	2.9%	4.1%	4.0%	5.2%	5.0%	4.6%	25.7%
Fujian	East	1.8%	2.6%	2.4%	1.8%	1.8%	1.9%	12.3%
Jiangxi	East	2.3%	2.0%	2.2%	2.5%	2.3%	2.6%	13.9%
Shandong	East	11.5%	9.0%	8.9%	9.2%	9.6%	10.1%	58.3%
Henan	South-central	5.1%	6.5%	6.7%	6.6%	7.0%	7.3%	39.1%
Hubei	South-central	4.5%	3.8%	4.0%	4.7%	4.4%	4.4%	25.8%
Hunan	South-central	3.7%	3.3%	3.3%	4.0%	4.6%	4.5%	23.5%
Guangdong	South-central	4.0%	6.3%	6.0%	4.7%	4.0%	4.4%	29.4%
Guangxi	South-central	2.7%	2.5%	2.6%	3.9%	3.9%	3.6%	19.3%
Hainan	South-central	0.1%	0.4%	0.4%	0.4%	0.3%	0.3%	1.9%
Chongqing	Southwest	4.1%	1.7%	1.8%	1.6%	1.7%	1.8%	12.8%
Sichuan	Southwest	6.5%	3.7%	4.0%	5.5%	4.7%	4.5%	29.0%
Guizhou	Southwest	3.9%	2.6%	2.5%	2.1%	2.5%	2.4%	16.0%
Yunnan	Southwest	2.2%	2.5%	2.3%	2.4%	3.3%	3.2%	15.9%
Tibet	Southwest	0.0%	0.1%	0.0%	0.1%	0.1%	0.0%	0.3%
Shaanxi	Northwest	3.3%	2.4%	2.7%	2.6%	2.4%	2.4%	15.7%
Gansu	Northwest	1.5%	1.3%	1.5%	1.4%	1.6%	1.5%	8.8%
Qinghai	Northwest	0.1%	0.3%	0.4%	0.3%	0.5%	0.5%	2.1%
Ningxia	Northwest	1.1%	1.0%	1.0%	0.4%	0.8%	0.8%	5.1%
Xinjiang	Northwest	1.7%	1.6%	1.7%	1.6%	1.9%	1.8%	10.3%
Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	

Source: :"Emissions of anthropogenic atmospheric pollutants and CO2" by researchers of Harvard University and Nanjiang University, Deutsche Bank

APPENDIX 19: Listed Companies mentioned in this report and their DB rating (if appropriate)

COMPANY NAME:	BBRG Ticker	Share Price		DB Rating
Air Liquide SA	AI FP	EUR	97.06	BUY
Air products and Chemicals, Inc	APD UN	USD	128.83	BUY
China BlueChemical Ltd.	3983 HK			
China Coal Energy Company Limited	1898 HK	HKD	4.06	HOLD
China Energy Ltd.	CEGY SP			
China Petroleum & Chemical Corporation	386 HK			
China Sanjiang Fine Chemicals Co., Ltd.	2198 HK			
China Shenhua Energy Company Limited	1088 HK	HKD	22.35	BUY
CNOOC Limited	883 HK	HKD	13.82	HOLD
Datang International Power Generation Co., Ltd.	991 HK	HKD	3.03	BUY
Dongfang Electric Corporation Limited	1072 HK	HKD	13.00	BUY
Feishang Anthracite Resources Limited	1738 HK			
GD Power Development Co., Ltd.	600795 CH			
General Electric Company	GE US	USD	26.29	BUY
Guanghui Energy Co., Ltd.	600256 CH			
Hangzhou Hangyang Co., Ltd.	002430 CH			
Inner Mongolia Yitai	900946 CH			
Inner Mongolia Yuan Xing Energy Co., Ltd.	000683 CH			
Jiangsu Sopo Chemical Co	600746 CH			
Johnson Matthey plc	JMAT LN	GBP	3,050	BUY
KBR, Inc.	KBR US	USD	23.51	BUY
Kingboard Chemical Holdings Limited	148 HK			
LCY Chemical Corp.	1704 TT			
Linde AG	LIN GY	EUR	154.11	BUY
Lotte Chemical	011170 KS	KRW	181,000	BUY
Methanex Corporation	MX CN			
Methanol Chemicals Company	Chemanol AB			
Mitsubishi Corporation	8058 JP			
Mitsubishi Gas Chemical Company, Inc	4182 JP			
Mitsui & Co Ltd.	8031 JP			
Nan Ya Plastics	1303 TT	TWD	71.60	BUY
Nylex Malaysia Bhd	NYL MK			
Petrochina Company Limited	857 HK	HKD	9.82	BUY
Petronas Chemicals Group Bhd	PCHEM MK	MYR	6.78	HOLD
Praxair Inc.	PX UN	USD	131.03	BUY
PTT Global Chemical PCL	PTTGC TB	THB	66.75	HOLD
Royal Dutch Shell PLC	RDSA LN	GBP	2,405	HOLD
Saudi Basic Industries Corporation	SABIC AB	SAR	115.98	BUY
Saudi International Petrochemical Co	SIPCHEM AB			
Shenergy Company Limited	600642 CH			
Siemens AG	SIE GY	EUR	96.77	BUY
SINOPEC Engineering (Group) Co., Ltd.	2386 HK	HKD	8.64	BUY
Sojitz Corporation	2768 JP			
The Dow Chemical Company	DOW UN	USD	52.12	HOLD
Wison Engineering Services Co., Ltd.	2236 HK			
Yang Quan Coal Industry Group Co., Ltd.	600348 CH			
Yingde Gases Group Company Limited	2168 HK	HKD	8.42	BUY

NOTE: Closing Price on 26 June 2014

Source: Bloomberg, Deutsche Bank

Appendix 1

Important Disclosures

Additional information available upon request

Disclosure checklist

Company	Ticker	Recent price*	Disclosure
PetroChina	0857.HK	9.78 (HKD) 30 Jun 14	6,17,SD11
Sinopec	0386.HK	7.40 (HKD) 30 Jun 14	17,SD11

*Prices are sourced from local exchanges via Reuters, Bloomberg and other vendors. Data is sourced from Deutsche Bank and subject companies

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Disclosures marked with an asterisk may also be required by at least one jurisdiction in addition to the United States. See Important Disclosures Required by Non-US Regulators and Explanatory Notes.

6. Deutsche Bank and/or its affiliate(s) owns one percent or more of any class of common equity securities of this company calculated under computational methods required by US law.

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Special Disclosures

11. Deutsche Bank AG and/or an affiliate(s) acted as a Financial Advisor to PetroChina Company Limited on the acquisition of the entire share capital of Singapore Petroleum Company.

11. Deutsche Bank AG and/or affiliate(s) is acting as financial advisor to China Petroleum & Chemical Corporation in relation to restructuring Sinopec Sales Co., Ltd. and introducing social and private capital to realize diversified ownership of its marketing segment.

For disclosures pertaining to recommendations or estimates made on securities other than the primary subject of this research, please see the most recently published company report or visit our global disclosure look-up page on our website at http://gm.db.com/ger/disclosure/DisclosureDirectory.eqsr

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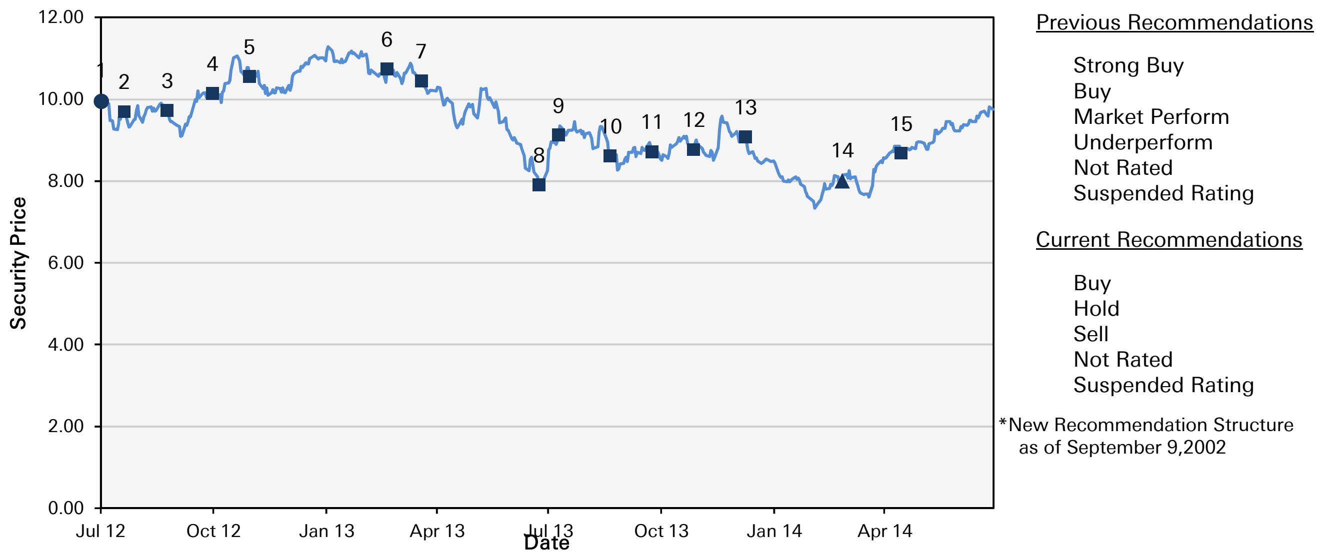
Historical recommendations and target price: PetroChina (0857.HK)

(as of 6/30/2014)



1.	03/07/2012:	Downgrade to Hold, Target Price Change HKD10.85	9.	11/07/2013:	Hold, Target Price Change HKD9.33
2.	22/07/2012:	Hold, Target Price Change HKD10.45	10.	22/08/2013:	Hold, Target Price Change HKD9.10
3.	26/08/2012:	Hold, Target Price Change HKD10.75	11.	25/09/2013:	Hold, Target Price Change HKD9.05
4.	02/10/2012:	Hold, Target Price Change HKD11.34	12.	29/10/2013:	Hold, Target Price Change HKD9.42
5.	01/11/2012:	Hold, Target Price Change HKD11.28	13.	10/12/2013:	Hold, Target Price Change HKD9.00
6.	21/02/2013:	Hold, Target Price Change HKD11.69	14.	27/02/2014:	Upgrade to Buy, Target Price Change HKD9.61
7.	21/03/2013:	Hold, Target Price Change HKD11.12	15.	16/04/2014:	Buy, Target Price Change HKD9.72
8.	25/06/2013:	Hold, Target Price Change HKD9.06			

Equity rating key

Buy: Based on a current 12- month view of total share-holder return (TSR = percentage change in share price from current price to projected target price plus pro-jected dividend yield) , we recommend that investors buy the stock.

Sell: Based on a current 12-month view of total share-holder return, we recommend that investors sell the stock

Hold: We take a neutral view on the stock 12-months out and, based on this time horizon, do not recommend either a Buy or Sell.

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2. Ratings definitions prior to 27 January, 2007 were:

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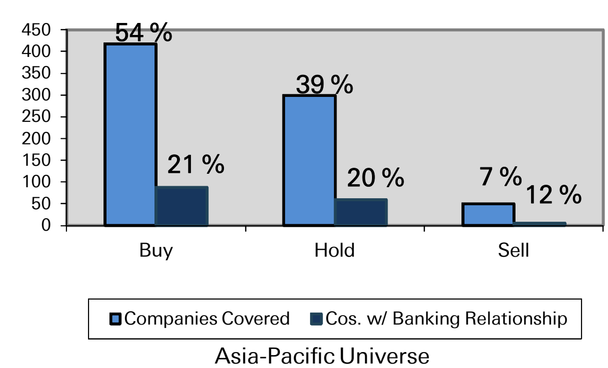
   Hold: Expected total return (including dividends) between -10% and 10% over a 12-month period

   Sell: Expected total return (including dividends) of -10% or worse over a 12-month period

Equity rating dispersion and banking relationships



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