Climate Change and Equity
China Chemicals

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Coal-to-chemicals

A potential growth engine but with environmental constraints

- **Coal-to-chemicals (CTC) is considered the largest potential growth option in China's basic chemicals industry**
- **China's low-cost coal is good for CTC economics, but other price sensitivities and logistics have delayed projects**
- **Environmental constraints are a concern as enforcement of water use and GHG emissions is set to get tougher**

CTC supports China's industry, especially the Strategic Emerging Industries, but growing concerns over the environment could put the reins on this controversial industry

China's desire to grow industry and develop alternatives to oil translates into the need for a solid supply of starting chemicals. CTC is considered by far the largest potential growth option for China's basic chemicals industry as the country looks to improve self-sufficiency in petrochemicals. As such, CTC should account for 63% of new ethylene and 46% of new propylene capacities over 2014-18e.

Some 1.8mt of CTC olefin capacity has already begun production, although the operational track record has been poor. Even the operational performance of new methanol-to-olefin (MTO) units has been weak due to feedstock shortages. There have been significant revisions to the start-up timelines with delays the norm. The majority of planned Chinese coal-based olefin capacity is inland, which could encounter potential water shortages, logistical problems and other environmental constraints.

We look at some of the environmental aspects of the industry such as water use and discharge, air pollutants and greenhouse gas (GHG) emissions. The CTC process in China requires multiple times the water and emits more GHG compared with traditional oil-based chemicals. Dealing with these issues in light of stricter regulations and tougher enforcement would put additional pressure on the investment and operational costs of these facilities. We think this could further delay capacity and see less than one-third actually coming on-stream, given these concerns. We also provide a read-across for the engineering segment in China and for European chemicals.

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CTC supports industry

- Many inputs for Chinese industry, especially SEIs, can be derived from coal-based chemicals but environmental concerns remain
- CTO is a significant portion of new olefins capacity, but timelines have slipped and operational performance remains underwhelming
- Economics are supported by low-cost coal, but logistics and prices of coal, oil and methanol dampen the sector's growth

Developing China's Industry

China has not been shy in expressing its desire to grow all aspects of its economy – from self-sufficiency in agriculture to more advanced industry to a burgeoning services sector.

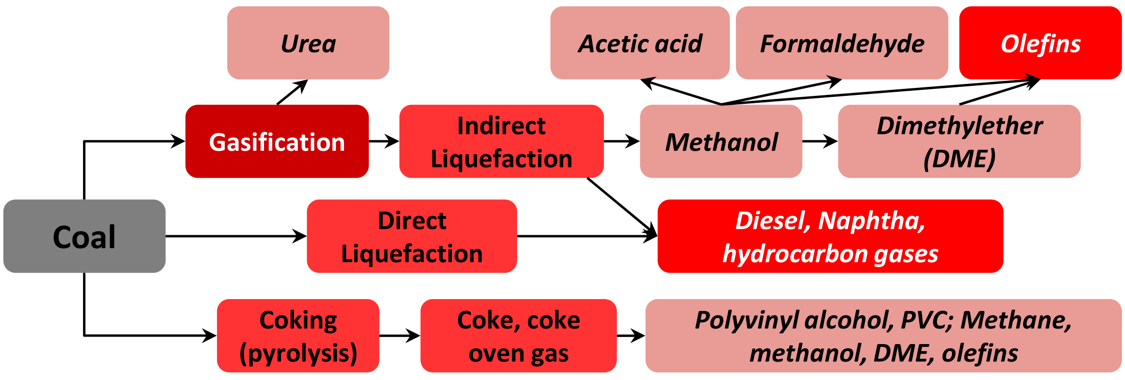
China's desire to grow a more advanced industry, coupled with its abundance of coal, means that it is looking right up the value chain to ensure that it has enough of the starting materials. Coal can be the initial starting point for many major products in the chemical industry, as shown in Chart 1. Importantly, the development of the chemical industry could also accelerate the development of alternatives to oil (including petrol, diesel, etc.).

China's demand for oil has far outstripped its supply; therefore, it became the world's largest net oil importer in 2013. Oil is used not only in transportation fuels but also for further refining into olefins; as such, a coal-to-olefins industry would also be a supplement to the more traditional petroleum-to-olefins industry.

It usually starts with coal-to-gas

The gasification of coal is one method of producing key chemical inputs such as urea, acetic acid, formaldehyde, DME and olefins. These in turn have many applications in other products and industries as diverse as textiles, plastics and cloud seeding (Table 1).

Chart 1: China's coal-based chemical industry



Source: HSBC (adapted from C.-J. Yang, R. B. Jackson/Energy Policy 41 (2012) 878–884)

Table 1: Example of uses for the main coal-based starting chemicals

Urea	Acetic acid	Formaldehyde	olefins
fertilisers	chemical reagent	textiles industry	highly useful in industrial chemical reactions
plastics	chemical solvent	auto components	polymerisation, oxidation, halogenation, etc.
adhesives	ester production	resins	detergents
explosives	inks, paints	paints	textiles, synthetic fibres
diesel combustion denitrification		explosives	personal care products
animal feed		disinfectants	pharmaceuticals
cloud seeding			plastics

Source: HSBC

Gasification can also be a part of the coal-to-liquids process. There are a number of different methods to produce oil from coal (e.g. direct or indirect liquefaction), and some of these methods first require a coal-to-gas step before further conversion to the desired oil products. In some ways, this first gasification step can make it easier to control pollutants, according to the IEA; we discuss environmental considerations later.

The chemical engineering involved in these processes is by no means simple. We do not go into these in any detail, except for mentioning that different coal types and qualities are suitable for different processes and require different technologies.

Feeding strategic emerging industries (SEIs)

The government has stated a desire to develop seven strategic emerging industries (SEIs) to advance its economy but also as part of the country's efforts to lower carbon intensity and improve resource efficiency. The target is for the SEIs to make up a significant share of the economy by the end of the 12th Five-Year Plan (12FYP) period (2015) and beyond.

We looked at the products and processes within the SEIs, which we think would require inputs from products derived from coal-to-gas. Table 2 gives a flavour of the importance of these starting chemicals to the SEIs. The list would probably include even more SEIs, if the full plethora of coal derivatives were included. Indeed, underground coal gasification technology itself is a SEI.

Policy support is evident but equivocal

The government touches on the coal-to-chemicals industry in various plans and policy documents, most explicitly the 12FYP on chemicals, the 12FYP on olefins and the 12FYP on fertilisers. However, details are limited, the targets varied, and the environmental considerations vague.

Table 2: SEIs that rely on possible derivatives of coal-to-gas

1.1 Energy-saving/efficient Industry	6.1.1 New Metal Functional Materials
1.2.1 Water Pollution Control	6.1.2 New Ceramic Functional Materials
1.2.2 Air Pollution Control	6.1.3 Rare Earth Functional Materials
1.2.3 Soil Pollution Control and Remediation	6.1.4 Purity Elements and Compounds
1.2.4 Waste/hazardous Waste Treatment and Disposal	6.1.5 Surface Functional Materials
1.2.7 Technologies to control GHG emissions	6.1.6 High-quality New Organic Active Materials
1.2.8 Environmentally Friendly Products	6.1.7 New Membrane Materials
1.3.5 Auto Parts and Electromechanical Products	6.1.9 Electronic Functional Materials
2.2.6 Important Electronic Materials	6.1.10 Eco-Materials
3.1.3 Chemicals and Drug Manufacture	6.1.11 New Energy Materials
3.1.5 Biotech-derived Pharmaceutical	6.1.12 High-quality Synthetic Rubber
3.3.2 Bio-Pesticides	6.1.13 High-performance Sealing Materials
3.3.3 Bio-Fertilisers	6.1.14 New Catalytic Materials and Additives
3.4.1 Bio-based Materials	6.2.4 Plastics and Synthetic Resins
3.4.2 Bio-Chemical Products	6.3.1 High-performance Fibre and Composite Materials
5.4 Biomass Industry	7 New Energy Automotive Industry

Source: HSBC (based on the NDRC's Strategic Emerging Industries Products and Services catalogue)

Development goals include: an olefin feedstock diversification rate of 20% and a 30% use of gasification technology for nitrogen fertiliser. For methanol, the production capacity cap is 40m tonnes per year by 2015, according to the 12FYP on chemicals, although other sources put this figure at 50m tonnes.

There is recognition that this industry could harm the environment, but the control elements are not apparent in the documents. For example, the 12FYP on chemicals expects new capacity to control the total discharge of major pollutants; the 12FYP on olefins mentions energy conservation and wastewater disposal; the 12FYP on fertilisers recognises that fertilisers are a non-point source pollutant, but there are few details on how to minimise the polluting effects and degradation.

Even the clampdown on air pollution in light of all the highly public smog incidents promotes more coal-to-gas. The Air Pollution Prevention Plan, released in September 2013, encourages the accelerated development of coal-to-gas, with a view that the gas could then be piped into major cities and burned for electricity generation (see *Air pollution causes cancer*, 25 October 2013).

New capacity could be a new growth engine

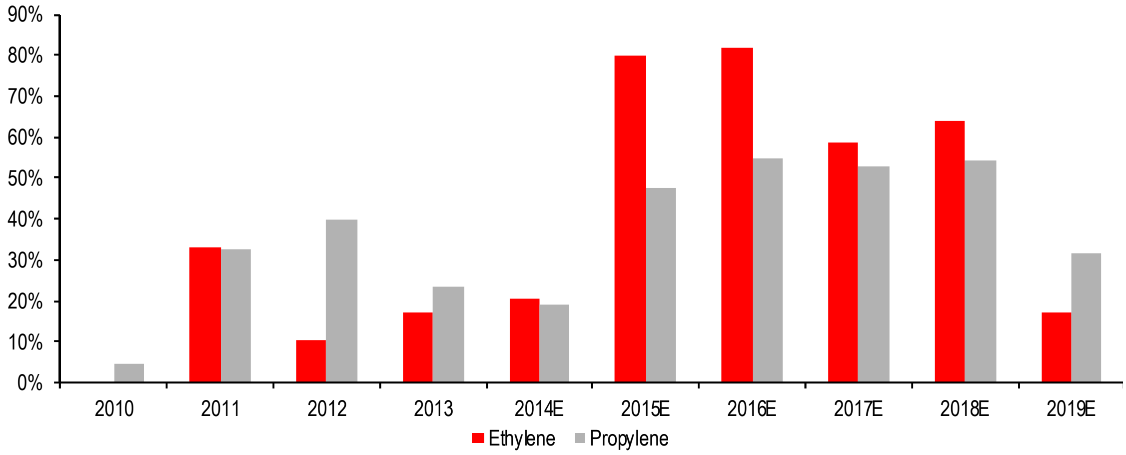
The current situation

Currently, around 63% of China's urea capacity and the vast majority of methanol capacity (four-fifths) is based on coal. China is encouraging the growth of all coal-based conversion industries (to liquids, to methanol, to olefins, to chemicals, etc.) despite the recognition of potential environment problems.

In our 20 February 2013 thematic *GEM Chemicals: Not getting carried away*, we did a detailed analysis of the Chinese coal-to-chemicals industry and concluded that: a) less than 30% of the total capacity set to come on-stream would materialise, and b) even the plants that would come on-stream would struggle to operate consistently. Our base case view on China's coal-to-chemicals capacity remains broadly unchanged. We still see significant constraints and challenges to commercial operations at most of these units.

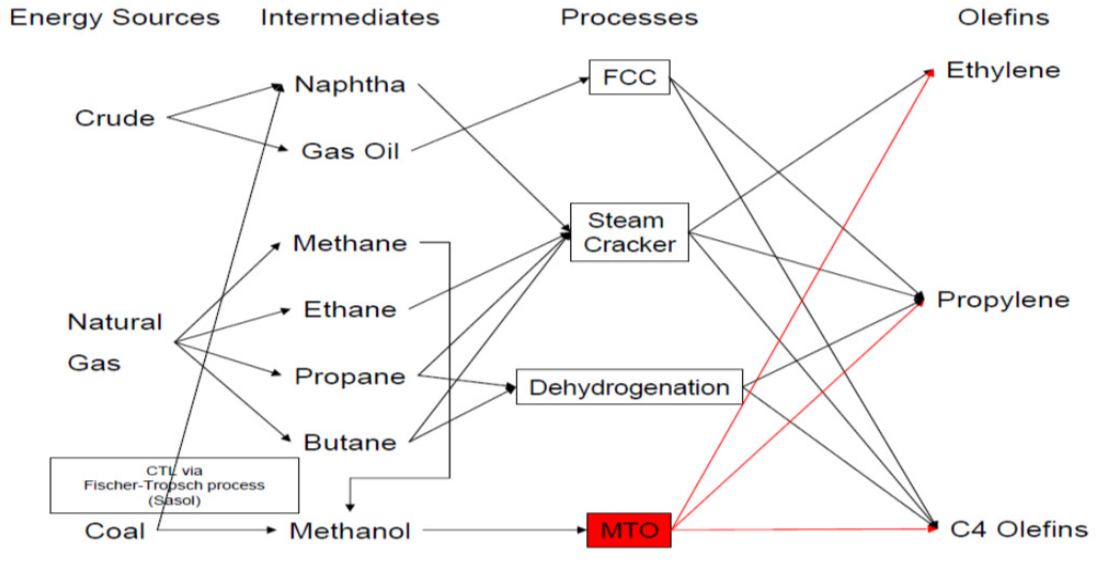
That said, coal-to-chemicals, along with methanol-to-chemicals is, in our view, by far the largest potential growth option for the China's basic chemicals industry, as China looks to improve its self-sufficiency in petrochemicals. As a result of this desire for self-sufficiency and lack

Chart 2: Coal-to-chemicals: share in new Chinese capacity



Source: IHS Chemicals, HSBC
*Coal-to-olefins, coal-to-propylene, methanol-to-olefins, methanol-to-propylene

Chart 3: Olefins production routes



Source: HSBC

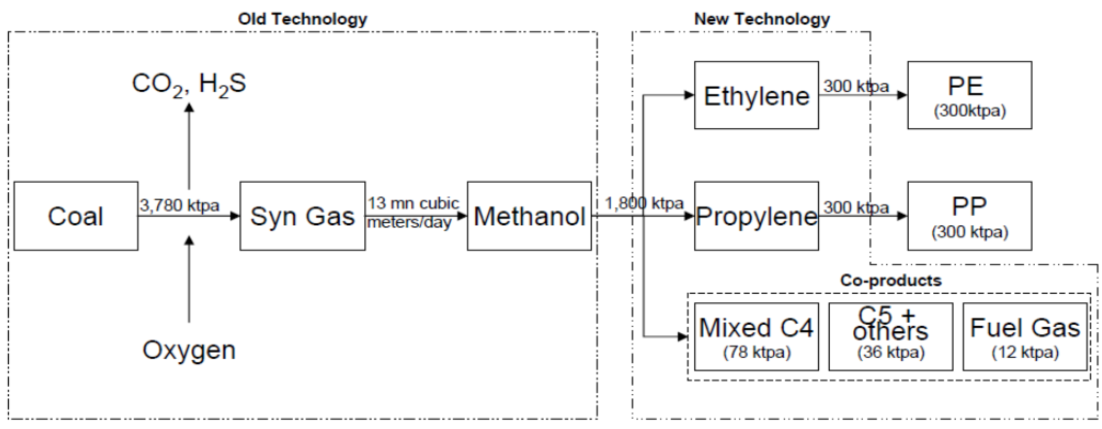
of other significant growth options, coal-to-chemicals accounts for 63% and 46% of new ethylene and propylene capacities, respectively, that consensus is assuming to come up over 2014-18 in China.

CTO – chemistry explained

The coal-to-olefins (CTO) process is best viewed as a combination of two separate steps. The first step involves converting coal into methanol (CTM) and is an established process that has been the primary route of methanol production in China. In this process, coal is first converted into synthesis gas, or syngas (carbon monoxide + hydrogen or $CO+H_2$), by gasification with oxygen. The purified syngas is then converted into methanol.

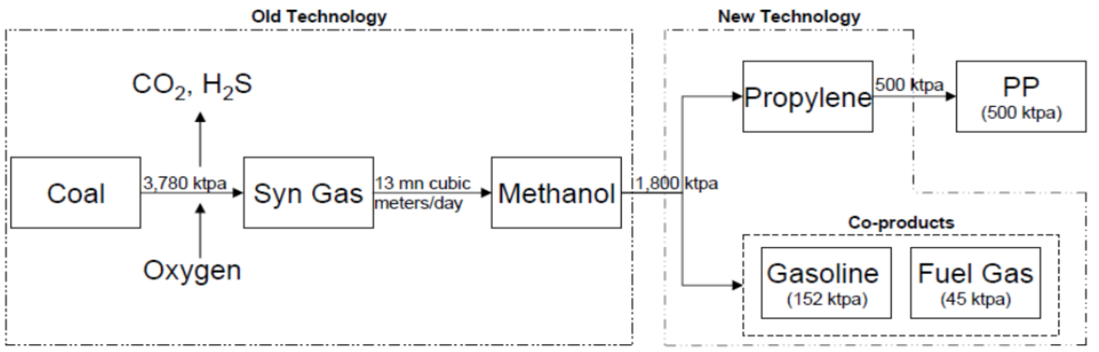
Methanol thus obtained from coal is then converted into olefins in the second step, which is classified as methanol-to-olefins (MTO), or methanol-to-propylene (MTP), based on the olefin product slate. The product slate from MTO is a mix of ethylene and propylene, while MTP produces primarily propylene.

Chart 4: Coal-to-olefins input/output chart



Source: HSBC

Chart 5: Coal-to-propylene input/output chart



Source: HSBC

In the MTO process, methanol is first converted into dimethyl ether (DME), which is then further processed into ethylene, propylene and heavier olefins. The MTO process requires c3 tonnes of methanol per tonne of ethylene and propylene produced. The average propylene/ethylene (P/E) ratio for this step is 0.9-1.

In the MTP process, methanol is partially converted to DME in the first step. The un-reacted methanol and DME are thereafter converted to C2-C8 olefins with propylene as the primary product. The MTP process uses c21% more methanol per unit of olefin produced than MTO, but it also produces more co-products.

The basic input/output sheets for the CTO and CTP (coal-to-propylene) processes are shown in the exhibits above. Water usage is high in CTO and CTP, with c15-30 tonnes of water required per tonne of olefin produced.

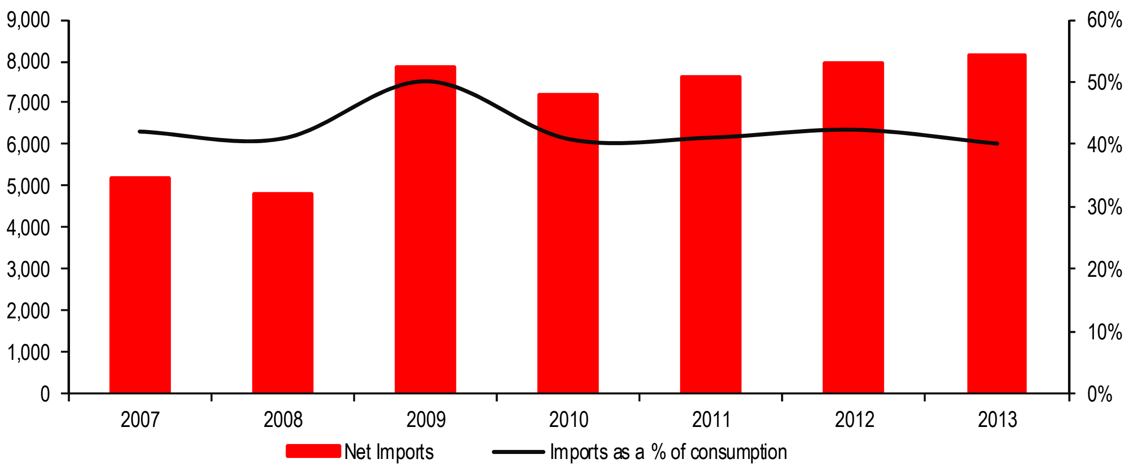
CTO to the front of the capacity addition queue

Route to self-sufficiency and the naphtha issue

A question that the chemicals research team often receives from investors when we talk about the role of China's net import demand in the investment case for emerging market chemical companies is "Why is China not self-sufficient in chemical production?"

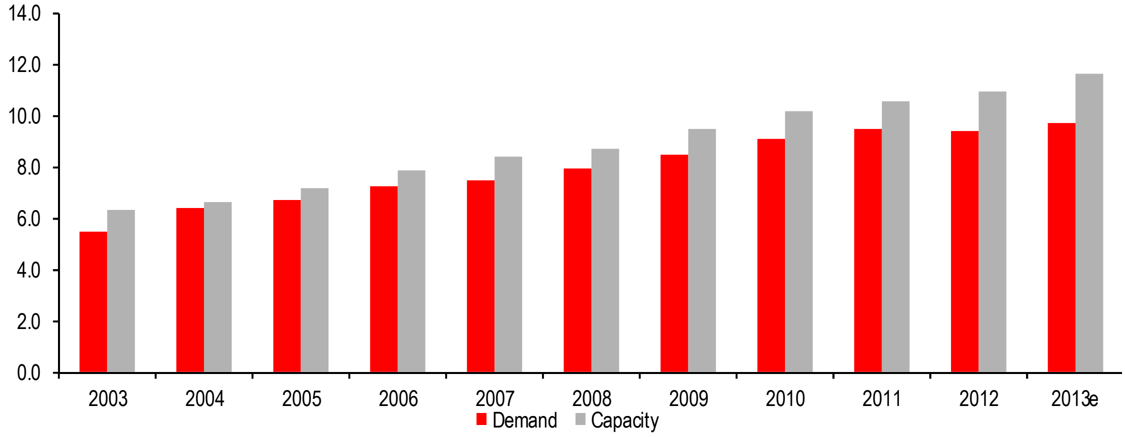
The context behind the question is the trend towards self-sufficiency-based investment in

Chart 6: China P/E import dependency



Source: IHS Chemicals, HSBC

Chart 7: China's refining capacity vs. demand



Source: IEA, HSBC estimates

China in several commodity-based industries (in particular) – e.g. steel, aluminium. In chemicals, however, a similar move towards self-sufficiency has been lacking.

China grew its ethylene capacity at a CAGR of 10.1% over 2007-13 compared to a global capacity CAGR of 3.5%, accounting for c28% of total global capacity added over this timeframe. Despite that rate of capacity growth, there has been a limited impact on China's polymer self-sufficiency (see Chart 6). Robust demand growth has meant that imported P/E still accounts for over 40% of total consumption.

The key here is the role of the refining industry as a source of feedstock for petrochemical production in China. Given limited domestic gas resources, China's ethylene industry has historically been based around naphtha, sourced primarily from the domestic refining industry. The ability to expand chemical capacity has therefore tracked the availability of naphtha and the pace of China's domestic refining capacity additions.

With chemical demand growing at an average of 2x refining demand over 2007-12, aiming for chemical self-sufficiency through the naphtha route would have meant adding refining capacity at a far greater rate than refining demand, leading to refining overcapacity. With refining being the far larger and strategically more important market, China has instead chosen to keep the refining industry supply-demand more or less in balance (see Chart 7).

CTO and MTO, however, offer a non-naphtha-based route to polymer production and a greater degree of self-sufficiency, which is the primary reason behind the raft of new projects being announced in China within this space.

The secular rise in energy prices over the last decade and the consequent increase in naphtha- based ethylene production costs have also had an impact on the relative competitiveness of CTO/MTO economics, making the projects more feasible than in the past.

Some projects have already started

A total of six coal-to-chemicals projects with a cumulative olefin capacity of 1.8m tonnes have started production to date, with the first plant starting in 2H 2010 (Table 3). A significant portion of these projects have the Chinese major coal companies involved one way or the other, as this provides feedstock access and security to the project, while providing a growth avenue for coal companies.

Table 3: Operational coal-to-chemicals projects in China

Project	Location	Capacity (ktpa)	Ethylene	Propylene	Start Date	Additional Details	Parent group in coal mining
Shenhua Group (Baotou)	Inner Mongolia	600	300	300	Aug-10	Integrated 1.8mtpa methanol unit	Yes
Shenhua Ningxia Coal Industry Group	Ningxia	500	0	500	Apr-11	Integrated 1.67mtpa methanol unit	Yes
Datang International Power Generation	Inner Mongolia	460	0	460	Aug-11	Integrated methanol supply of 1.68mtpa	Yes
SNP – Zhongyuan	Henan	200	100	100	Oct-11	Based on purchased methanol	No
Ning Bo Heyuan (Skyford)	Zhejiang	600	300	300	Jan-13	Based on purchased methanol	No
Wison Nanjing Clean Energy	Jiangsu	300	100	200	Sep-13	Partial Integration into methanol	No
Total		**2,660**	**800**	**1,860**			

Source: IHS Chemical, ICIS News, HSBC

Operating track record however remains poor

Investors point to the start-up of two plants – the Ningbo Heyuan 200ktpa ethylene MTO project in Q1 2013 and more recently the 300ktpa Wison Clean Energy MTO plant in September 2013 – as evidence that CTO/MTO plants are viable.

However, data suggest that operational performance of even the new MTO units remains poor. Although it is early days for the Wison plant, the Ningbo Heyuan unit has been running for almost 12 months and has already had multiple turnarounds and outages – at both the MTO unit, as well as the downstream polypropylene (PP) and MEG (monoethylene glycol) units. The downstream units have also on several occasions had to cut operating rates on feedstock shortages. While these could simply be teething troubles that all new start-ups have to go through, the operating track record to date is relatively poor.

Project timelines have been slipping

CTO/MTO project start-up estimates have been in a state of constant flux with significant revisions to start-up timelines. Over the course of 2013, the estimates of new capacities starting up in 2014 has been revised down from 2.25m tonnes to 0.6m tonnes (Table 5).

Table 4: Ningbo Heyuan MTO configuration, operating history

Plant configuration	
Methanol requirement	1.8mtpa
Products	
200ktpa	ethylene
400ktpa	propylene
Saleable capacity	
300ktpa	PP unit
500ktpa	MEG unit
Ningbo Heyuan operating history	
Dec-12	Trial production started at MTO plant
Jan-13	To start commercial trial runs at MEG plant
Mar-13	MEG plant operating at 70%
May-13	MEG plant running at 100%
Jul-13	PP plant shut for week long turnaround, boiler failure
Jul-13	MTO plant shut due to power failure, 3-4 weeks for repairs
Aug-13	PP operating rates cut to 80% on feedstock shortage
Sep-13	PP operating rates cut by 30% on feedstock shortage
Sep-13	PP plants shut, MTO plan outage, restart in 2 weeks in end September
Dec-13	PP operating rates cut to 80%, after the restart in end September

Source: ICIS News, HSBC

Table 5: CTO* capacity progress – estimates for 2014 ('000 tonnes)

Projects listed as coming on-stream in 2014	As of January 2013
Shanghai PC	300
Yulin Energy and Chem Co	300
Qinghai Salt Lake	300
Jiutai Energy (IM)	300
Shaanxi Yanchang	450
Shanxi Coking	300
Sinopec Zhijin	300
Capacity estimate	**2,250**
Revised projects listed as coming on-stream in 2014	**As of October 2013**
Pucheng Clean Energy	300
Yulin Energy and Chem Co	300
Qinghai Salt Lake	160
Baofeng Energy Group	300
Capacity estimate	**1,060**
Further revised projects listed as coming on-stream in 2014	**As of January 2014**
Pucheng Clean Energy	300
Baofeng Energy Group	300
Capacity estimate	**600**

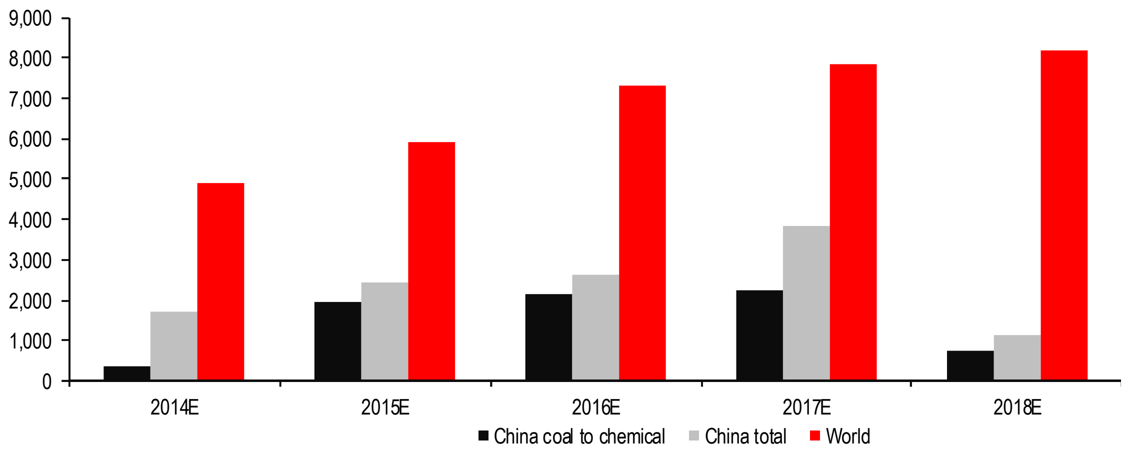
Source: IHS Chemical, Bloomberg BI, HSBC
*Ethylene capacity

How significant is coal-to-chemicals

As highlighted earlier, coal-to-chemicals is the largest avenue of new capacity under consideration in China over the medium term. The total coal-to-chemicals-related capacities that the market is envisaging over the 2014-18 period stands at 7.4mt ethylene and 9.1mt of propylene, accounting for 63% and 46% of total new capacities, respectively, that the consensus is assuming to come up in China over the same period.

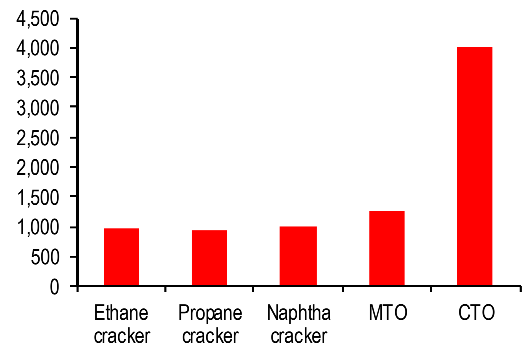
To put it in a global context, this accounts for c30% of the global ethylene capacity additions that the market is envisaging over the 2015-17 period before the ethane-based new capacities in the US start coming online from 2017-18 onwards (see Chart 8). As a results of its size vis-à-vis both Chinese markets and global capacity additions over the next few years, coal-to-chemicals becomes one of the key factors impacting the overall global supply/demand scenario in the ethylene chain.

Chart 8: Consensus ethylene capacity additions (in thousands of tonnes)



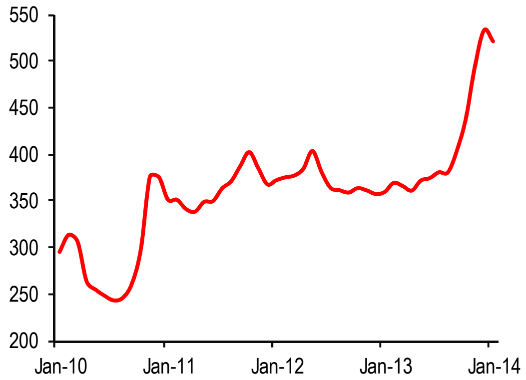
Source: IHS Chemicals, HSBC

Chart 9: China olefins* capital costs (USD/t)



Source: HSBC estimates
Note: *Based on Ethylene + Propylene capacity

Chart 10: Asian methanol prices (USD/t)



Source: Thomson Reuters Datastream, HSBC

A word about economics

Not all coal-to-chemicals capacity is created equal

Furthermore, there is a distinction between CTO- and MTO-based capacities. CTO capacity is generally integrated into coal and mostly inland, while MTO capacity generally relies on outsourced methanol (mostly imported) and is situated along the coast to facilitate feedstock supply. The majority of planned Chinese CTO/MTO projects over the next couple of years are inland CTO projects.

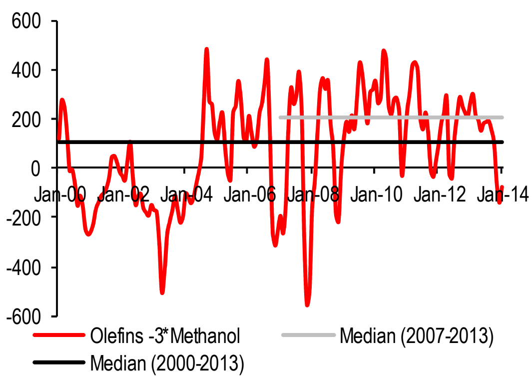
A word about capital costs

The CTO process is highly capital intensive when compared to traditional olefins production routes. The bulk of the capex in CTO relates to units upstream of MTO (coal-to-methanol). The MTO process, on the other hand, is comparable to the traditional olefins production routes in terms of capital intensity (Chart 9).

MTO economics: sensitive to the olefin-methanol spread

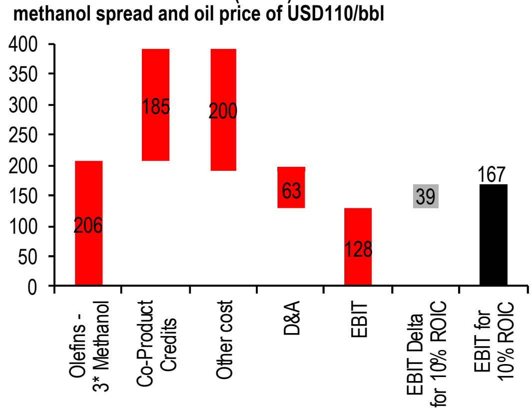
MTO projects have ready access to markets – product demand is highest along the coast – but have the most volatile economics, as profitability is a direct function between prices of olefin and methanol.

Chart 11: MTO feedstock spread (USD/t)



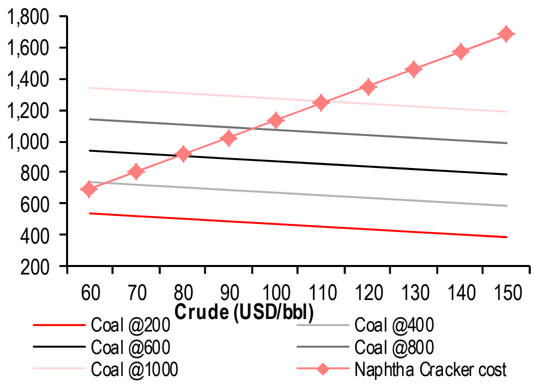
Source: IHS Chemicals, HSBC estimates

Chart 12: MTO economics (USD/t) based on historical* olefin-methanol spread and oil price of USD110/bbl



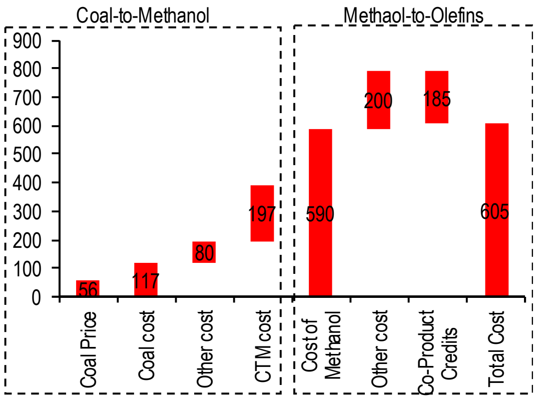
*Historical spread based on the median 2007-2013 level, co-product credits based on an oil price of USD110/bbl
Note: excludes cost related to carbon capture
Source: HSBC estimates

Chart 13: Olefin cash costs (USD/t) – CTO vs. naphtha cracker (as a function of coal (RMB/t) and oil (USD/bbl) prices)



Source: HSBC estimates

Chart 14: CTO cash cost economics (USD/t)



Source: HSBC estimates
*Based on an Oil price of USD110/bbl, Coal price of RMB350/t

Methanol prices have risen sharply since mid-2013 and are now at five-year highs (Chart 10), leading to negative cash margins for methanol-based MTO plants at current levels (Chart 11).

The economics of the MTO/MTP processes are basically driven by the pricing difference between olefins and methanol. However, prices of both sets of products are derived from crude prices. Even if we ignore the recent sharp rise in methanol prices, the dependence of both olefins and methanol prices on crude and their historical relative pricing does not instil a lot of confidence in the economics of MTO, in our view (see Charts 12). The price difference between olefin products and methanol needs to widen significantly from both its current levels, as well as historical (2007-13) levels for MTO/MTP to become economically attractive.

Moreover, the methanol requirement for MTO is fairly large in size, leading to both logistical constraints, as well as an impact on merchant methanol pricing. The Ningbo Heyuan project alone, at full capacity, would consume 1.8mntpa of methanol – out of a traded global market of c25m tonnes, and Chinese imports of c5m tonnes.

CTO supported by low-coal cost, but a number of constraints remain

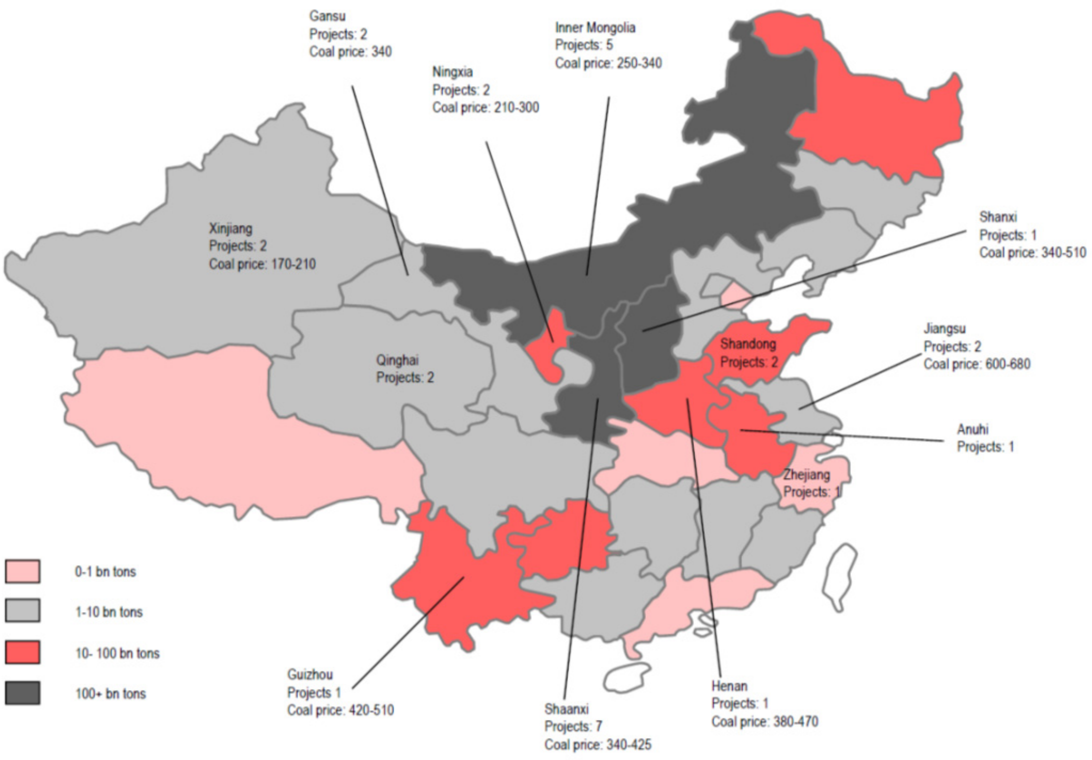
The CTO process has significantly lower cash costs than the traditional naphtha-based route (which is the predominant production route in Asia), as seen in Chart 13, primarily due to the low pricing of coal vs. oil.

The coal requirement in the coal-to-methanol process depends on the quality of the coal (primarily the carbon content), with coal requirements dropping as coal quality, and implicitly, coal prices increase. The average coal requirement on our estimates is c2.1 tonnes per tonne of methanol based on the most common grades of coal traded in China. This leads to c6.2 tonnes of coal required per tonne of olefin produced by the CTO route. The cost model for the MTO process is similar, but the starting point is market-linked methanol prices (Chart 14).

China – coal vs. project distribution

In Map 1 on the next page, we detail the distribution of the planned coal-to-chemicals projects vs. existing Chinese coal resources and the mine-mouth coal price across the various provinces of China. The projects located close to the Eastern coast in Jiangsu, Shandong, Shanghai and Zhejiang provinces are primarily based on

Map 1: China coal resources, CTO/MTO projects*, and coal prices (RMB/t)



Source: Cleaner Coal in China © OECD/IEA 2009, figure 3.1, page 36, IHS Chemicals, ICIS, Company reports, HSBC estimates

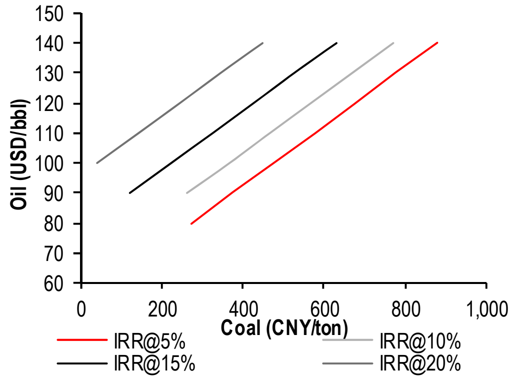
purchased methanol, while those in the central/Western part are predominantly backward integrated into coal production (either partially or completely). The MTO projects based in the Eastern coastal region would have easy access to imported methanol, while projects in the other regions would rely on the in-land methanol sources.

Coal pricing varies across the regions and is in the RMB170-430/t range in central/Western China where most of the CTO projects are planned. For plants located away from the coal mines, the input coal prices would be higher due to freight costs. Coal can be transported across China by three primary routes – trucks, train and via the sea. The cost of transportation is most expensive via truck, while it is cheapest via sea. The sea freight cost between Qinhuangdao port and Guangzhou port, for example, is currently cRMB40/t. However, the options for sea transport are obviously limited to areas that have port access – mainly Eastern China. This leaves rail transport as the dominant method for coal transportation. The cost of rail freight between Inner Mongolia and Shanghai is around RMB120-140/t, while that from Inner Mongolia to Qinhuangdao port is around RMB60-75/t, and that from Inner Mongolia to Qinghai is around RMB150-180/t. We estimate that a freight cost of RMB100/t would lower the ROIC for a CTO project by c2ppt.

CTO economics: coal and oil price sensitivities

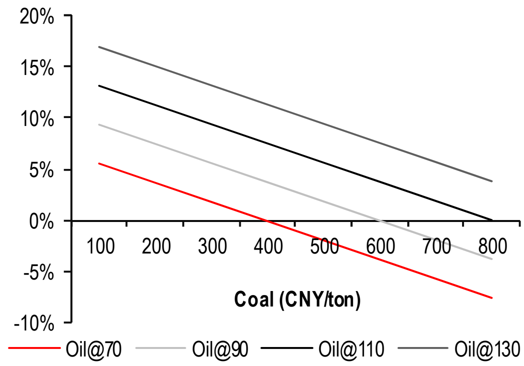
The profitability of CTO projects is dependent on both coal and oil prices. Production costs are linked to coal prices, while the pricing of both olefins and their co-products is linked to crude prices. Charts 15 and 16 show the IRR and ROIC profiles of CTO projects under different scenarios of coal and oil prices.

Chart 15: IRR of CTO as a function of Coal (RMB/t) and Oil (USD/bbl) prices



Source: HSBC estimates

Chart 16: ROIC of CTO as a function of Coal (RMB/t) and Oil (USD/bbl) prices



Source: HSBC estimates

The low cash cost in CTO arising from low coal prices, don't necessarily translate into high returns due to comparatively much higher capital cost vis-à-vis the traditional routes. At coal prices of RMB300-400/t, a 10% IRR requires oil prices to be in the USD95-105/bbl range. Producers integrated into coal, however, can generate slightly higher returns by transferring coal to their coal-to-chemicals business at below-market prices. This discount could be in the order of 15%, this being the average operating margin of China's coal mining industry. With access to coal at a 15% discount to the market price, a CTO project can generate a c2ppt higher IRR or a c1ppt higher ROIC. To put it differently, given a market price for coal of RMB300-400/t, a 15% discount would imply that a 10% IRR could be achieved, even if oil prices were lower by cUSD5/bbl.

Putting a price on carbon

China has discussed the possibility of a carbon tax in the past as part of wider environmental tax reforms (see *Trade-and-cap – and tax*, 20 February 2013). The energy sector would be significantly affected by this, although it would depend on the level of the tax.

Carbon trading has arrived in China. Five regional platforms have already commenced, with the final two expected this year. (For more details on carbon trading in China, see page 4 of *China's year of the environment*, 17 December 2013.) The 12FYP does signal the possibility of a national emissions trading scheme, although any national scheme is dependent on the success of the pilot schemes.

We do not think a national scheme would happen for a few years, given data accuracy problems, the difficulty of a national emissions cap, lack of verification capacity, and the readiness of participants on a national level. However, coal-to-chemicals facilities that fall under the jurisdiction of an ETS scheme (pilot or national) would likely be obliged to participate. Given the emissions of this coal-based sector and also because the chemical processes involved produce carbon dioxide, this would be an added cost of operation and could affect the economics of the industry. (For more on carbon emissions, see page 19).

Inland capacity requires logistics

Route to market for products and co-products

Inland CTO projects are primarily located in central/Western China, with Inner Mongolia, Shaanxi, Ningxia and Xinjiang having the largest share of projects, instead of costal and Eastern region, which represent the bulk of polymer demand. This leads to the logistical issue of getting the product to market.

The CTO projects are located close to the feedstock (coal) to integrate these projects into low-cost mine mouth coal instead of being closer to demand, as it is easier and cheaper to transport polymers instead of coal, given that it takes c6.2 tonnes of coal to make one tonne of olefin.

The co-products, on the other hand, are a different story. The main co-products include fuel gas, heavier olefins and gasoline, and are produced in much smaller quantities than the olefins – total co-product yields for the MTO/MTP processes are only 7% and 11%, while olefins yield 33% and 28%, respectively. The smaller quantities of the co-products produced, coupled with the far-off location of the coal-to chemicals plants, make it difficult for these products to be sold at their normal market prices. The co-products, as a result, are either sold at a discount to market prices or are consumed internally as fuel, realising only their fuel-linked value.

The table below lists the new projects and their start-up timelines being considered by the market.

Table 6: China coal-to-chemicals projects

Company	Location	Capacity ktpa	Ethylene ktpa	Propylene ktpa	Start timeline
Shenhua Ningmei	Ningxia	500		500	Q3 2014
PuCheng Clean Energy	Shaanxi	680	300	380	Q3 2014
Baofeng Energy	Ningxia	600	300	300	Q3 2014
Shandong Shenda	Shandong	400	170	230	Q1 2015
Fugu Hengyuan	Shaanxi	200		200	Q1 2015
Shandong Hengtong	Shandong	300	100	200	Q1 2015
China Coal Yuheng	Shaanxi	600	300	300	Q2 2015
Yulin Energy & Chem.	Shaanxi	600	300	300	Q2 2015
Zhejiang New Energy	Zhejiang	600	300	300	Q2 2015
China Coal Mengda	Inner Mongolia	600	300	300	Q2 2015
Jiutai Energy (IM)	Inner Mongolia	600	300	300	Q2 2015
Qinghai Salt	Qinghai	320	160	160	Q2 2015
Fund Energy (Changzhou)	Jiangsu	385	175	210	Q3 2015
Jiangsu Sailboat PC	Jiangsu	600	300	300	late-2015
SXYCPC-Yan'an E&C	Shaanxi	700	450	250	Q1 2016
Huating Coal Group	Gansu	200		200	Q1 2016
Shenhua Xinjiang	Xinjiang	720	270	450	Q1 2016
Shenhua Xiwan	Shaanxi	600	300	300	H2 '16
Qinghai Damei	Qinghai	600	200	400	Q3 2016
Shanxi Coking Corp.	Shanxi	600	300	300	Q3 2016
SNP - Zhong'an Coal Chem	Anhui	600	300	300	Q3 2016
SNP - Zhongtian Hechuang	Inner Mongolia	1,370	670	700	Q4 2016
SNP - Hebi	Henan	600	300	300	Q1 2017
SNP - Zhijin	Guizhou	600	300	300	Q1 2017
Yili Meidianhua	Xinjiang	600	300	300	Q1 2017
Huahong Huijin	Gansu	600	300	300	Q3 2017
China Coal Yuheng	Shaanxi	600	300	300	Q1 2018
Baotou Shenhua	Inner Mongolia	700	250	450	Q2 2018
CPI/Total JV	Inner Mongolia	1,000	400	600	Q3 2018
Total		**17,075**	**7,645**	**9,430**	

Source: IHS Chemicals, HSBC

Environmental constraints

- Water use is a concern as competition for water within provinces increases; wastewater clean-up facilities add to investment costs
- GHG emission are higher for coal-based chemicals, which could be a problem as capacity is locked in; CCS adds c5% to costs
- Stricter regulations and tougher enforcement may further delay capacity build-up, as well as add to investment and operating costs

Environmental concerns

Since the technology and processes associated with coal-to-chemicals are often project-specific and almost always proprietary, there is little external scientific analysis of the environmental cost. We find little information on the subject and the little that there is tends to be estimates.

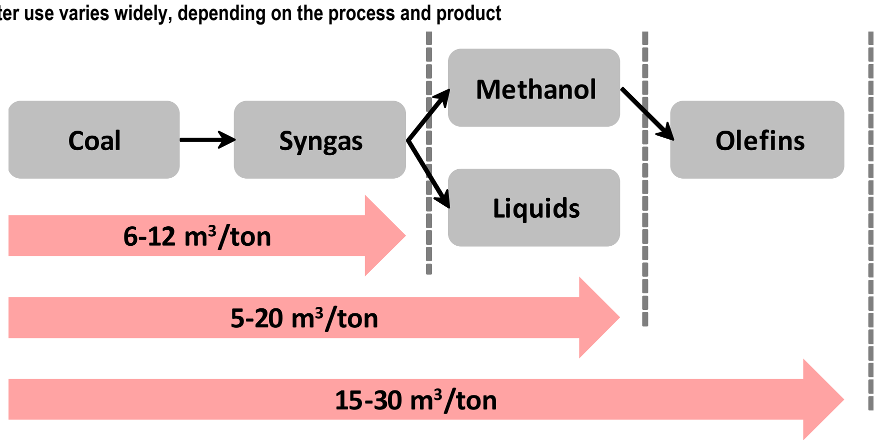
Potential capacity lock-in

The apparent support and build-out of coal-to-chemicals has potential consequences for the environment. The conversion of coal into gas and subsequently other fuels and chemicals uses water and emits pollutants in the form of air emissions, GHG emissions and wastewater. The operational life of these plants can be long and, once built, would lock in some of the environmental consequences such as water use or emissions unless retrofits and upgrades were incurred but these would come at a future cost.

Water: use and discharge

Water is required along various stages of the coal-to-chemicals process: in different quantities, depending on the end product; and, in different ways, depending on the particular process or reaction.

Chart 17: Water use varies widely, depending on the process and product



Source: HSBC (based on IEA, Chen et al, Yang et Jackson, Xiang et al)

Steam: Water is required for the boilers to convert to steam, which may be used for on-site power generation (or in chemical reactions).

Coolant: In many cases, water is necessary as a coolant as the chemical reactions require controlled temperatures.

Cleaning: Water may also be used for washing, either the coal to ensure the quality desired and/or the synthetic gas to remove impurities.

Process: Water is also needed for the gasification process to meet the correct hydrogen quantities, during the liquefaction process, and also for the "water-gas shift reaction" (which converts water and carbon monoxide into hydrogen and carbon dioxide for further processing into other chemicals).

Consumption – how much (more)?

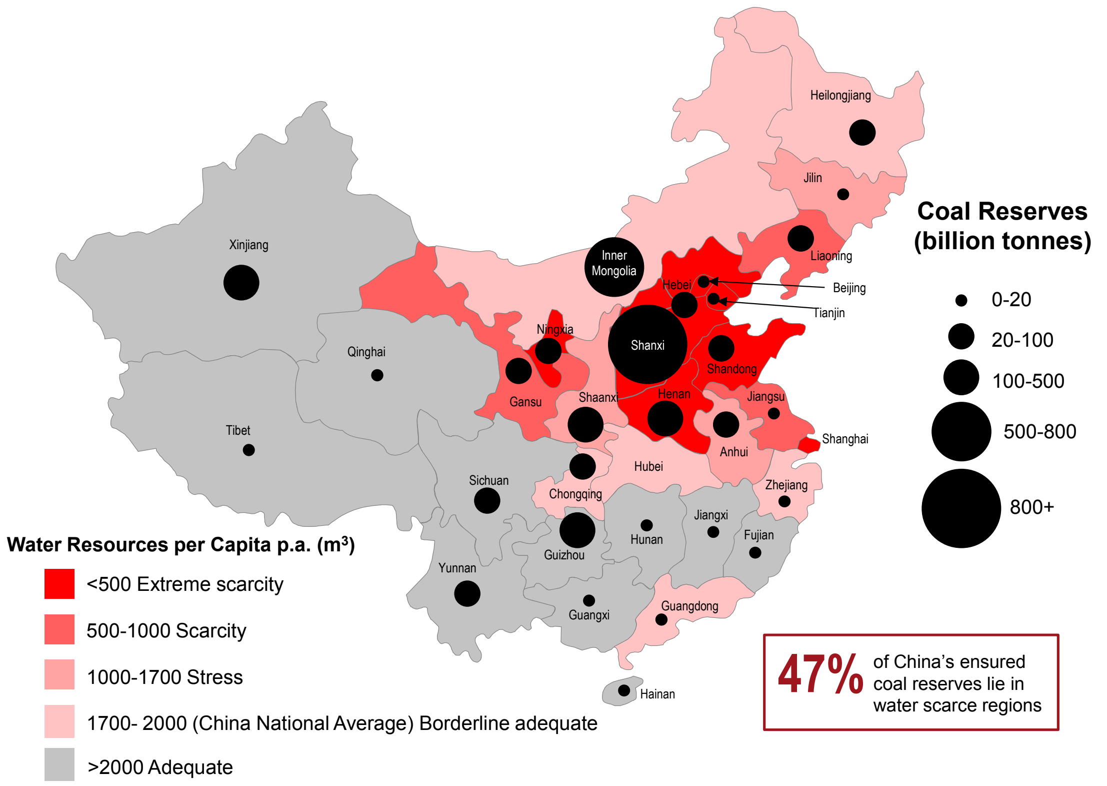
Coal-based chemicals require multiple times more water compared with traditional oil-based chemicals. Xiang et al. estimate that it requires 4.2x as much water to produces olefins from coal than from oil.

More water than traditional methods

The overall water used by any particular facility will depend on its production capacity and the type of end product. Depending on the process being described, various estimates put the water use at 5-30 m^3 of water per tonne of product produced (Chart 17). This is essentially many tonnes of water used per tonne of product produced. It is unclear from the literature what type of water (fresh, salt) is or can be used in each of the processes.

The mining of the coal itself also requires water – for more details see *The water-related challenges of China's coal and power industries*, June 2013.

Map 2: China's ensured coal reserves are located in regions with challenging water levels



Source: China Water Risk (based on State Electricity Regulatory Commission, China Statistical Yearbook and Provincial 12 FYPs)

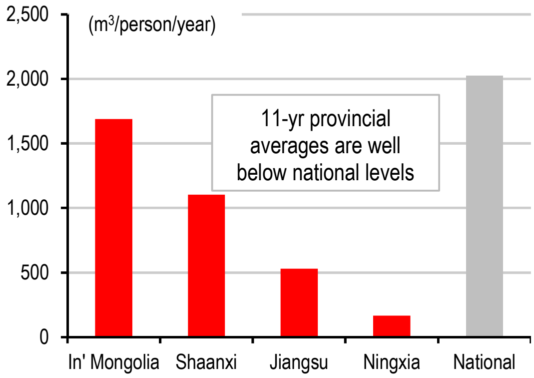
Shortages – location mismatch

There is a mismatch between the location of coal reserves and water resources. The per-capita water resources and water resources per sqm in China's key coal producing provinces such as Inner Mongolia, Shanxi and Shaanxi is well below the national average. The development of coal-based chemical industries in China's coal-rich but arid regions could lead to the further depletion of ground water, and also exacerbate water pollution issues.

Many provinces are already water-stressed

Some ten provinces house the various existing and planned coal-to-chemicals projects in China. However, more than half feature within just four provinces: Inner Mongolia, Shaanxi, Jiangsu and Ningxia. The average water resource per capita for the eleven years to 2012 has been below water-stress levels (1,700m^3/person/year) in Inner Mongolia and Shaanxi; in Jiangsu and Ningxia, they have been well-below water scarcity levels (1,000m^3/person/year).

Chart 18: Many CTC projects are in low-water provinces



Source: China National Statistical Yearbook

If the projects in these provinces were to operate at full capacity, we calculate that they could use 108-216m tonnes of water in 2015, or 183-366m tonnes in 2018. This is a large amount for water-stressed and -scarce provinces. For Ningxia, our calculations show that this could be up to 2.4-4.8% of the annual renewable water resources of the entire province.

Water quotas are difficult to enforce

Some provinces stipulate a water quota by industry. For example, Jiangsu, which revised its quotas in 2010, allocates 35m^3 of water per tonne of polyethylene and 33m^3/t of PVC; for Inner Mongolia, one tonne of methanol should use no more than 10m^3. However, it is not clear, which production methods (oil or coal based) these refer to or how they are enforced.

The precise source of water is important

It is unclear what the exact source of water is for these projects. For example does/would the water come from a nearby lake, a free flowing river, or groundwater resources. Any potential water availability problem would be dependent on the source of the water – with groundwater being the most precarious. We do believe that local authorities are cognisant of allowing groundwater to be depleted and do try to allocate more surface water to these facilities.

Projects are required to secure water rights before construction, but this does not necessarily always occur and sometimes (according to NGO reports) the agreements can be unclear. Moreover, there are grey areas as to jurisdiction: for example, local water rights are agreed and assigned by local authorities, provincial water caps must be met, and increasingly, national environmental standards must be applied and enforced.

Water diversion – not again?

A balance of water supply, rights and allocation is not easy to achieve. In Shaanxi, the provincial authorities proposed increasing the water supply to local coal-to-chemicals facilities. However, an analysis by a water official from Shaanxi, published in the Chinese Journal of Water Resources and Architectural Engineering, concluded that the CTC plants would result in a water shortage of about 1bn m^3 in 2020, growing to a 1.4bn m^3 shortage in 2030. (We calculate this to be around 2.4-3.4% of Shaanxi's total annual water resources.) The analysis suggested transferring water from the Yellow River to "solve the water demand gap"; however, river diversions also cost money.

An increasingly vocal public is joining the debate on water availability as the competition for water heats up. Some mechanisms have been put in place to solve this problem such as water quotas by industry and water rights transactions (where industry invests in water-saving technology/irrigation for agriculture so that more water is freed up for industrial use).

Discharge – clean-up is important

Local water availability is dependent not only on the *quantity* of water but also its *quality*. Assuming a project has access to appropriate water resources (i.e. at the correct temperature and purity etc.), the water used must be treated before it can be fed back into the water system or reused.

Water used in various stages of the coal-to-chemicals process will inevitably be mixed with chemicals. For example, water used for cleaning (scrubbing) will be laced with the impurities it removed and water used for reactions will contain some leftover chemicals. There is evidence that the authorities are stepping up the enforcement of pollution regulations to provide safe drinking water for the people but also useable water for the agricultural industry.

Wastewater must be treated

There is limited detailed analysis on the volumes of wastewater produced, but we would expect most of the water used would have to be treated in some way – at least according to how polluted it is. There is a similar dearth of analysis on the content of wastewater discharge, but the effluent produced is often mixed in with hydrocarbons, chemical salts, acids, etc., which must all be treated. Wastewater treatment first requires the appropriate facilities to be installed, which further adds to the capital investment, then it requires continual operation, which adds to the operational and maintenance costs.

Potential drinking water contamination

There is also the potential for contamination of local water sources through spills, leaks or other accidents. The acknowledgement of "cancer villages" in February 2013 put the treatment of wastewater firmly in the public eye. Beyond drinking water contamination, the chemicals contained within the wastewater can leak into the soil, which affects food safety and food security, see *No water, no food* (March 2014). Mercury and arsenic from CTC processes are particular problems related to soil pollution.

Pollution – air and carbon

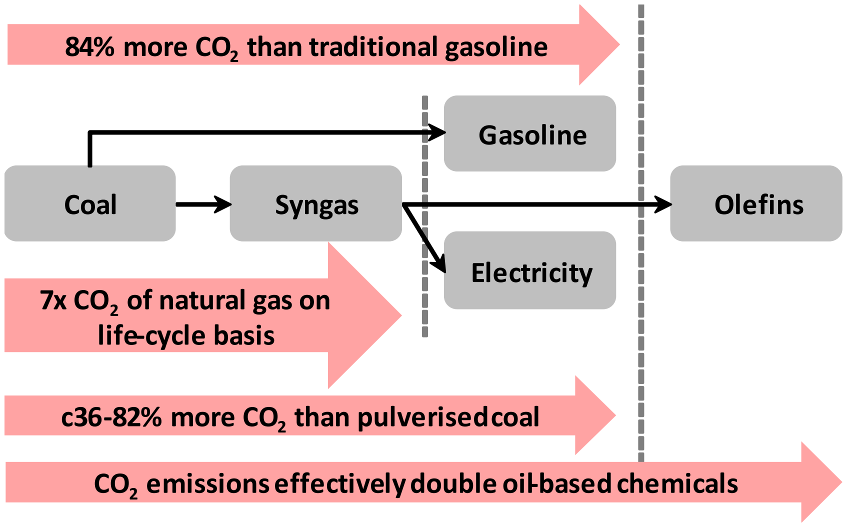
Various gases are involved in the many different chemical processes – some are desired products, whilst others are by-products. If scrubbed correctly, these gases can be captured and treated appropriately; however, leaks and deliberate venting allow escape into the atmosphere. The various gases involved, for example, carbon monoxide, hydrogen sulphide, sulphur oxides and nitrous oxides contribute both to air pollution and health problems.

Volatile compounds and PM

The high temperatures also bring about volatile organic compounds (VOCs) and gaseous metals, for example, volatile mercury. These can be detrimental to human health. Also, particulate matter (PM) in its various forms can be released into the atmosphere if not properly captured. PM has been the main culprit of China's many smog incidents over the past 12-18 months.

Pollution control equipment can be installed to minimise these emissions, but again this requires additional capital investment and higher operating costs.

Chart 19: CO_2 emissions from coal-based methods are higher than more traditional methods



Source: HSBC estimates (based on Yang et Jackson, Zhu et al, Ren et Patel)

Carbon pollution – GHG emissions

Coal-based chemicals and the related processes produce carbon dioxide (CO_2) along the way. This can be direct (e.g. burning coal to make heat) or indirect as a by-product. There are two methods for looking at carbon emissions from the industry: 1) comparing it with traditional oil-based chemicals, and 2) comparing it on a per unit of energy basis. The calculations ought to take into account a full life-cycle analysis.

There are three main areas where CO_2 can be emitted during the coal-to-chemicals process:

1) **Burning coal:** at various stages of the chemical process to produce heat for chemical reactions, and perhaps also for onsite power generation.

2) **Gasification:** the coal-to-gas process produces CO_2 but volumes depend on the type of coal and type of gasifier. Essentially, the coal (carbon or C) reacts with oxygen to produce CO_2 (and, if carbon capture is to be done then the water-gas shift reaction must also occur: $CO+H_2O = H_2 + CO_2$).

3) **Process:** where the synthetic gas is further processed into methanol/olefins. This segment produces the most CO_2, but this, in theory, could be captured and either stored or used elsewhere.

More CO_2 emissions than traditional methods

Estimates from various sources of literature suggest that coal-based-chemical emit more CO_2 than traditional oil-based ones on a life-cycle basis (Chart 19). However, some estimates, primarily by the China Coal Institute, suggest that on a per unit of energy produced basis, CO_2 emissions of power generation are higher than that of coal-to-olefins.

In our view, the absolute emissions on a life-cycle basis are more important from a global warming perspective. Life-cycle represents actual emissions into the atmosphere as opposed to hypothetical heat content, which may be stored in the end product but never released as emissions.

Carbon capture

One potential carbon benefit of the coal-to-chemicals process is that the CO_2 can, in theory, be captured more easily as it is self-contained within the system. However, most coal-to-chemicals plants are constructed to be "carbon capture *ready*" rather than actually capturing carbon. Even then, the process is by no means simple. It is not a case of just capturing the CO_2 at the end of the pipe, various changes need to be made to the entire system, which adds to the construction cost. Even then, a suitable capture area must be found nearby.

Estimates of how much it would cost to install and operate carbon capture are limited and vary depending on the exact technology and process used. Although not a direct comparison, EPRI (the Electric Power Research Institute) suggests that for an IGCC power generation facility (which also uses gasification), the additional cost would be in the order of 5%. Studies by the IEA in relation to a specific H_2 production plant also suggest an additional 5% of capital costs.

Operational costs would also be higher as the carbon capture system must be turned on. Previously, CO_2 emissions were not as closely regulated, and in China, emissions targets are on a carbon intensity basis and not by absolute volume. Hence, the emissions profile of coal-based-chemicals depends on what is vented and what is actually captured.

Enforcing a tougher environment

The remote areas in which many coal-to-chemicals plants operate may have, in the past, meant that enforcement of environmental regulations were weak. We believe that this is now changing.

2013 turned out to be the year of environmental protection in China, driven by new leadership, growing public disquiet over pollution, and noticeably tougher enforcement. Following various air and water pollution incidents and official acknowledgement of "cancer villages", more stringent environmental initiatives such as enhanced emission limits for industry have been put into place. We think that even tighter regulations will come into force and, more importantly, the level of enforcement of these will increase. Premier Li Keqiang heralded this incoming change by declaring "war on pollution" at the recent National People's Congress meetings.

Laws, sanctions, compliance

China's new leadership is tackling the environment in a way none of its predecessors have – openly admitting enforcement of environmental laws has been inadequate, reforming environmental laws, and ensuring better compliance with such laws.

Large SOEs, which previously were considered "untouchable", are being reprimanded for the first time as shown by the Sinopec and PetroChina sanctions in September. The positive surprise for us has been the change in enforcement, which for a long time has been the weakest link in forcing change through. For example, the Ministry of Environmental Protection, which has historically been seen as lacking muscle, is slowly being given the tools it requires to enforce regulations.

The proposed amendments to various environmental laws (air, water, soil, etc.), the moves to achieve greater compliance, and many high-level officials discussing the importance of the environment were a welcome change. In 2014, we expect more policies and enforcement tools to be rolled out to stem the deterioration in the environment and the related public outcry.

CTC outlook

For the coal-to-chemicals industry, we think that incoming regulations, coupled with a stronger will to enforce them, may make environmental approvals more difficult to obtain. This could affect both existing and planned facilities. Ultimately, we believe that stronger enforcement would lead to increases in the investment and running costs of coal-to-chemicals plants.

Over the 2013-17 period, Chinese coal-based (CTO/MTO) ethylene capacity has been billed as potentially the single most important source of new ethylene supply, both in China, as well as globally. However, we see less than one-third of this capacity as coming on-stream, given concerns around environment, logistics, MTO economics, and timeline slippages.

We take a brief look at the read-across for the engineering and construction sector, as well as European chemicals in the following pages.

HSBC

Engineering from China

- We estimate that China will invest a total RMB1.1trn in coal-to-chemicals projects from now until 2020
- Our capacity estimates discount the project list by 40-45%
- Sinopec Engineering is a key player because of its experience, proprietary technology, ties with large SOEs and safety record

Building CTC facilities

China's coal-to-chemicals (CTC, including coal-to-liquids, coal-to-synthetic gas, etc.) is benefitting from a more positive policy environment, and we believe this is constructive for companies with exposure to China's CTC engineering and construction (E&C) market.

Market size

From an engineering perspective, we estimate that China will see a total RMB1.1trn invested in coal-to-olefins (CTO), coal-to-gas (CTG) and coal-to-liquids (CTL) projects that are already under construction or plan to start production by 2020. Of this amount, we estimate investment in untendered new projects may generate around RMB387bn worth of new engineering, procurement and construction (EPC) contracts from 2014-18.

- **CTO:** RMB117bn of EPC contracts to build 12mtpa of new capacity to 2018
- **CTG:** RMB218bn of EPC contracts to build 89bcm of new capacity to 2020
- **CTL:** RMB52bn of EPC contracts to build 14.5mtpa of new capacity to 2018

Our estimates exclude potential investment in expanding coal-based aromatics and MEG capacities because of a lack of transparency.

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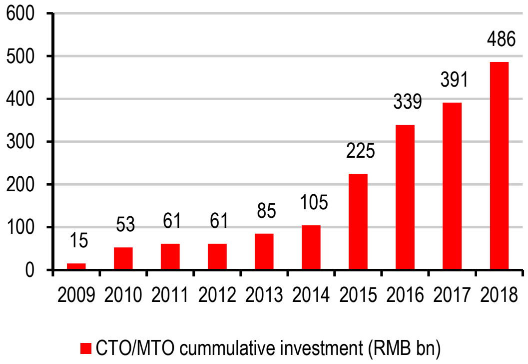
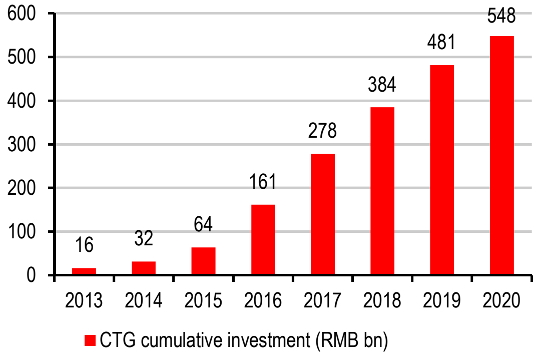
Chart 20: China's cumulative investment in coal (methanol)-to-olefins projects, 2013-18e, RMBbn



Source: AsiaChem, HSBC estimate

Chart 21: China's cumulative investment in coal-to-olefins projects, 2013-20e, RMBbn



Source: AsiaChem, HSBC estimate

We have taken a large haircut (40-45% discount) on the existing list of CTC projects. We keep those, where we think the project owners have relatively stronger financing capabilities. These include the leading SOEs in the coal, power and oil & gas industries, as well as top private companies from Inner Mongolia, Xinjiang, Shaanxi and Shanxi provinces.

Key players

Sinopec Engineering (SEG), along with China National Chemical Engineering Corp (CNCEC) and China Huanqiu Contracting and Engineering Corp are the major players in the CTC E&C market. SEG has more expertise with coal-to-olefins projects and CNCEC more with coal-to-gas projects.

According to our industry analysis, SEG will likely take a 40% share in the CTO E&C market and a 25% share in the CTG and CTL markets. Currently, SEG has RMB39bn of coal chemicals projects in its backlog, which represents 38% of the total project backlog in 2013 (up from 9% in 2010).

SEG's strengths

With 60 years of industry experience, SEG has developed strong execution capabilities in China in both engineering and the construction of large-scale oil refining, petrochemical and coal-to-chemicals complexes using in-house technology. Over the past decade, SEG has been involved in building the majority of new Chinese refining units with 10mtpa capacity and ethylene crackers with 1mtpa capacity.

Solid client base

SEG tends to work on projects with China's leading coal, power and oil & gas companies; as such, the chances of cancellations due to financing are low.

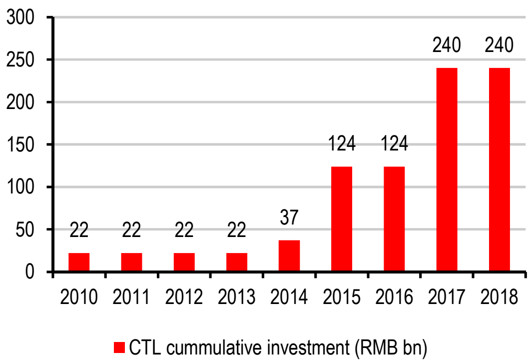
In addition, SEG's sister company Sinopec has ambitious plans to ramp up its CTO and CTG capacity in the next 4-7 years to reduce reliance on imported crude oil and natural gas. We think that SEG will likely be the designated EPC contractor for almost all of those projects if these get the go ahead. In Q4 2013, SEG won an RMB18.7bn EPC contract to build the world's largest CTO project in Inner Mongolia. The project was co-invested by Sinopec, China Coal and Shanghai Shenergy.

A leader in CTO technology

SEG's ownership of proprietary MTO technology gives it a core competence that should help it win more CTO EPC contracts.

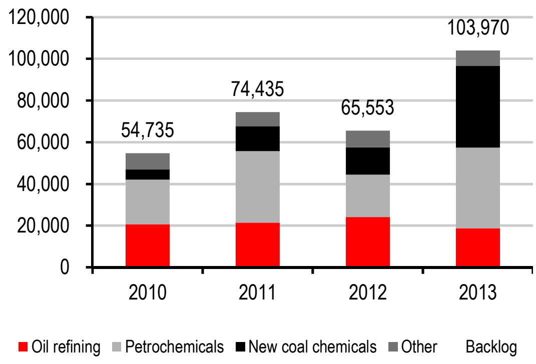
- SEG's proprietary SMTO (Synthesis MTO, including both reaction and separation)

Chart 22: China's cumulative investment in coal-to-liquids projects, 2013-18e, RMBbn



Source: AsiaChem, HSBC estimate

Chart 23: SEG end-2013 backlog breakdown by industry, RMBm



Source: Company reports, HSBC

technology achieved operational success during a trial run at the company's Zhongyuan project in 2013. It will be adopted by the world's largest CTO project, the 1.2mtpa Zhongtian Hechuang CTO project in Ordos, Inner Mongolia. SEG is the EPC contractor for both projects.

- DMTO technology – co-developed by the Dalian Institute of Chemical Physics (DICP MTO or DMTO), the Chinese Academy of Sciences and SEG's wholly-owned Luoyang subsidiary – was adopted by the Shenhua Baotou project and the Skyford MTO project in Zhejiang. Again, SEG was involved in the engineering and construction of both projects.

Good safety record

SEG stands out among China's hydrocarbon engineering companies for its good safety track record – none of SEG's refineries or petrochemical plants has recorded any serious accidents.

Gases from Europe

- Historically, most Western chemical companies used natural gas or naphtha-based feedstocks and not the CTC process
- Western chemical companies can provide engineering expertise, catalysts systems and industrial gases to Chinese projects
- Take or pay contracts are beginning to emerge

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West provides East

Approach of Western chemical companies to coal-to-chemicals

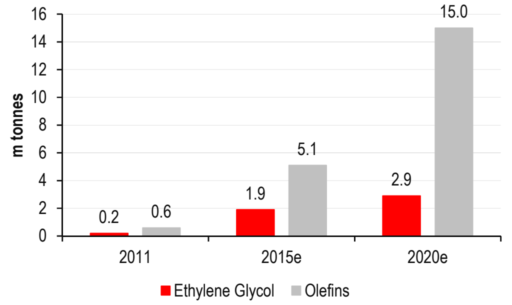
The Fischer-Tropsch process on which most coal-to-chemicals technology was based was originally pioneered in Europe in the 1920s, so for developed market chemical producers, this is not a new area. However, as most chemical companies, up until recent used either natural gas or naphtha-based feedstocks, coal-to-chemicals had become a little used process.

Supplying technology, engineering and industrial gases to China

So far, developed market chemical companies are technology providers, supplying equipment and consumables to Chinese coal-to-chemicals projects, for example, industrial gases, engineering expertise and catalyst systems.

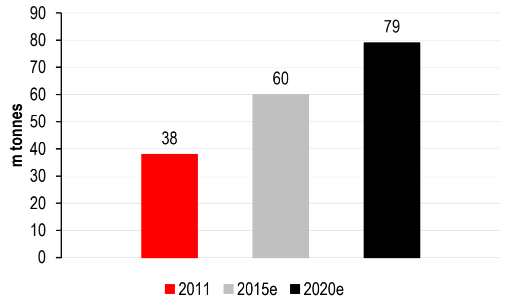
The coal-to-chemicals process is a large user of industrials gases, particularly in the gasification of coal and then in chemical process further downstream. Most gasification processes use large amounts of oxygen for the partial oxidation of the feed hydrocarbon. For example, pure oxygen is used to transform coal in synthetic gas to produce hydrogen. Also, hydrogen and ammonia are necessary for the production of caprolactam, an intermediate for nylon in the textiles industry.

Chart 24: Significant increase in China's ethylene glacial and olefin capacity from coal-to-chemicals plants



Source: Johnson Matthew

Chart 25: Expected growth of methanol capacity in China



Source: Johnson Matthew

Catalyst supplier

In the catalyst space, there are numerous suppliers for the various steps in the process; some of the biggest include Johnson Matthey, BASF and Albermarle. Johnson Matthey is the leading supplier of catalyst methanol from the syngas process, which is one of the major steps in the coal-to-olefins process, as well as supplying catalysts for oxo alcohols, formaldehyde and mono-ethylene glycol.

Moving towards take or pay contracts

Currently, Western industrial gas companies are supplying industrial gas units from an engineering point of view and have so far not entered into long-term supply contracts (take or pay) due to the uncertainty around some of the projects. However, there are some examples of take or pay contracts, which have been signed.

For example, last year, Air Liquide entered a long-term supply contract with Fujian Shenyuan New Materials to supply industrial gases for its caprolactam production project located in Lianjiang Kemen Economic & Development Zone in Fujian Province. Under the terms of the contract, Air Liquide will invest in an industrial gases complex of eight units, including an air separation unit of 2,000 tonnes of oxygen per day, a gasification unit, a purification unit of synthesis gas, and an ammonia plant to supply hydrogen, nitrogen and ammonia. These plants, to be commissioned at the beginning of 2016, should produce 75,000 Nm^3/h of hydrogen and 250,000 tonnes per year of ammonia.

Linde has also signed a long-term contract with Shenhua Group to supply oxygen to its Ningxia coal-to-liquids project, one of the largest in China. This will include six major air separation units each supplying 100,000 (Nm^3/h), which will be used in the product of 4m tonnes of liquid fuels.

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Disclosure appendix

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