

China Coal and Power

The water-related challenges of China's coal and power industries

China is at a crossroads. The coal industry from mining to power and coal-to-chemicals accounts for one-sixth of China's water withdrawals

This is not sustainable; water tables are declining and in some areas coal mining is already constrained

We believe China can achieve water sustainability in coal by adopting energy efficient growth policies and better technologies. If not, increasing coal-related water withdrawals will put further constraints on growth



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Disclosures and Disclaimer This report must be read with the disclosures and analyst certifications in the Disclosure appendix, and with the Disclaimer, which forms part of it

Summary

It is inescapable that China needs coal, and that coal needs water. In 2011, the coal industry, from mining to power generation and coal-to-chemicals conversion, accounted for roughly one-sixth of China's water withdrawals. This level of water use is not sustainable; water tables are declining and in some areas coal mining is already being constrained.

We develop a scenario analysis using the long-run coal demand forecasts from the International Energy Agency and assumptions on water use in the coal supply chain now and in the future to assess future coal-related water withdrawals. This analysis shows that China should be able to reduce its coal-related water use, even compared to 2008 levels, if it adopts energy efficient growth policies (restricting coal use to c2020 levels) and better technologies. If not, coal-related water withdrawals will continue to increase, and put further constraints on growth.

One implication of this is that long-run volume growth rates in the coal sector will be limited; the growth rates of the past decade are over. Another is that investment decisions in the coal supply chain – whether by companies, investors or lenders – will increasingly have to factor in water-related risks.

How important is this? Hypothetically, if coal mining in China were severely constrained from a lack of water from say 2030, our valuation on China Shenhua could reduce by as much as 26%, on China Coal by as much as 45%. No wonder then, that Shenhua's strategy has already shifted from 'mine the coal' to 'distribute the coal'. In the extreme if power stations were shut through a lack of water, removing the terminal value from 2030 could reduce our DCF-based valuation by about 30% for Huaneng Power.

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Water-related challenges in China's coal industry

- ▶ We develop a scenario-based approach to examine the water-related challenges in China's coal industry
- ▶ We believe that while current water withdrawal rates are unsustainable, China can achieve water sustainability in coal
- ▶ This may have significant long-term implications for coal companies including restricting volume growth, and placing greater emphasis on water-related risks

Coal and water – two inextricably linked commodities

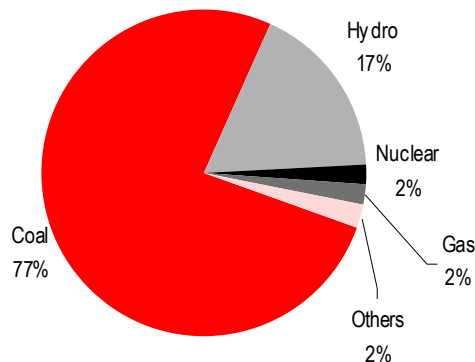
It is inescapable that China needs coal – coal accounted for almost 80% of China's energy needs in 2012 – and that coal, in turn, needs water. In 2011, the coal industry, from mining to power generation and coal-to-chemicals conversion accounted for roughly one-sixth of

China's water withdrawals. This level of water use is not sustainable; water tables are declining and in some areas coal mining is already being constrained by water shortages.

Yet, China can achieve water sustainability in coal

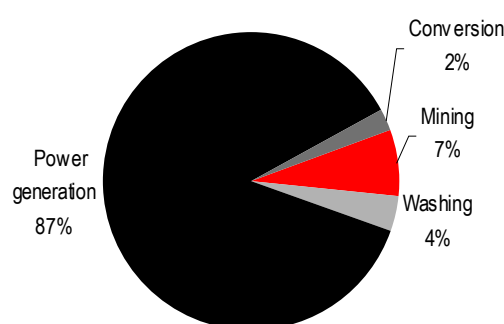
In this report we examine China's future coal-related water needs. We first examine China's current water usage (withdrawal rates) across the

China: Sources of power generation in 2012



Source: CEC, HSBC

Water use (bn m³) of coal supply chain in China



Source: HSBC estimates, IEA World Energy Outlook 2010

coal supply chain. Then, following the approach of Pan et al, Energy Policy 48 (2012) 93-102)¹, we combine these estimates of water intensity – together with some assumptions for how technological progress in the future will reduce unit water consumption at each stage in the chain – with the long-range coal consumption forecasts presented by the International Energy Agency in its World Energy Outlook 2010.

This analysis shows that China should be able to reduce its coal-related water use, even compared to 2008 levels, if it adopts energy efficient growth policies (restricting future coal use to roughly the expected 2020 levels) and importantly, if it adopts better technologies.

It also shows that by following the ‘status quo’, or even by adopting more energy efficient growth policies but not advancing technologically, China’s coal-related water withdrawals will continue to increase. This will place greater and greater strain on economic growth.

Implications for coal stocks

One implication of this is that long-run volume growth rates in the coal sector may be limited. Whereas the sector saw substantial volume growth over 2003-12 – China Shenhua’s coal output grew c270% during the period and China Coal’s grew by c340% – volume growth rates (excluding growth from potential M&A) will likely slow. This is already happening; Shenhua has markedly shifted its strategy from growth to integration.

Another implication is that investment decisions in the coal sector – whether by companies, investors or lenders – will increasingly have to factor in water-related risks. Investing in, or lending to, a coal project today, one will want to know whether it may be water-constrained in 10 or 20 years’ time. Increasing emphasis will have to be spent on assessing water risks in future.

How important is this? Hypothetically, if coal mining in China were severely constrained from a lack of water from say 2030, it could reduce our valuation on China Shenhua by about 26% and our valuation on China Coal by about 45%. In short, the issue is both substantial and urgent.

Implications for power stocks

Hypothetically, if power stations were shut for lack of water from say 2030, our DCF-based valuation on Huaneng Power could be impacted by about 30%. The power industry is well aware of water scarcity and is adjusting behaviour. Some examples of this include a shift away from coal to non-coal new build power generation and increasing use of recycled water.

¹ A supply chain based assessment of water issues in the coal industry in China; L. Pan et al., Energy Policy 48 (2012) 93-102

Water use in coal mining and processing

- ▶ China relies heavily on coal, and the coal supply chain, on water
- ▶ China's coal supply chain, from mining to power generation, accounts for roughly one-sixth of China's water withdrawals
- ▶ Coal fired power generation accounts for the majority of water use, though recycling rates are increasing

A supply-chain approach

We outline the water withdrawals at each stage of the coal supply chain – mining, washing, coal fired power generation and coal-to-chemicals.

Coal mining

China has some 15,000 coal mines with a combined production of 3.7bn tonnes in 2012. Roughly 70% of these mines are located in water-scarce regions and 40% are estimated to have severe water shortages. Water shortages are particularly severe in North China. In some areas, coal production – especially smaller mines – has already been hampered by a lack of water resources.

In coal mining, water is predominantly used for cooling mining equipment, reducing dust levels, washing tunnels and extinguishing fires.

According to Pan et al (Energy Policy 48 (2012) 93-102) a typical large-scale mine might use 0.25-0.30m³ of water per tonne of coal mined. In provinces that have varied water and coal resources, the water use standards per tonne of coal mined range from 0.06m³ to as much as

1.6m³, and smaller mines may consume even more. Open pit mining typically uses less water than underground mining, but in China, c95% of the coal mined is from underground mines.

Underground mining tends to damage aquifers. It can cause fissures that can be dangerous for underground mining. To avoid these dangers, water close to underground mines is often pumped or drained to the surface. Pit drainage in China amounts to c4.2bn m³ per annum according to Meng et al (2009)² which broadly represents a rate of 1.1-1.2m³ per tonne of coal mined. In Shanxi, now China's second largest coal producing province, 1.07m³ of underground water reserves are lost to mine one tonne of coal.

Pan et al estimate that China withdraws an average of c2.3m³ of water per tonne of coal mined both in direct mine operations and in aquifer drainage.

² *Environmental cumulative effects of coal underground mining; L. Meng et al., Proceedings of the International Conference on Mining Science & Technology (ICMST2009) 1, 1280-1284*

All in all, China's coal industry operates predominantly in water scarce areas, is a significant user of water and many operations are water-inefficient. The flip side is that there is lots of room for improvement, which if successful should mean lower water usage per tonne of coal mined in future.

Coal washing

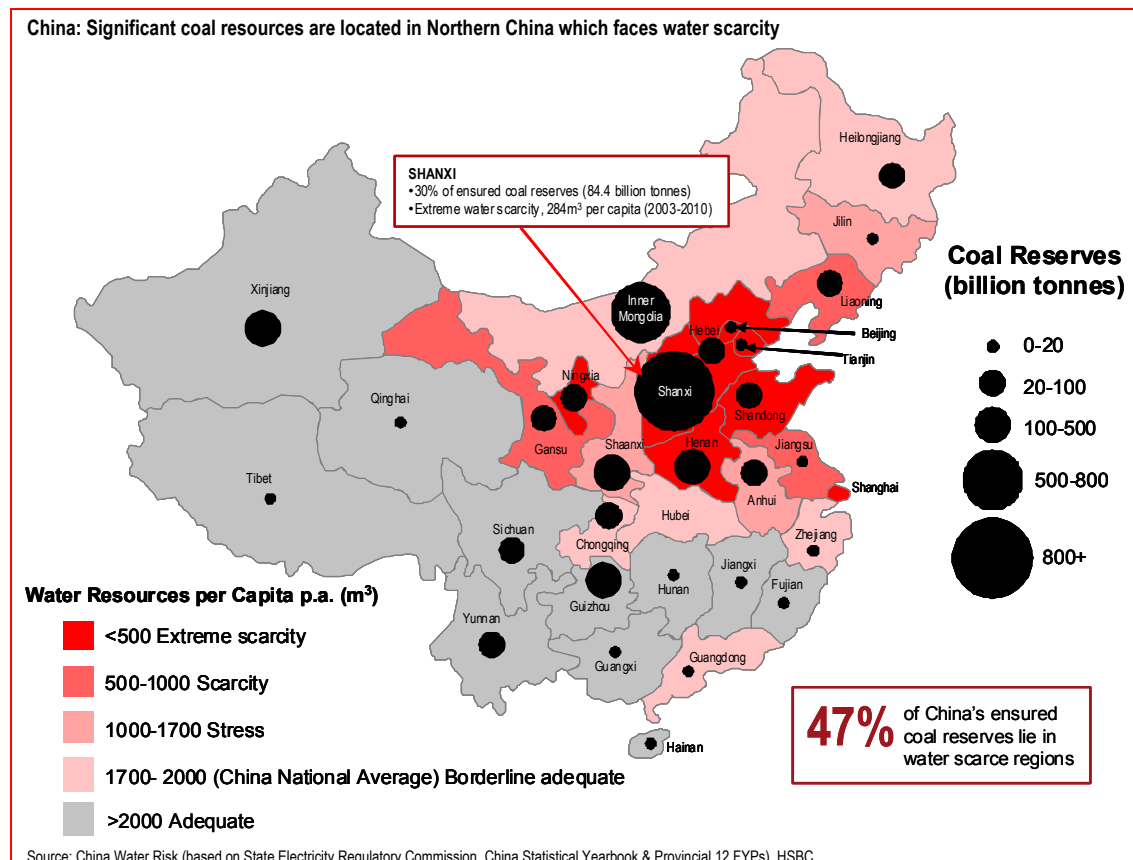
Coal is washed to improve its quality before being converted to power. The washing process reduces the levels of ash and sulphur in the coal, and thus increases the efficiency of the power units. It means that less effort has to be spent on desulphurisation in the power industry and it also reduces the need to transport non-carbon units.

In China, the ash content in raw coals is typically 25-27% and the sulphur content is c1%. Typically 60-80% of the ash content can be removed and

50-70% of the sulphur can be removed by physical preparation methods including sieving and washing. Coal washing is a mature technology and an efficient process.

Although coal can be prepared using either dry or wet methods, in China wet washing accounts for c94% of all coal washing. Typically, wet washing uses 2.5m³ of water per tonne of raw coal washed. Of this amount, most is recycled in closed loops. According to Pan et al, the average water consumption is c0.2m³ per tonne of washed coal, of which three-quarters typically stays in the product and by-products and the remainder is used in the process.

The waste water in the coal washing process contains toxic metals (such as mercury) and sulphur-based acids and must be treated carefully. Polluted water adds to issue of water scarcity.



Despite the obvious advantages of washing coal before burning, there are also some impediments in China including:

- ▶ Water scarcity – even in closed loop systems there is water consumption which may be unacceptable in very arid areas.
- ▶ Much of China's coal is young in geological terms, degrades quickly in water, and is not therefore suitable for wet washing.
- ▶ Cold weather in northern China means that in winter some coals cannot be washed as the risk of freezing is increased.

Coal-fired power generation

Thermal coal power generation accounted for c50% of total coal consumption in 2012, c40% of industrial water withdrawals and 11% of industrial wastewater discharges according to China Water Risk. About 77% of China's power generation came from coal in 2012.

In coal fired power plants water is mainly used in cooling, ash removal and boiler feed according to CEC. Average water consumption decreased from 3.9kg/KWh in 2001 to 2.34kg/KWh in 2011. This compares to an average of c2.52 kg/kwh in developed countries according to Pan et al.

In the US, the average water consumption is only about 1.78 kg/kwh, though this is because about 40% of US power capacity is gas fired. Water usage in gas-fired generators is typically less than half of that in coal fired generators.

In China, the majority of thermal power plants use recirculated water cooling – with large cooling towers. Only c5% using dry cooling (in northern regions), which use no water but are more expensive and require more auxiliary power. In Inner Mongolia, most newly approved power plants will adopt air-cooling instead of water-cooling.

Power station sites suited for once-through cooling are very limited as they need to be located close to large bodies of water (seas, lakes or rivers). Typically these are developed first as they have a lower capital cost and we expect there would be few remaining power station sites in China for which once-through cooling is available.

For more on how power stations use water please see detailed section from page 22 of this report.

Coal-to-chemicals

Historically, China has used a coal-to-chemicals conversion process to produce coke (which is used in steel making and other metallurgical processes as a reducing agent, and as a fuel) and synthetic ammonia. About 80% of China's ammonia production is synthetic ammonia produced from coal.

Relative to other usages of coal, coal-to-chemicals usage is small, accounting for only 1.3% of total industrial water consumption in 2009 (Pan et al).

Under China's industrial standards, water usage in a coking plant is required to be below 2.5m³ per tonne of coke production, and 95% of the water must be recycled. The water usage per tonne of synthetic ammonia production should not be more than 27m³ per tonne.

Surprisingly perhaps, newer coal-to-chemical plants tend to be more water intensive than older plants with a typical modern indirect coal-to-liquid plant consuming c10m³ of water per tonne of liquid production. China is expanding its coal-to-chemicals capacity rapidly suggesting that water usage may increase, yet the overall level of usage is smaller than in other parts of the coal chain.

Water withdrawals in the coal supply chain

Industrial water consumption in the coal supply chain was 90.6bn m³ in 2008. Coal-fired power generation accounted for the lion's share of this consumption.

Coal chain production indicators and water withdrawals in China

	Unit	2008
Coal demand by sector		
Total coal demand	Mtoe	1,413
Power generation	Mtoe	777
Industry	Mtoe	387
Transport	Mtoe	3
Building	Mtoe	64
Electricity generation	TW/h	2,759
Electricity capacity	GW	563
Production indicators for water withdrawals		
Coal mining	mn tce	2,827
Coal preparation (physical and chemical)	mn tce	1,414
Coal-fired power generation	TW/h	2,759
Coking production	mn tce	324.0
Coal-derived synthetic ammonia production	mn t (Ammonia)	39.8
Coal-to-Liquids	mn t(Liquid fuels)	1.5
Water withdrawals		
Coal mining	bn m ³	6.5
Coal preparation	bn m ³	3.5
Coal-fired power generation	bn m ³	78.6
Coal conversion industry	bn m ³	1.9
Total	bn m ³	90.6

Note: toe is tonne of oil equivalent, tce is tonne of coal equivalent
Source: HSBC estimates, IEA World Energy Outlook 2010

Future coal-related water needs

- ▶ We examine the long-run water needs of China's coal industry using scenario analysis
- ▶ In theory, China should be able to reduce its coal-related water use, even compared to 2008 levels, if it adopts energy efficient growth policies and better technologies
- ▶ In the absence of these factors, coal-related water withdrawals will continue to rise, placing further constraints on growth

Assessing future water use in China's coal supply chain

In this section we adopt the approach of Pan et al (Energy Policy 48 (2012) 93-102) to develop a scenario analysis approach to assess China's future coal chain water withdrawals. We use a combination of the water usage parameters for each stage of the coal supply chain discussed in the previous section, and China's long-run coal consumption forecasts set out in the International Energy Agency's World Energy Outlook Report 2010. We make some broad-based assumptions about how water usage may be reduced in future through technological advancements. We develop three scenarios, based on 1) the status quo being maintained; 2) China adopting newer, more energy efficient development policies and 3) water use being reduced as a result of technological progress.

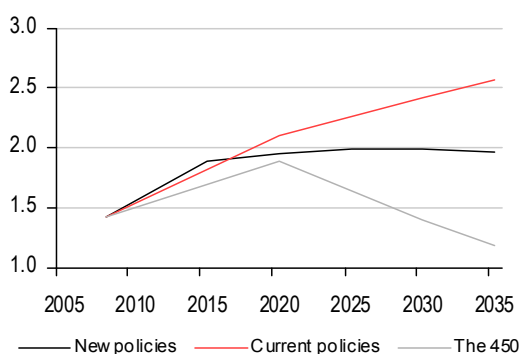
World Energy Outlook 2010

According to the IEA's World Energy Outlook 2010, the increase in China's energy demand between 2000 and 2008 was more than four times faster than in the previous decade. This was driven by rapid economic growth and a shift towards energy-intensive industries, and helped along by the loose monetary policies adopted from 2003 onwards.

Prospects for further growth remain strong; China's per capita energy demand is still only c35% of the OECD average. This means the development of China's future energy system will have major implications for global demand and supply outcomes not only in coal but also in oils and natural gas, as well as for the prospects of limiting climate change.

In World Energy Outlook, 2010, the IEA sets out three scenarios to examine the long-run energy trends.

China coal demand (bn tonnes of oil equivalent) under three IEA scenarios



Source: IEA World Energy Outlook 2010, HSBC

Current policies scenario

This scenario serves as a 'base case' in which government energy and environmental policies developed up to 2010 are assumed to remain in place, unchanged over the long run.

In the Current Policies Scenario, China's total primary energy demand is expected to rise by an average of 2.6% per annum in 2008-35. This comprises average annual growth of 3.7% in 2008-20 and 1.7% in 2020-35.

Coal demand is forecast to rise by an average of 2.2% in 2008-35 with average annual growth of 3.4% in 2008-20 and 1.4% in 2020-35.

In this scenario, China's coal demand is expected to rise from 1.4bntoe (billion tonnes of oil equivalent) in 2008 to 2.6bntoe in 2035.

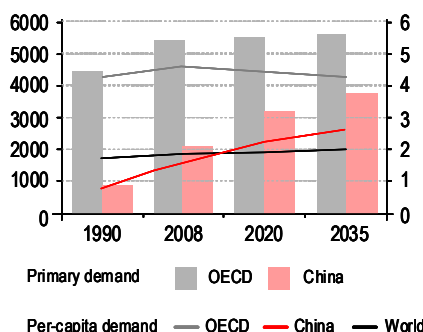
In 2008, China consumed 2.76bn tonnes of coal. (This is lower grade coal than the standard coal used in the IEA report.) The Current Policies Scenario, assuming consistent coal quality, suggests Chinese coal demand could rise to 4.11bn tonnes in 2020 and further to 5.03bn tonnes in 2035.

New policies scenario

The New Policies Scenario takes into account broad policy commitments that have been announced so far, even if there are as yet, no firm plans in place to implement these commitments.

In the New Policies Scenario, China's total primary energy demand is expected to rise by an average of 2.1% per annum in 2008-35 with average annual growth of 3.3% per annum in 2008-20 and 1.1% per annum in 2020-35, reaching two-thirds the level of the whole of the OECD by 2035.

Total primary (m tonnes of oil equivalent) and per capita (tonnes of oil equivalent) energy demand in China and the OECD in the New Policies Scenario



Source: IEA World Energy Outlook 2010, HSBC

In this scenario, the IEA estimates that coal demand will grow at an average of 2.7% per annum in 2008-20 before flattening out in 2020-35. Overall, coal demand is limited to rising at an average rate of 1.2% in 2008-35, rising from 1.4bntoe in 2008 to 2.0bntoe in 2035.

In the New Policies Scenario, the IEA expects coal's weight in the primary energy basket to decline from 66% in 2008 to 53% in 2035. Over the forecast period, China's dominance as a coal consumer increases in the world. China's share of global coal demand increases from 43% in 2008 to 50% in 2035.

Coal consumption in the power sector has been the key driver of coal demand and is expected to remain so over the forecast horizon of 2008-35.

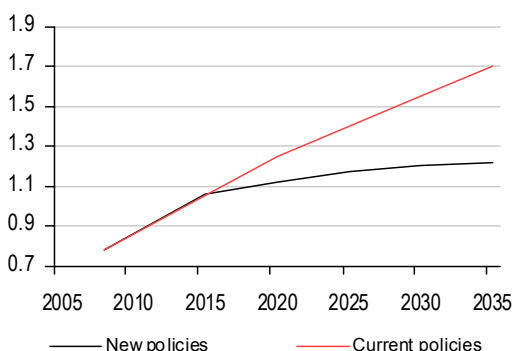
Coal demand and coal fired power of China

		Unit	Current Policies Scenario				New Policies Scenario			
			2008	2020e	2030e	2035e	2015e	2020e	2025e	2030e
Total primary energy demand	mtoe	2,131	3,288	3,907	4,215	2,887	3,159	3,369	3,568	3,737
Total coal demand	mtoe	1,413	2,104	2,422	2,574	1,879	1,952	1,981	1,990	1,975
Coal as % of primary energy	%	66%	64%	62%	61%	65%	62%	59%	56%	53%
Power generation	mtoe	777	1,252	1,551	1,701	1,059	1,123	1,171	1,200	1,220
Industry	mtoe	387	519	520	519	505	506	492	476	454
Transport	mtoe	3	0	2	3	1	1	1	2	3
Building	mtoe	64	72	62	56	73	70	63	54	54
Electricity generation	TW/h	2,759	5,037	6,605	7,440	4,199	4,595	4,850	5,060	5,246
Electricity capacity	GW	563	1,011	1,348	1,540	843	945	987	1,040	1,091
Implied load factor		56%	57%	56%	55%	57%	56%	56%	56%	55%

Notes: mtoe is million tonnes of oil equivalent
Source: IEA World Energy Outlook 2010, HSBC

IEA forecasts that power generation from coal will increase by an average of 3.1% per annum until 2020 and then at a more moderate pace of 0.6% annually until 2035. IEA's forecast assumes that China sets up 600GW of new coal-fired power generation capacity over the forecast period. This is comparable with current combined coal capacity of the US, EU and Japan.

China: Power generation from coal (bn tonnes of oil equivalent)



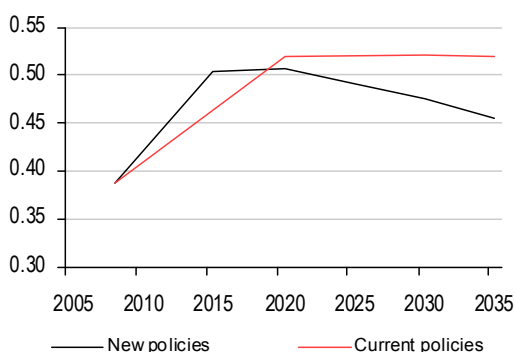
Source: IEA World Energy Outlook 2010, HSBC

China also uses coal to produce coke and synthetic ammonia. This usage represents about half the level of usage in power generation. The IEA assumes that coal used in coke and synthetic ammonia production will grow at c4% per annum until 2015, flatten out until 2020 and then decline in 2020-35.

For the purpose of assessing water usage in the coal industry, we restrict our analysis to the

Current Policies and New Policies Scenarios developed by the IEA.

China: Industry usage of coal (bn tonnes of oil equivalent)



Source: IEA World Energy Outlook 2010, HSBC

In the New Policies Scenario, again assuming consistent coal quality, Chinese coal demand could rise to 3.82bn tonnes in 2020 and further to 3.86bn tonnes in 2035.

The '450' scenario

The IEA's '450' scenario refers to a level of greenhouse gases in the atmosphere of 450 parts per million (ppm), which is the level at which climate experts believe there is a reasonable chance of limiting the increase in global temperatures to 2°C. In this scenario, the level of total coal demand in China would be less than in 2008. Given the economic growth to come and China's reliance on coal, this seems optimistic to us. We do not use this scenario in our analysis.

Calculating the coal-related water usage

To assess the level of water usage in China's coal to power chain, we aggregate water usage at each stage in the chain. This includes water used in mining, washing, burning and use in conversion applications such as coal-to-chemicals and coal-to-liquids. We calculate these usage levels by multiplying the water intensity of each stage (the water used per tonne mined, washed etc) with the number of tonnes derived from the IEA forecasts.

We make some simplifying assumptions as follows:

- 1 We assume that China's coal needs are met domestically in the long run; that is, that coal production and coal demand are the same. China has vast resources of thermal coal and should be self-sufficient in our view in the longer term. This means that all increase in coal demand would translate directly into a corresponding increase in water usage.
- 2 As washing of coal is beneficial in lowering ash content and sulphur, we assume that the rate of coal washing rises to 75% in 2020 and to 90% in 2030.
- 3 In our third scenario, we assume that the use of water gradually declines as a result of technical progress, to what is considered state of the art today, by 2025.

That is, for coal mining, we assume that China overall achieves the Shanxi large-scale mine water intensity in 2008 of c0.3m³ by 2025.

Combined with a slight reduction in pit drainage to 1.0m³ by 2025 (from 1.07m³ in 2008), we assume coal washing uses 1.3m³ of water per tonne mined by 2025. We also assume slight improvements over the next decade.

For coal washing, we assume that the state-of-the-art level is achieved by 2020. This industry is relatively new in China, and the technology mature. We assume that water usage is reduced by a further 30% over the following 15 years to a level of 1.0m³ per tonne washed by 2035.

Coal power plants withdrew water at an average rate of 28.5m³/MWh based on 2008 data according to Pan et al.

It is possible that by using 2008 as a starting point, the base level of water withdrawals in the power industry in the model is too high. China has installed a substantial amount of modern power generating equipment in the past few years and there is likely to already have been substantial improvement in water withdrawal rates.

China's coal fired power new capacity installations were high in 2007 at some 68GW (2008: 44GW) and this may mean the 2008 water withdrawals were higher than normal. The government plans to install some 195GW of coal fired capacity in 2011-15, suggesting an average rate of c49GW per annum. This is c13% less than

Water use in different stages of coal chain

Stages	Unit	Current technology 2008	Technical progress				
			2015e	2020e	2025e	2030e	2035e
Coal mining	m ³ /t	2.30	2.10	1.80	1.30	1.15	1.00
Coal washing	m ³ /t	2.50	2.20	1.50	1.33	1.17	1.00
Coal-fired power generation	m ³ /MWh	28.50	25.00	20.00	14.00	12.00	10.00
Coking production	M ³ /t	2.50	2.40	2.30	2.25	2.15	2.00
Coal-derived synthetic ammonia production	m ³ /t	27.00	26.00	25.00	24.00	22.75	21.50
Coal-to-Liquids	m ³ /t	10.00	9.67	9.33	9.00	8.55	8.10

Source: HSBC estimates

the average in 2007-08. Please see our report: [China Power Equipment: Initiating coverage](#) (29 April) for details.

We believe that China has the potential to significantly lower water withdrawal rates in coal fired power plants from 2008 levels and may indeed already have done so.

We assume a 50% reduction in water use by coal fired power plants between 2008 and 2025 and another 30% reduction in water use between 2025 and 2035.

For coal-to-liquids plants, we believe only a modest improvement in water usage is possible. This is relatively new technology and we believe it could be difficult for the industry to lower its water footprint while the focus is on expansion. We assume a modest 10% reduction in water use per tonne of liquids fuel production between 2008 and 2025 and another 10% reduction between 2025 and 2035.

For coal to synthetic ammonia we assume a 10% reduction in water usage per tonne of ammonia production between 2008 and 2025 and another 10% reduction between 2025 and 2035. The industry represented only 1.3% of total industrial water usage in 2008, we do not expect a major policy focus on curtailing water usage in this industry.

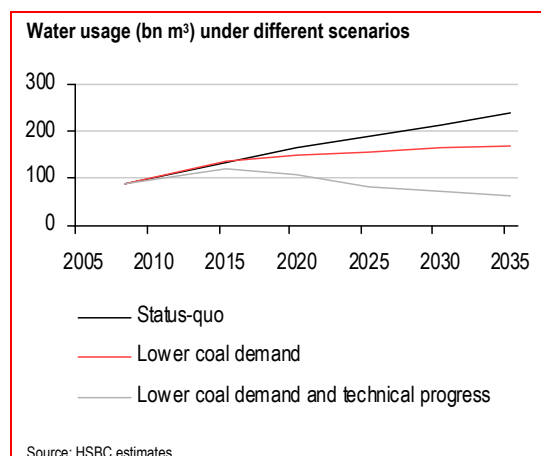
Water consumption under different scenarios

Based on this data, we look at three scenarios to assess usage of water in coal:

- ▶ Scenario 1: Status quo
- ▶ Scenario 2: Lower coal demand
- ▶ Scenario 3: Lower coal demand and technological progress

We did not consider a scenario combining current policies with our assumptions of technological

progress because substantial technological progress seems unlikely without policy support.

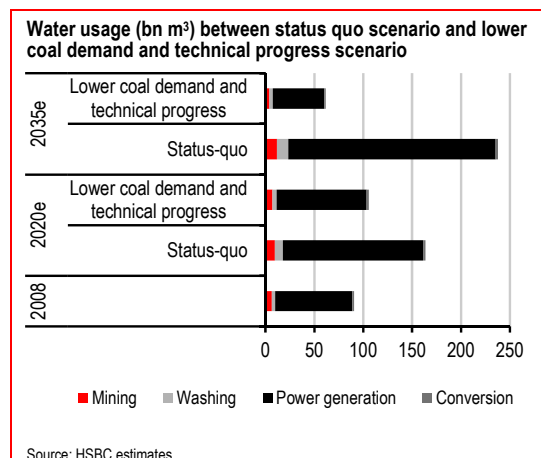
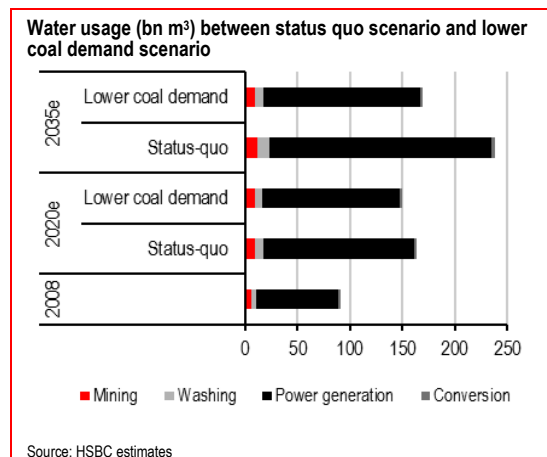


Scenario 1 – Status quo: This scenario combines assumptions in the IEA’s Current Policies Scenario with our assumptions on water use assuming current technology. This scenario aims to assess water usage without any change in policies or technology advancement. This scenario highlights that water usage in the coal chain could increase from the 2008 level by c80% by 2020 and by c160% by 2035 if the status quo is maintained.

Scenario 2 – Lower coal demand: We arrive at this scenario by combining assumptions under the New Policies Scenario of the IEA with our assumptions of water usage under current technology. This scenario assesses the impact of reduction in water usage through policy initiatives to reduce coal consumption. This scenario does not factor in any improvement in technology that could drive down water usage in each stage of the chain.

New Policies are assumed to have limited impact through 2020 and as a result, water consumption in this scenario remains high at a level of 65% above the 2008 level in 2020. As the impact of New Policies kicks in, we see a sharp reduction in the growth trajectory for water usage in 2020- 35. We estimate an increase in water usage of c85%

over 2008 levels by 2035, vis-à-vis our estimate of c160% under the status quo scenario. The reduction is mainly attributable to the IEA's assumption of flattened growth in power generation from coal over 2020-35.



Scenario 3 – Lower coal demand and

technological progress: We arrive at this scenario by combining assumptions under the IEA's New Policies Scenario with our assumption of technological progress. In this scenario, we assume that water usage in each stage of the chain also reduces as a result of technological progress. We estimate that water usage could drop back below the 2008 level by 2025. Our assumption of lowering of water usage in power generation segment, a dominant water consumer, is the main driver behind our estimate of lower water usage.

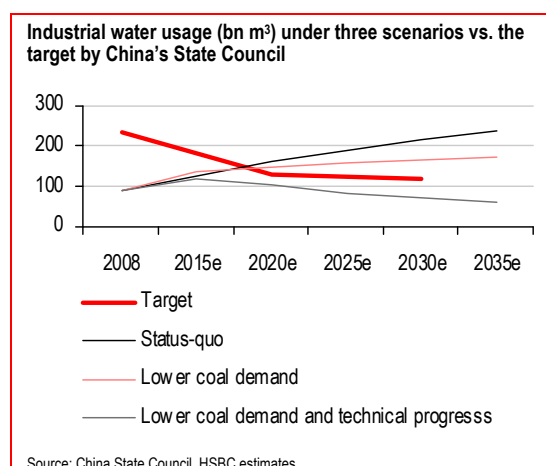
Estimate of water use by coal supply chain in China

		Current Policies Scenario				New Policies Scenario				
		2008	2020e	2030e	2035e	2015e	2020e	2025e	2030e	2035e
Coal demand and coal-fired power of China										
(IEA World Energy Outlook, 2010)										
Total coal demand	Mtoe	1,413	2,104	2,422	2,574	1,879	1,952	1,981	1,990	1,975
Power generation	Mtoe	777	1,252	1,551	1,701	1,059	1,123	1,171	1,200	1,220
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Transport	Mtoe	3	0	2	3	1	1	1	2	3
Building	Mtoe	64	72	62	56	73	70	63	54	54
Electricity generation	TW/h	2,759	5,037	6,605	7,440	4,199	4,595	4,850	5,060	5,246
Electricity capacity	GW	563	1,011	1,348	1,540	843	945	987	1,040	1,091
Implied load factor		56%	57%	56%	55%	57%	56%	56%	56%	55%
Assumptions to work out coal production and consumption rates										
1Mn tce of coal equals	Mtoe	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Coal demand met per tonne of coal mining	Mn tce	0.714	0.714	0.714	0.714	0.714	0.714	0.714	0.714	0.714
Coal sent for preparation as % of coal production	%	50%	75%	90%	90%	60%	75%	80%	90%	90%
Coal usage in coke production out of industry usage of coal	%	59%	59%	59%	59%	60%	60%	60%	60%	60%
Coal usage in synthetic ammonia manufacturing out of industry usage of coal	%	41%	42%	42%	42%	40%	40%	40%	40%	40%
Coal required per ton of Ammonia production	Mn tce	5.75	5.75	5.75	5.75	5.75	5.75	5.75	5.75	5.75
Coal consumption per tonne of liquid production	Mn tce	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Coal production and consumption rates of coal supply chain in China										
Coal mining	Mn tce	2,827	4,210	4,846	5,150	3,760	3,906	3,964	3,982	3,952
Coal preparation (physical and chemical)	Mn tce	1,414	3,157	4,361	4,635	2,256	2,929	3,171	3,583	3,556
Coal-fired power generation	TW/h	2,759	5,037	6,605	7,440	4,199	4,595	4,850	5,060	5,246
Coking production	Mn tce	324.0	433.7	434.6	433.7	432.9	433.7	421.7	408.0	389.1
Coal-derived synthetic ammonia production	Mn t(Ammonia)	39.8	53.5	53.6	53.5	50.2	50.3	48.9	47.3	45.1
Coal-to-Liquids	Mn t(Liquid Fuels)	1.5	0.0	1.0	1.5	0.5	0.5	0.5	1.0	1.5
Water use of coal supply chain in China										
Scenario 1: Status-quo										
Coal mining	bn m ³	6.5	9.7	11.2	11.9					
Coal preparation	bn m ³	3.5	7.9	10.9	11.6					
Coal-fired power generation	bn m ³	78.6	143.6	188.2	212.0					
Coal conversion industry	bn m ³	1.9	2.5	2.5	2.5					
Total		90.6	163.7	212.8	238.0					
Scenario 2: Lower coal demand										
Coal mining	bn m ³					8.6	9.0	9.1	9.2	9.1
Coal preparation	bn m ³					5.6	7.3	7.9	9.0	8.9
Coal-fired power generation	bn m ³					119.7	131.0	138.2	144.2	149.5
Coal conversion industry	bn m ³					2.4	2.4	2.4	2.3	2.2
Total						136.4	149.7	157.6	164.6	169.7
Scenario 3: Lower coal demand and water usage										
Coal mining	bn m ³					7.9	7.0	5.2	4.6	4.0
Coal preparation	bn m ³					5.0	4.4	4.2	4.2	3.6
Coal-fired power generation	bn m ³					105.0	91.9	67.9	60.7	52.5
Coal conversion industry	bn m ³					2.3	2.3	2.1	2.0	1.8
Total	bn m ³					120.2	105.6	79.4	71.4	61.7

Note: toe is tonne of oil equivalent, tce is tonne of coal equivalent
Source: HSBC estimates, IEA World Energy Outlook 2010

China's long-term water planning

China's State Council published the "Comprehensive Plan for National Water Resources" in November 2010, setting out targets for annual water use based on the expected levels of GDP and industrial value added (IVA). The State Council targets that China's industrial water usage be reduced from a level of 232m³ per RMB10,000 of GDP in 2008 to 120m³ in 2020 and further to 70m³ by 2030. It also targets to reduce water usage per RMB10,000 of industrial value added from 130m³ in 2008 to a level of 65m³ in 2020 and further to 40m³ in 2030.



Industrial value added was 49% of Chinese GDP in 2004 (broadly the start of the loose monetary policy period and the previous commodities up-cycle) and had fallen to 40% in 2009. Pan et al assume China's economic restructuring continues and that industrial value added falls further to 35% of GDP by 2020 and to 30% by 2030. Under this scenario, they calculate the amount of water

consumed in industry would fall from 168m³ in 2008 to 127m³ in 2020 and to 120m³ in 2030.

To put these forecasts into perspective, in 2008, China's water usage in the coal industry was c91bn m³, representing 54% of the total industrial water usage in China of 168bn m³ according to Pan et al. In the first two of our scenarios – the status quo and lower coal demand scenarios – our estimate is that water usage in the coal chain will be more than the State Council targets for all of Chinese industry. Even assuming technological progress reduces the water use in the coal chain, in our most optimistic scenario – lower coal demand and combined with technological progress water usage – China's coal chain would use an estimated 106bn m³ of water in 2020. This represents 83% of the State Council's target for total industrial use, suggesting to us that the target is overly optimistic.

By 2030, the State Council targets industrial water usage of 120bn m³. Again, this is less than we predict in scenarios 1 and 2 for just the coal chain. In scenario 3, we predict coal chain water use at 71bn m³ in 2030 and this represents 60% of the State Council's target. This is more broadly in line with the 2008 figures and thus seems realistic, rather than overly optimistic. The fact that our forecasts are closer to the State Council's targets in 2030 than in 2020 arises from two factors. First, in the IEA's New Policies Scenario there is little growth in coal demand in 2020-30. Secondly, we assume substantial technological benefits – especially in the power segment – from 2020 onwards.

The water use plan of China

Year	GDP RMB bn	IVA RMB bn	Water use for RMB10,000 GDP m ³	Water use for RMB10,000 IVA m ³	Total water use (TWU) bn m ³	Industrial water use (IWU) bn m ³	IWU/TWU %
2008	30,067	12,911	231.8	130.3	584	168	28.8
2020	55,833	19,542	120.0	65.0	670	137	19.0
2030	100,000	30,000	70.0	40.0	700	120	17.1

Source: China State Council, HSBC

China's energy consumption will increase substantially over the next 20 years and much of this will be coal fired. In addition, China is looking to develop coal resources in the northwest (including Xinjiang), needs to improve the level of coal washing and has an embryonic coal-to-liquids industry that is likely to be water intensive.

Our analysis suggests that if the State Council's targets are to be met, China will have to make substantial technological progress in the use of water in the coal chain.

An outline of China's water resource issues

- ▶ China has c21% of the world's population yet only c6% of its freshwater
- ▶ The agricultural and economic heartland of northern China is arid
- ▶ Coal production is already being constrained in some areas

China's water problem

Some of the greatest challenges of human development arise when large or dense populations challenge the boundaries of what nature can provide. China's continued rapid economic development presents several issues. Among these, water resource constraints – embroiling geological, geographical, social, economic and political aspects – are arguably some of the most worrying.

China has responded by implementing what is arguably the world's most ambitious water resource management programme. Even so, it is not without difficulties. In particular, government policies still generally favour economic growth over sustainable resources development.

In this section, we provide a brief outline of China's water resources issues and the current policy response of the Chinese government. More detailed analyses of these issues are available in the following reports: [*No water, no power: Is there enough water to fuel China's power expansion?*](#) (19 September 2012) and [*China's rising climate risk*](#) (6 October 2011) by Wai-Shin

Chan, Nick Robins and Zoe Knight from HSBC's Climate Change research team.

China's water footprint...

China has c21% of the world population with only c6% of its freshwater and c9% of the world's farmland. China's water resources amounted to c1,730m³ per capita in 2011. This represents less than one-quarter of the world average, less than about one-third of the average in developed countries of c6,200 m³ and close to the UN's 'stress' level of 1,700m³.

While, the national statistics do point to the scale of the issue, they also hide significant regional discrepancies in both rainfall and irrigation.

...driven by geography and climate

Large areas of eastern China and most of southern China are affected by the East Asia monsoon climate. The monsoon is prevented from penetrating deeply into the northwest of the continent by mountains meaning that precipitation is low there. In winter, China is impacted by dry cold air masses from Siberia.

According to the Food and Agriculture Organisation of the United Nations, China's average annual precipitation is 645mm, though this varies widely by region. In some regions of the southwest and in the coastal areas of the southeast, the mean annual precipitation exceeds 2,000mm. It is greater than 1,000 mm to the south of the middle and lower parts of the Yangtze River. Precipitation is lower in central and, especially in, northern China. It averages between 400mm and 900mm in the Huai River basin, in the northern plains, northeast and central China. Yet, precipitation levels are less than 400mm in some parts of northeast China and most of the northwest. It is less than 25mm in the Tarim river basin in the northwest (the longest inland river) and the Qaidam river basin in the west, of which one-third is desert.

Agricultural and economic focus in the north

This climate variation between northern and southern China, combined with wide differences in population density and economic activity, means that some areas have plenty of water, while others face chronic shortages.

In southwest China, where water is plentiful and the land less densely populated, water supply is as high as 25,000m³ per capita per annum, several times higher than the world average.

In contrast, in more densely populated and also more arid northern China, water supply falls to just 500m³ per capita per annum. Although northern China has only c20% of China's water resources, it contains 65% of China's cultivated land and produces one half its grain and nearly all of its wheat and maize. Northern China accounts for roughly half of China's GDP.

According to the Food and Agriculture Organisation of the United Nations, drought

affects an average of 15.3m ha of farmland every year, representing c13% of the total farming area.

Over the past few decades, areas experiencing water shortages have tended to rely on ground water to make up for shortages. Since the 1970s – or perhaps even earlier – the rate of water withdrawal has been unsustainable to the extent that water tables have been dropping by roughly one metre per annum across northern China.

This has obvious problems; it makes water more difficult and more expensive to access and it increases the risk of saltwater entering aquifers (areas of underground water-bearing permeable rock or materials such as gravel or sand) from which groundwater can be extracted), making them unfit for human consumption.

Northern China irrigation is poor

While China clearly does suffer from a huge imbalance in its water resources and the demand upon it from across different geographies, in some instances this is not helped by poor water system management. Northern China depends heavily on irrigation in its agriculture. According to the Food and Agriculture Organisation of the United Nations, less than half of the water withdrawn for irrigation actually reaches crops, the remainder lost through rapid evaporation and poor equipment, the result of decades of under-investment (even though the first irrigation channels in China were built c4,000 years ago).

China's overall economic productivity of water is just cUSD3.50/m³. This compares to cUSD36/m³ in the developed world.

Increasing demand for food crops such as wheat – by some estimates China will need to raise its production of agricultural products by c30% by 2030 to feed a growing population – will place further stress on scarce water resources.

The three routes of the South-North Water Transfer Project



Source: HSBC, China State Council

Coal and water

The use of coal as the primary fuel source in China places additional pressure on the country's water resources. China's largest coal basin stretches across arid northern China. In this area, water scarcity is already constraining coal production, especially for smaller scale mines.

By some estimates, it takes between 3m³ and 12m³ to process one tonne of coal.

Policy responses so far

The Chinese government has adopted two basic policies aimed at addressing these water issues. One is 'move water to where it's needed'. The other is 'use water more efficiently'.

Moving the water

China's South-North Water Transfer Project SNWTP is a multi-decade water infrastructure project that aims to transfer some 44.8bn m³ per annum from the Yangtze River in central and southwest China to the Yellow River and Hai River in northern China.

The project has three routes – eastern, central and western – with the first currently under construction and second in advanced planning stages. The total investment is anticipated to be cRMB500bn (cUSD80bn) though the final cost may well be substantially higher.

The three routes all pose substantial challenges. For instance, the plan calls for the eastern and central routes to be channelled under the Yellow River. The western route will require pumping water over part of the Himalaya's at elevations of 10,000-16,000 feet above sea level.

Yet, however technically challenging or expensive the project, it is expected to meet projected water demand in northern China, and to China's government, that must be attractive.

The 'three red lines'

In early 2012, the State Council announced the 'three red lines' policy. Under the policy, China aims to:

- 1 Limit total national water consumption to less than 700bn m³ per annum by 2030, amounting to about three-quarters of China's total annual exploitable freshwater resources.
- 2 Achieve 95% adherence to water quality standards in industry, up from just 46% in 2011
- 3 Attain or approach world advanced levels of water use efficiency by 2030, reducing water consumption per RMB10,000 of industrial value added to below 40 m³, and raising water use efficiency of farmland irrigation to above 60%.

These policies will be supported by planned investment of RMB1.8trn (cUSD288bn) in 2011-15 mainly for improvements in irrigation, reservoirs and water delivery systems in rural areas.

China water use 'Three red lines' targets

	Unit	2012	2015e	2020e	2030e
Total quantity of water consumption	bn m ³	600	635	670	700
Water consumption per RMB10,000 industrial value added	m ³	120	84	65	40
Water use co-efficiency of farmland irrigation		50%	53%	55%	60%
Water quality compliance rate		46%	60%	80%	95%

Source: The Ministry of Water Resources of China, HSBC

Water usage in China's power sector

- ▶ The power sector has used c10% of China's water to fill and replenish the water systems of coal-fired power stations
- ▶ Of this 10%, about 12% is consumed through evaporation and needs to be replenished
- ▶ China is well aware of water scarcity and is actively trying to controlling water use in the power sector

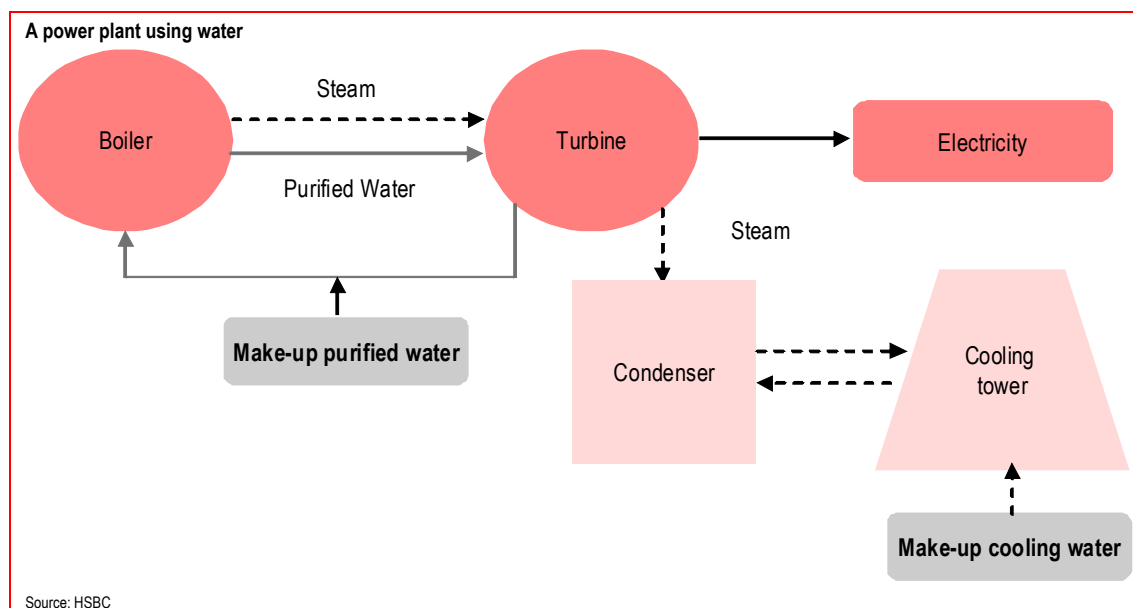
Understanding the power sector's use of water

Large water withdrawals for new power stations...

New coal fired power stations initially need a large volume of water (to fill the water cooling system which runs through the power station like a little river). Historically the power sector has been c10% of China's water use. We expect this proportion to fall as the growth rate of thermal new power station falls and renewable energy (which uses minimal water) continues to take a larger share of total new build, though in absolute terms this is expected to rise over the next few years as China's use of coal-fired power increases.

...and to replenish water lost through evaporation

Once commissioned the majority of the stock of water remains in the power station and is recirculated. Water lost through evaporation (the wafts of white cloud out of the cooling towers) has been c12% of the water withdrawn by the power industry (implying the systems need to be completely replenished about once every eight years).



How a power station uses water

Cooling power plants

Water is used by thermoelectric plants (coal, natural gas, and nuclear) in two separate systems.

- 1 Water is heated in the boiler into high-pressure steam to drive turbines. This is a closed loop and minimal water is lost in this system.

- 2 Once through the first cycle, the steam is cooled and condensed back into water. The water cooling system runs through a power station like a little river. The majority of water used by the power sector is the initial 'filling of the river' on commissioning. Most of this water is reused and only about 12% is lost through evaporation (the clouds of steam coming out of the cooling tower) and needs to be replenished (see process chart).

This cooling function to condense the steam can be done in three ways: once-through, recirculating and dry cooling.

Cooling power plants

Methods	How to work	Comments
Once-through cooling	If a coal or nuclear plant is next to a large volume of water (big river, lake or sea), cooling can be achieved by simply running water through the plant and discharging it at a slightly higher temperature.	The simplest method and water consumption is minimal. Many nuclear power plants have once-through cooling, since their location is not determined by the source of the fuel, but depends first on where the power is needed and secondly on water availability for cooling.
Recirculating cooling	Where a power plant does not have abundant water, it can discharge surplus heat to the air through cooling tower or ponds which mostly use the physics of evaporation.	This evaporates up to 5% of the flow and the cooled water is then returned to the power plant's condenser. The 3-5% is effectively consumed, and must be continually replaced.
Dry cooling	Where access to water is even more restricted, power plant can be cooled simply by air without relying on the physics of evaporation.	Uses less than 10% of the water required for a wet-cooled plant, but a lot of power (around 9-10% of a power station's output) is consumed by the large fans required and capital cost is around 15% higher.

Source: World Nuclear Association, HSBC

In China, the majority of thermal power plants use cooling towers, with only c5% using dry cooling (in northern regions), which use no water but are more expensive and require more auxiliary power.

Power station sites suited for once-through cooling are very limited as they need to be located close to large bodies of water (seas, lakes or rivers).

Typically these are developed first as they have a lower capital cost and we expect there would be few remaining power station sites in China for which once-through cooling is available.

Water use by fuel types

The amount of cooling required by any steam-cycle power plant is determined by its thermal efficiency regardless of whether it is fuelled by coal, gas or nuclear, i.e. how much heat has to be discharged into the environment.

Nuclear power requires more water than coal power: operating nuclear plants often do have slightly lower thermal efficiency at 30-35% than coal counterparts of similar age at around 40-45%. This is because coal fired plants discharge some waste heat with combustion gases, whereas nuclear plants rely on water and virtually all the waste heat has to be dumped into the condenser cooling water.

Gas power needs only one-third the amount of water as coal power: a gas turbine plant will discharge most of its waste heat in the exhaust. The exhaust is passed through a steam generator and the steam is used to drive another turbine. This results in overall thermal efficiency of over 50%.

Combined heat and power plants need less engineered cooling provision since the by-product heat is actually used for something and not dissipated uselessly.

How much water used by power industry in China

There are two sets of data typically used to describe and measure water used in thermal power plants. It is important to understand the difference between the two.

Water use/withdrawals

Withdrawal is the total amount of water a power plant takes in from a source such as a river, lake, or aquifer. Some of this water is returned. Withdrawal is important for several reasons: water intake systems can trap fish and other wildlife; water withdrawn for cooling but not consumed returns to the environment at a higher temperature and this can potentially harm wildlife; and when power plants tap groundwater for cooling, they can deplete aquifers. Power plants that use once-through cooling technology tend to have high rates of withdrawal.

Most studies focus on water use on a withdrawal basis, and this is the approach we have followed.

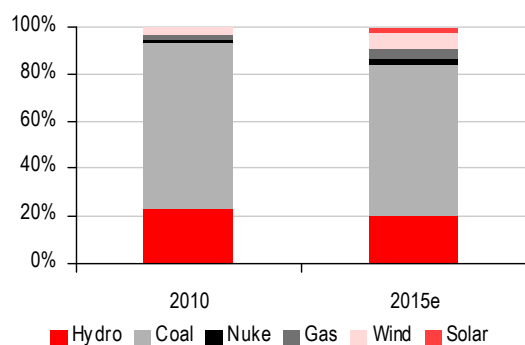
Water consumption

Consumption is the amount of water lost to evaporation during the cooling process. Consumption reduces the amount of water available for other uses, including sustaining ecosystems. Power plants that use re-circulating cooling technology tend to have lower rates of water withdrawal, but consume more water through evaporation. Water consumption is a key indicator for regulators to assess the efficiency of water use in power plants.

Obviously, water has to be withdrawn before it can be consumed. Typically, the Chinese power sector consumes about 12% of the water that it withdraws.

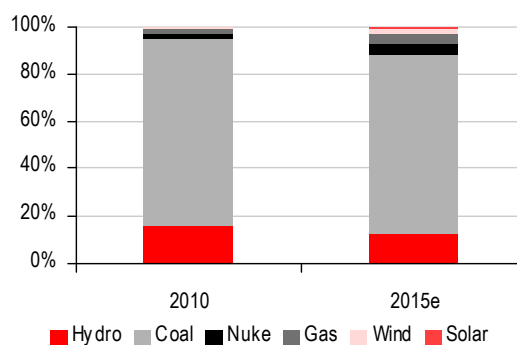
China has continued to improve the efficiency of water use in thermoelectric power plants with unit water consumption rates declining from 3.9 kg/KWh in 2001 to 2.34kg/KWh in 2011, down 40% over the decade as shown in the chart.

2015 official installed capacity



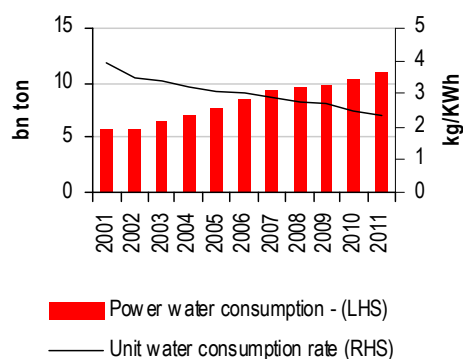
Source: CEC, NEA, HSBC estimates

2015 official generation



Source: CEC, NEA, HSBC estimates

Water consumed by thermal power



Source: China Electricity Council, HSBC

The majority of the source for power sector recycled water is urban waste water. China has strong policy support and targets to improve treatment capacity by 2015 which will likely increase the supply of recycled water available and help the power sector to meet its targets.

Urban waste water treatment

	2010	2015e	CAGR
Waste water treatment volume (mt per day)	125	208	11%
Waste water treatment rate (%)	78%	85%	2%
Reclaimed water production capacity (mt per day)	12.1	38.85	26%

Source: State Council, HSBC

Water source – fresh or recycled?

According to Frost & Sullivan, of the 71bn tons of water used by the thermal power industry in China in 2008, about 65-75% of water is used in the cooling process and 75-80% of the cooling water was recycled from wastewater. In other words, more than half of the water used by thermal power comes from recycled sources.

China's State Council has issued the "Norm of water in take" act for thermal power industry in April 2010 to strictly control the water usage in this industry. According to the Act, not only does the water intake of thermal power plants need to comply with legislation, but the recirculating cooling tower wastewater should achieve at least 90% of recycling rate in 2010 onwards.

Water use by power in future

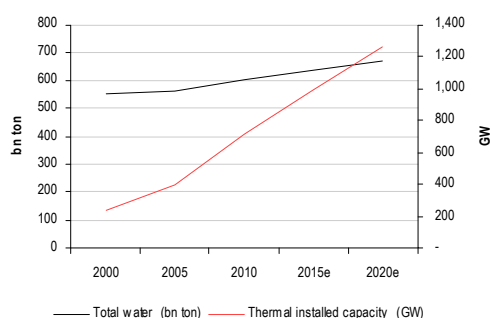
The government set a higher growth target for thermal power installed capacity than national water withdraw caps during 2010-20, as shown in the chart. We believe China will continue to introduce more water efficient technology and management in order to replenish the strict water intake requirement.

Less coal power new-build will reduce water use

In two reports [China Power: The power market is changing: less is more](#) (25 September 2012) and [China Power Equipment](#) (29 April 2013), we discuss why we concluded that China needs only 50-84% planned new generation capacity by 2015,

reflecting the maturing economy and more efficient use of existing coal-fired power station fleet. Very broadly, we estimate 1.8mt of water could be saved from consumption if China adds only 50-84% of planned coal power capacity by 2015.

Total water used / cap vs. thermal installed capacity



Source: State Council, CEC, HSBC

Total water used / cap vs. thermal installed capacity

	Total water bn ton	5-yr CAGR	Thermal installed capacity GW	5-yr CAGR	Total water / capacity bn ton/GW
2000	549.8		238		2.31
2005	563.3	0.5%	391	10%	1.44
2010	602.2	1.3%	710	13%	0.85
2015e	635.0	1.1%	928	6%	0.68
2020e	670.0	1.1%	1,260	5%	0.53

Source: State Council, CEC, HSBC

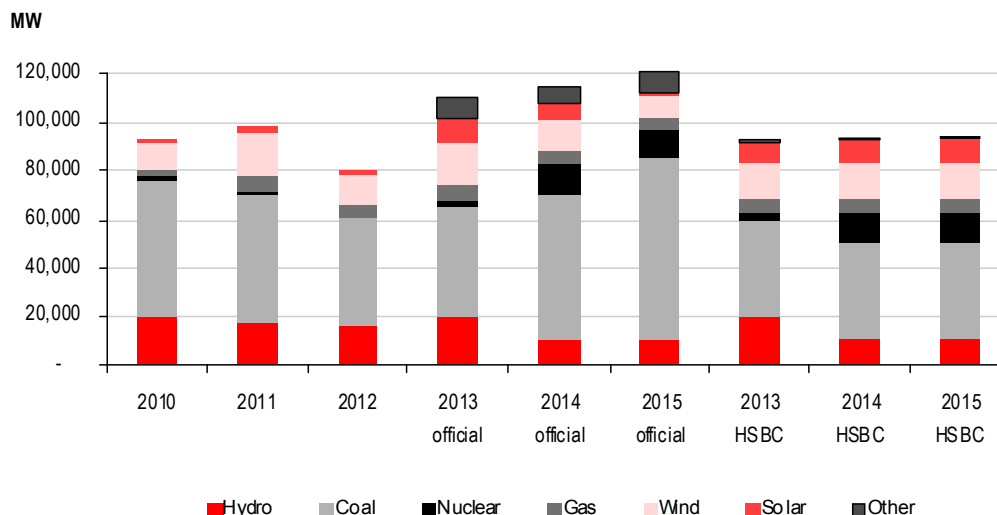
Alternative energy uses little water

Hydro and coal fuel sources have dominated China's installed power capacity for the past two decades. Coal power still contributes c80% of total power generation despite a gradual decline in its share of total capacity (74% of total capacity in 2005 vs. 69% in 2011) because it has a higher utilisation rate than other forms of power generation.

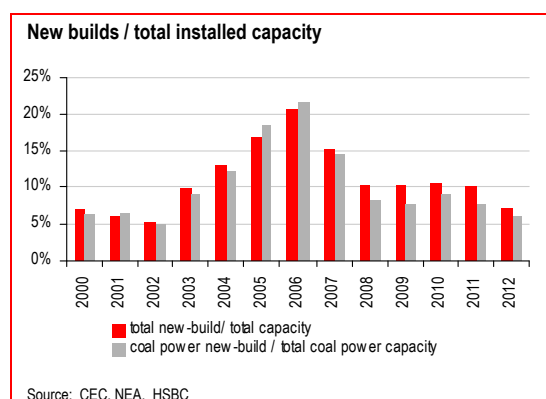
China saw a fuel mix change in the past decade, as the number of coal new-builds was capped by environmental concerns and a desire to diversify fuel sources. There has been a significant increase in renewable energy new-builds, especially wind (6% of total installed capacity in 2012 versus none in 2005), solar, and gas. Total renewable installed capacity (excluding hydro) accounted for 9% of total capacity in 2011 (7% of generation) versus 2% of total capacity (2% of generation) in 2005.

We believe increasing renewable energy could help to save water to some degree. Hydropower uses water as its fuel by running it through turbines and discharging it to a water body further downstream. In this process, the water remains unpolluted and the hydropower production process is therefore by definition non-consumptive. Wind and solar power generation use virtually no water.

China new builds by fuel type – HSBC forecasts vs officials



Source: HSBC estimates, CEC, NEA



On 8 January 2013, in China's annual national energy work conference, Liu Tienan, Director of National Energy Administration, said China would add an additional 18GW wind and 10GW solar capacity in 2013, which beat market expectations. We believe this affirmed the new government's encouraging attitude to alternative energy development.

China renewables energy Five-Year Plan

Capacity	2011	2015e	new builds pa	2012-15e CAGR
Hydro	230,510	290,000	14,873	6%
Coal	732,810	928,000	48,798	6%
Nuke	12,570	43,000	7,608	36%
Gas*	32,650	60,000	6,838	16%
Wind	45,050	100,000	13,738	22%
Solar	2,140	21,000	4,715	77%
Total	1,055,760	1,452,000	99,060	8%

Source: NEA, CEC, HSBC estimates

* HSBC estimates

Water-scarce areas

China has a history of using dry cooling technology in thermal power plants since 1960s, especially in water-scarce areas, in the northern region, northeast and northwest. By the end of 2010, 5% (35GW from around 30 plants) of total coal power capacity used dry cooling facilities in China. This is mature technology commonly used in water-scarce areas. Dry cooling uses less than 10% of the water required for a wet-cooled plant, but a lot of power (c9-10% of power station's output) is consumed by the large fans required.

Initiatives

China Resources Power actively implemented the concept of a circular recycling economy. For instance, by using the advanced technology of treating water with lime rocks, Shouyangshan Power Plant realized zero discharge of water. After being treated in a ground water treatment pool, water from coal mines is available for reuse for mine dust prevention, grouting and fire fighting; and the sewage water is mainly used to water the plants in industrial sites, thus preventing waste water generated from mine production and sewage water from polluting the daily natural water systems.

Huadian Power completed China's first demonstration project of 300MW coal fired generation units circulating water waste heat in Jiamusi thermal power plant. It could save about 7mt of standard coal per year.

Huaneng Power carries out the water saving work according to the requirements for saving resources and reducing cost. The individual power plants carry out the cascade utilization of water in accordance with the grade of the water quality, paying great attention to the in-service rate and the treatment efficiency of the water treatment equipment. The company pushes forward the management standardization work strictly according to the standard for the examination of the power-generation fresh water consumption, carries out the water balance test and water consumption examination work to further reduce the water consumption of the power plants.

Guodian Power improved its utilisation of recycling solid emissions by 2% y-o-y to 50mt in 2010. It produced 50.34mt of reclaimed water by 1% y-o-y. Its utilisation rate of producing reclaimed water increased to 90.4% in 2010.

Notes

Notes

Disclosure appendix

Analyst Certification

The following analyst(s), economist(s), and/or strategist(s) who is(are) primarily responsible for this report, certifies(y) that the opinion(s) on the subject security(ies) or issuer(s) and/or any other views or forecasts expressed herein accurately reflect their personal view(s) and that no part of their compensation was, is or will be directly or indirectly related to the specific recommendation(s) or views contained in this research report: Simon Francis, Jenny Cosgrove, Wai-shin Chan, Kirtan Mehta and Summer Huang

Important disclosures

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Rating definitions for long-term investment opportunities

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