The Hidden Costs of China's Coal-to-Chemical Sector

S&P Dow Jones Indices
ESG Analysis

A framework to stress test investments for environmental risks

September 2017

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This report is supported by Energy Foundation China, but it doesn't represent the view of Energy Foundation China.

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EXECUTIVE SUMMARY

In the future policy scenarios, the total costs from potential environmental risks are about 35% - 64% of coal-to-chemical product unit prices.

Quantifying environmental externalities is one of the priorities in green finance development in China. Both Chinese and international policy makers are emphasizing the importance of stress testing environmental risks for investment, including the use of scenario analysis. This project looks at the hidden environmental risks and financial implications in China from the bottom up, using the coal-to-chemical sector as an example.

This report presents an assessment framework to measure the hidden costs from seven risk factors under various scenarios and illustrates how investors could integrate this into existing risk and financial analysis:

- *Regulatory risks*: energy standard compliance, environmental tax, national carbon emissions trading scheme (ETS), pollutant emission right trading system, water cap compliance, and water resource tax
- *Physical risks*: water stress

To illustrate the methodology of internalizing environmental risks, this project takes the coal-to-chemical sector as an example, which produces petrochemicals, or fuels based on coal. The sector expects tremendous growth by 2020, yet it is not without significant environmental impacts. The results show that:

- In the future policy scenarios, the total costs from potential environmental risks are about 35 - 64% of coal-to-chemical product unit prices.
- Potential loss of production from regulatory compliance accounts for most of the total costs. Water is also the most prominent driving factor of risks compared to other indicators like greenhouse gas (GHG) emissions.
- Although the financial implications are relatively low in the most likely scenario, they may significantly increase as risks evolve in the future.
- The 13th Five-Year Plan (13FYP) growth target for coal to oil and coal to gas implies these risks will intensify as capacity will grow in high-risk areas as well as becoming more spread out across regions.
- Environmental risks have adverse impacts on the financial performance of projects such as lower internal rate of return (IRR), higher breakeven threshold, and higher risk of projects becoming stranded assets.

Building on these insights, Trucost recommends ways that policy makers could continue to address financial risks and opportunities through robust and consistent regulation and enforcement to encourage sustainable business decision making. This could provide a clear and effective incentive for businesses to consider environmental impacts in the management of their operations.

Investors should consider integrating this kind of in-depth assessment of environmental risks into their current financial analysis. Investors should also recognize that ex-ante and ongoing due diligence are also vital to increase the resilience of portfolios to environmental risks.

INTRODUCTION

Using China-specific impact and risk data, Trucost analyzed the hotspots of risks across key products and regions to illustrate the potential hidden costs to be considered in financial analysis.

Background

Quantifying environmental externalities has been one of the priorities in green finance development in China. In particular, environmental stress testing is the key to translating externalities into credit and investment risks. The "Guidelines for Establishing the Green Financial System," jointly published by seven government departments including the People's Bank of China (PBoC), the Ministry of Finance, and the National Development and Reform Commission (NDRC) prior to the G20 summit last year, encourages financial institutions to take environmental and social risks into their risk analysis via stress testing. The international investor community is also experiencing similar momentum with the Task Force on Climate-related Financial Disclosures (TCFD) calling for measurement and disclosure on climate-related risks using scenario analysis (TCFD, 2017).

Trucost is devoted to quantifying environmental externalities in China to help financial institutions better manage the impacts of their investments. In March 2017, Trucost and the Industrial and Commercial Bank of China jointly launched an environmental stress-testing framework for the aluminum sector in China, assessing how much externalities could potentially be internalized as financial costs for businesses and the implications for credit risk. To further demonstrate how to incorporate environmental risks in financial analysis, EFC appointed Trucost to expand the assessment framework and take the coal-to-chemical sector as a representative example.

The coal-to-chemical sector plays a crucial role in China for diversifying the use of coal and buffering economy disruptions during the low-carbon transition away from coal power generation. In particular, the modern coal-to-chemical products – coal to oil, coal to gas, coal to olefins, and so on – receive ongoing policy endorsement for their growth and development. In the 13FYP, the Chinese government sets goals of a five-fold increase in capacity for coal to oil and coal to gas by 2020. While tremendous growth is expected for modern coal-to-chemical products, their environmental impacts, especially GHG emissions and water use, are often controversial. It is unclear to investors how these environmental impacts may translate into financial costs, and most importantly, how these risks could be incorporated into existing financial analysis to improve risk management.

Objectives

To better inform investment decision making, this project aims to develop a pragmatic framework for investors to assess environmental risks using the coal-to-chemical sector as an example. This report describes how Trucost developed a stress-testing framework to measure the hidden financial cost of the sector given its environmental impacts under various scenarios. Using China-specific impact and risk data, Trucost analyzed the hotspots of risks across key products and regions to illustrate the potential hidden costs to be considered in financial analysis. Using case studies, this report further demonstrates how investors could leverage this framework in their existing risk analysis and management practices. With the framework and findings, this project intends to provide recommendations for the industry, its investors, and policy makers on closely linking environmental risks and financial analysis in the future.

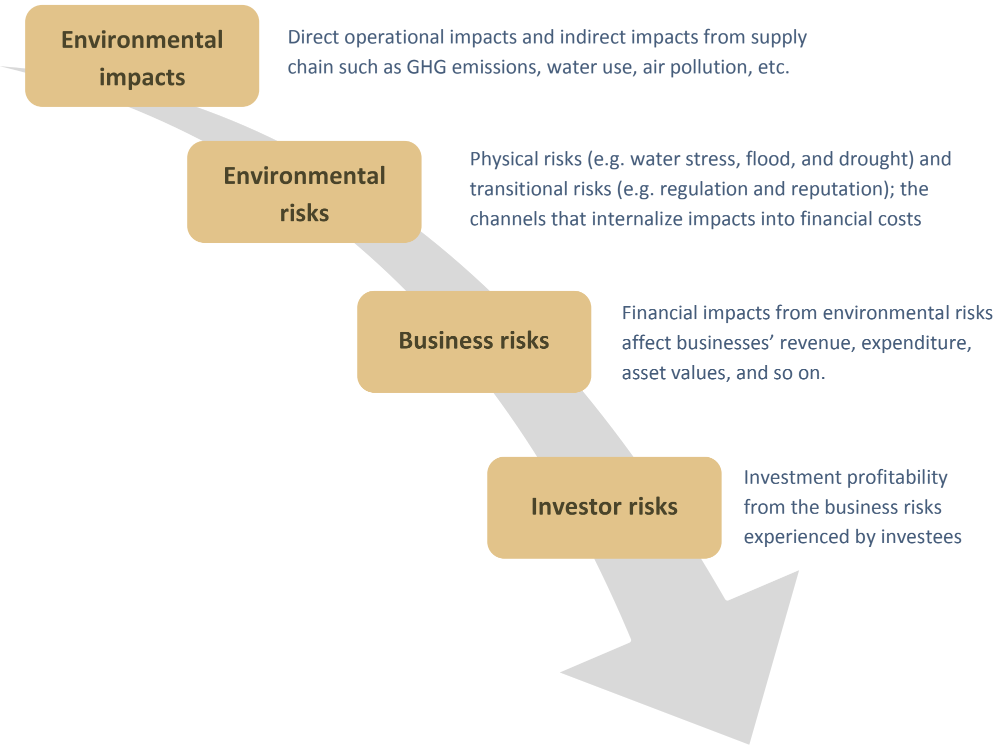
This report illustrates how some of these risks translate into financial cost under different scenarios and how companies and investors could incorporate these into financial analysis.

SCOPE & METHODOLOGY

DEFINTION OF ENVIRONMENTAL RISK AND ASSESSMENT FRAMEWORK

Economic development often results in environmental impacts such as air pollution, water depletion, greenhouse gas (GHG) emissions, and other issues. Environmental impacts could be internalized and lead to adverse effects on the financial performance of businesses and investors – also known as environmental risks. Environmental risks can be categorized into physical risks and transitional risks. Physical risks relate to potential losses from floods, droughts, rising sea levels, and other climate change impacts on the environment. Transitional risks stem from the shift to a greener or low-carbon economy, which could be further broken down into regulatory risks, technology risks, market risks, litigation risks, and reputational risks. All of these risks could impose positive and/or negative impacts on businesses' revenue, operational costs, capital expenditure, insurance, etc. Exhibit 1 below illustrates how environmental impacts could become risks for businesses and investors.

EXHIBIT 1: THE KEY TYPES OF ENVIRONMENTAL RISKS FOR STRESS TESTING



The transfer from environmental impacts to business risks could occur via different risk factors. Exhibit 2 lists the various types of environmental risks and their definitions.

EXHIBIT 2: THE KEY TYPES OF ENVIRONMENTAL RISKS FOR STRESS TESTING

Physical risks		The potential loss from floods, droughts, water stress, rising sea level, and other environmental-risk-related impacts on the ecosystem.
Transitional risks	Regulatory risk	Risks associated with regulation compliance such as emissions standards, pollution control, market-based mechanism, and so on.
	Technology risk	The impacts of technological changes required for the transition to a greener economy. It often involves changes in CAPEX and OPEX for business to continue their production under the new regime.
	Market risk	The pass-through of other risks throughout supply chain, for example changes in supply of production input due to physical risks and changes in demand by reputational risks.
	Litigation risk	Litigation arising from regulatory compliance or environmental incidents initiated by nongovernmental bodies.
	Reputational risk	The potential damage to a brand's reputation as a result of environmental incidents, regulatory infringement, or sales of environmentally unsustainable products or services.

The overall framework is applicable to any sector, while specific risk factors may vary across sectors and regions. This report illustrates how some of these risks translate into financial costs under different scenarios and how this could be incorporated into financial analysis by companies and investors.

EXHIBIT 3: EXAMPLE OF LOSS OF PRODUCTION FROM REGULATION NON-COMPLIANCE

In January 2013, the Ministry of Environmental Protection issued an administrative punishment decision to China Shenhua Coal to Liquid and Chemical Co., Ltd. – a subsidiary of Shenhua Group – for the outstanding environmental measures at its coal to olefin project in Baotou, Inner Mongolia. The decision imposed production suspension and a fine of 100,000 CNY for the project (Ministry of Environmental Protection, 2013). The cost of production suspension is estimated to be approximately 4.1 million CNY per day (Xinhuanet, 2013). This demonstrates the possibility and scale of the financial risks related to environmental regulation compliance.

SCOPE

This research focuses on the direct environmental impacts of the coal-to-chemical sectors and seven key products, including coal to oil, coal to gas, coal to olefins, coal-based methanol, coal-based ammonia, coking, and calcium carbide. This would include any environmental impacts generated during the operational phase. Applying the risk framework as shown in Exhibit 1, two types of risk factors are considered more relevant to the sector and measurable – regulatory and physical risks. These two risk factors can be further broken down into seven sub-factors, imposing financial implications for businesses in this sector. The seven risk factors were selected based on their policy relevance – commonly discussed in environmental policy development or having at least partial legal or administrative basis for implementation – and feedback from experts during stakeholder consultation. Note that the physical risks here only include water stress – defined as impacts on production caused by water stress in the region – and not other event-based physical risks due to data availability. Exhibit 4 shows the breakdown of the risk factors covered in this research.

EXHIBIT 4: KEY ENVIRONMENTAL RISK FACTORS INCLUDED IN THE ANALYSIS

RISK FACTOR	RISK SUB FACTORS	POTENTIAL FINANCIAL IMPACTS
Regulatory risk	Energy standards compliance	Loss of production from suspension due to non-compliance with energy standards
	Water cap compliance	Loss of production from suspension due to non-compliance with water cap
	Environmental tax	Tax payment according to a list of pollutants and wastes
	Water resource tax	Tax payment for water consumption
	National carbon ETS	Cost for purchasing permits when emissions exceed allocation for coal-based ammonia, methanol, and calcium carbide[1]
	Pollutant Emission Right Trading System	Cost for purchasing pollutant emission permits
Physical risk	Water stress	Loss of production from the lack of water due to regional water stress

The risk factor represents potential costs that are not currently accounted for in the sector's financial metrics. The financial costs estimated here are additional to what is currently charged in the market (i.e. baseline costs). While three of the risk factors are measured by the potential loss of production, the factor with the largest loss will be selected for cost aggregation in the analysis. In particular, the potential loss of production from regulatory risks is given priority, while the realization of water stress risks involves higher uncertainty than the regulatory risks[2].

Each of these risk factors is associated with specific environmental indicators such as air pollutants, water use, GHG emissions, and so on. Except for environmental tax and national carbon ETS, all other risk factors are subject to regional variation. Although the environmental impact data for a particular coal-chemical product is China's industry average, the financial cost of the product could still vary across

[1] Although coal-to-olefin projects may involve methanol as intermediate products and could indirectly be included under the national carbon ETS, project and regional data of that share of methanol production within coal-to-olefin production in terms of emissions is not available. It is also not yet clear how this will be accounted for in cap allocation, therefore, the national carbon ETS cost is not applied to coal to olefins in this analysis.

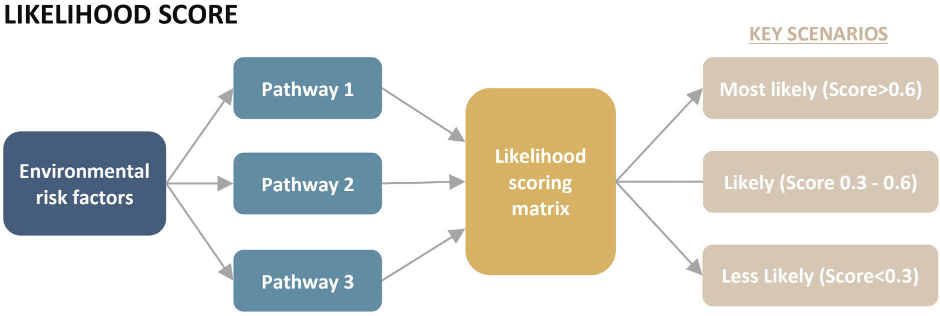
[2] Water stress risks are measured by comparing the share of water available to a project or asset from local water stress and economic activity and the sector average water intensity (ECOLAB, 2017). Therefore, the actual water stress highly depends on the water use and economic condition in the region, which imposes some uncertainty in estimating the potential loss from water shortage.

regions for this reason. The data for environmental impacts of the seven key products is based on China-specific Life-Cycle Assessment (LCA) data, whereas risk factor data is collected based on the review of China's environmental policies, water data from the World Resource Institute, and government statistics.

SCENARIO ANALYSIS

Trucost constructed several plausible pathways for each of the seven risk factors based on policy review, discussions, and debates, as well as stakeholder consultation[3]. For example, the plausible pathways for environmental tax are the lower limit and upper limit of tax rates as stated in the law. These pathways were categorized into a set of key scenarios based on their likelihood scores. Exhibit 5 below illustrates the process of scenario development.

EXHIBIT 5: BUILDING SCENARIOS FROM RISK FACTORS, PATHWAYS, AND LIKELIHOOD SCORE



Likelihood was assessed based on a set of criteria that is considered influential for risk factors to be realized. Trucost developed two different likelihood matrices for regulatory risk and physical risk (water stress). Both matrices generated a likelihood score for each pathway using the weighted sum of scores of all criteria. Weighting for regulatory risks was constructed based on an interaction matrix, assuming that if a criterion has positive correlation with other criteria, the criterion will have a relatively higher influence over the likelihood of the risk factor[4]. The interaction matrix was developed by Trucost based on review and examples of environmental policy development process in China. Exhibit 6 below lists the criteria of the likelihood matrix for regulatory risks and their definitions, with a score of zero indicating low likelihood and a score of two for high likelihood.

[3] As part of the project, Trucost and EFC organized two consultation workshops collecting feedback and comments from local experts from the industry, financial institutions as well as non-governmental organizations in regards to the research framework and methodology.
[4] Where some criteria do not apply to a particular risk factor, the weighting is adjusted accordingly.

EXHIBIT 6: LIKELIHOOD MATRIX FOR REGULATORY RISKS

CRITERIA	DEFINITION	LIKELIHOOD SCORE			WEIGHTING
		2 (HIGH)	1 (MEDIUM)	0 (LOW)	
Legal status	Is there any legislation passed for the risk factor?	Yes, passed as law	Yes, passed as guidance	No	13%
Endorsement from central government	Is this risk factor addressed in major environmental policies or by government officials?	The implementation is clearly stated in major environmental policies (e.g. 13 Five-Year Plan)	Policy relevant to implementation is undergoing development or consultation	The potential development of this risk factors is discussed	13%
Implementation authority	Is there any authority designated for the implementation and with necessary capacity?	Authority(s) is appointed for implementation with existing capacity to support the implementation (e.g. finance department to collect environmental tax)	Authority(s) is appointed for implementation with the need to build new capacity to support implementation (e.g. emission trading platform)	Authority designation is unclear or non-existent	13%
Effective timeline	Is there any timeline for risk factor to be implemented?	1 - 3 years	3 - 5 years	> 5 years or unknown	12%
Endorsement from local government	Is there any implementation plan by provincial government?	All or most of the provinces have published implementation plans	Some of the provinces have published their implementation plans	Few or no provinces have published their implementation plan	12%
Implementation resources	Is resource (e.g. data, scope) available and ready for implementation? Capability to support the required stringency for implementation?	Resources are available and ready for implementation, or there is clear evidence that resource preparation is underway for all relevant provinces. Implementation is supported by full capability	There is evidence of only a minor number of provinces starting / undergoing the preparation, with sufficient capability to implement	It is unclear whether resource or capability is available and ready for most provinces	11%
Effectiveness of pilot schemes	If there are any pilot schemes in place, how effective is the implementation?	It achieves or more than achieves the targeted outcomes	It is slightly under achievement	There is little achievement	10%
Leverage of existing policy / enforcement structure	Does the risk factor leverage the implementation mechanism of any existing policies?	It is a replacement of an existing scheme and adopts its implementation mechanism in place	It is a revision of an existing scheme	It is a new scheme with little reference to existing measures in place	8%
Measure stringency	What is the nature of the policy driving this risk factor?	Tax / fees	Compliance standards	Voluntary / event-based	7%

Source: Trucost 2017

The likelihood matrix for water stress risk adopts and expands on the "Water Risk Monetizer" (WRM) methodology developed by Trucost in collaboration with Ecolab (ECOLAB, 2017). Exhibit 7 summarizes the scoring criteria and weighting for the likelihood score for water stress risks.

EXHIBIT 7: LIKELIHOOD MATRIX FOR WATER STRESS RISKS

CRITERIA	DEFINITION	LIKELIHOOD SCORE			WEIGHTING
		2 (HIGH)	1 (MEDIUM)	0 (LOW)	
Baseline water stress score	Average potential for reduced water availability at the present based on WRI data on water stress, weighted by current coal chemical production across provinces	< 30%	30% - 60%	>60%	33%
Future water stress score	Average potential for reduced water availability in the future based on WRI data on water stress, weighted by current coal chemical production across provinces	< 30%	30% - 60%	>60%	33%
Inter-annual variability score[5]	Average inter-annual variability, weighted by current coal chemical production and water supply across provinces	< 30%	30% - 60%	>60%	8%
Seasonal variability score[4]	Average seasonal variability, weighted by current coal chemical production and water supply across provinces	< 30%	30% - 60%	>60%	8%
Legal status	Is there any legislation passed for the risk factor?	Yes, passed as law	Yes, passed as guidance	No	3%
Endorsement from central government	Is this risk factor addressed in major environmental policies or by government officials?	The implementation is clearly stated in major environmental policies (e.g. 13 Five-Year Plan)	Policy relevant to implementation is undergoing development or consultation	The potential development of this risk factors is discussed	3%
Effective timeline	What is the effective timeline of the risk measures from WRI?	1 - 3 years	3 - 5 years	> 5 years or unknown	2%
Endorsement from local government	Is there any implementation plan by provincial government?	All or most of the provinces have published implementation plans	Some of the provinces have published their implementation plans	Few or no provinces have published their implementation plan	3%
Leverage of existing policy / enforcement structure	Does the risk factor leverage the implementation channel of any existing policies?	It is a replacement of an existing scheme	It is an revision of an existing scheme	It is a new scheme with little reference to existing measures in place	3%
Measure stringency	What is the nature of the policy driving this risk factor?	Tax / fees	Compliance standards	Voluntary / event-based	2%

Source: Trucost 2017 (ECOLAB, 2017; WRI, 2016)

Note that likelihood does take into account the potential timeline of a risk factor ("effective timeline" as one of the scoring criteria). Aggregating all criteria, the likelihood score therefore is an indirect representation of whether a risk factor is likely to be materialized in the near term.

[5] High inter-annual and seasonal variability means there is a larger variation in water supply between years and as such, the water basin could be prone to more severe droughts and floods (ECOLAB, 2017).

Similar to mainstream risk assessment framework, these matrices provide an overarching structure for investors to rank different pathways and select scenarios of interests based on their own risk profile. The criteria are also applicable to other sectors and could vary across risk factors if necessary. To shortlist a few sets of key scenarios, Trucost categorizes plausible risk factor pathways by their likelihood scores into "Most Likely" (score > 0.6), "Likely" (score between 0.3 and 0.6), and "Less likely" (score < 0.3). Exhibit 8 below summarizes the final set of risk factors included in these three scenarios.

EXHIBIT 8: SUMMARY OF RISK FACTORS BY SCENARIOS

RISK FACTOR	SCENARIOS		
	MOST LIKELY	LIKELY	LESS LIKELY
Energy standards compliance	Compliance against the "average values" in current standards	Compliance against the "advanced values" in current standards	
Water cap compliance	***Compliance against the "average values" in current standards***	***Apply average of current caps to provinces currently without any cap***	Apply "advanced values" in current standards when available and the average of current caps to provinces and products currently without any cap
Environmental tax	Lower limit of tax rate proposed in law	Upper bound of tax rate proposed in law	
Water resource tax	N/A	***Assume national implementation based on the Hebei pilot***	***Assume national implementation with the raise in tax based on the difference between current water resource fees and tax***
National carbon ETS	30 CNY / tCO_2e	65 CNY / tCO_2e (average of initial price range 30 - 100 CNY / tCO_2e)	200 CNY / tCO_2e
	100% free allocation for cap based on "average energy intensity" for calcium carbide, methanol, and ammonia industries		
Pollutant Emission Right Trading System	N/A	Assume national implementation at average price of pilot schemes in Inner Mongolia, Shaanxi, Hunan, Jiangsu, and Gansu	
Water stress	***Water stress up to 2020***	***Water stress up to 2030***	

Note: Italic text indicates risk factors with regional variations

Source: Trucost 2017, provincial industrial water caps, (Environmental Protection Department of Hunan, 2016; IMDRC, 2016; IdeaCarbon, 2017; Ministry of Industry and Information Technology, 2014; National Energy Administration, 2017; National People's Congress, 2016; SXDRC, 2017; State Council of the People's Republic of China, 2017; Tanpaifang, 2017; Tanpaifang, 2016) (WRI, 2016; Xinhuanet, 2015)

APPLICATION IN FINANCIAL ANALYSIS

Scenario analysis provides a range of plausible outlooks for environmental risks. This framework allows investors to conduct a materiality assessment for their portfolios using regional and sector averages as defaulted in this analysis. This would enable financial institutions to identify hotspot projects or products in their investment portfolio that need further assessment and provide insights on high-level risk management strategy. This framework could also be enhanced with asset-level data to conduct company or site-specific analyses. The output of such company analysis could feed into investors' current financial and risk analysis in forms ranging from cost ratio to balance sheet. In the following section, Trucost provides some examples of this application using some case studies.

LIMITATIONS

Due to data constraints and relevance to the sector, risk factors from Exhibit 1, including reputational risk, litigation risk, market risk, technological risk, and event-based physical risk, are not included in this research.

Reputational risk is mainly driven by underperformance against stakeholders' expectations, namely investors, consumers, and the government. While state-owned companies dominate coal-to-chemical production in China, the sector is mostly concentrated in the upstream of the chemical or petroleum products' value chain. These two factors weaken the influence of investors and consumers on the sector's reputational risks. Though government has the most influence on the sector's reputation, the Chinese government takes the role of facilitator towards the sector's development in alignment with the national strategy on alternative use of coal as well as research and development in this area. At the same time, the government closely monitors and regulates the environmental performance of the sector, including imposing fines for incidents revealed in certain projects. However, reputational costs derived from such a relationship is yet unclear.

Litigation risk is another factor excluded from this research. The supporting infrastructure for materializing litigation risk is undergoing its early development in China. While the Environmental Protection Law passed in 2015 provided the legal foundation and rights for civil society to sue polluters, the high legal cost creates a significant financial barrier for civil society to initiate any litigation

(Chinadialogue, 2016). To further empower civil litigation rights against environmental damages, a few "ecosystem damage compensation pilot schemes" have been developed in Jilin, Jiangsu, Shandong, Hunan, Chongqing, Guizhou, and Yunnan under the guidance and support of China's State Council and Ministry of Environmental Protection (Ministry of Environmental Protection, 2016; State Council of the People's Republic of China, 2015). There have been few successful cases where polluters were sanctioned for compensation (see Exhibit 9). While the relationship between damages and compensation evaluation is determined on a case-by-case basis, further data and progress in national implementation would be essential for the measure of litigation risks in China.

EXHIBIT 9: EXAMPLE OF LITIGATION RISKS IN CHINA

In July 2016, the Intermediate People's Court of Dezhou City required Jinghua Group, a power generator and glass manufacturer, to pay compensation of 21.9 million CNY towards restoring air quality in the city and make a public apology via a media platform at provincial level or above. The All-China Environment Federation – a government-affiliated NGO – initiated this case against the firm's violation to air pollution standards. The compensation amount accounts for both air quality restoration cost (25%) and ecosystem damage compensation (75%), assessed by the China Academy of Environmental Planning (All-China Environment Federation, 2016).

There are three main types of market risks: fluctuations in market price for production input due to environmental causes like water stress, financial costs from other risk factors (as in Exhibit 1) passed through the supply chain, and the changes in demand driven by environment-related concerns. Given that the scope of this research focuses on the direct impact and costs araised from the operational phase, these market risks are not included in the analysis. However, the conventional risk assessment and due diligence currently in place at financial institutes should cover, at least in part, the risks from changing market price and demand that are directly or indirectly driven by environmental reasons.

Additionally, risks analyzed here may not fully reflect the financial costs arising from environmental incidents – either due to non-compliance of environmental regulations or technical issues – in the form of fines or pollution clean-up fees. Environmental incidents that have previously occurred in the coal-to-chemical sector prove the associated costs could be significant (see Exhibit 10). Although it is challenging to systematically quantify these kinds of costs, investors should apply due diligence processes on the compliance of projects with regulations and their incident management systems.

EXHIBIT 10: EXAMPLE OF REGULATORY FINES AND COSTS ARISEN FROM INCIDENTS

In April 2016, highly saline sewage leaked from the evaporation pond of the Datang Duolun coal-to-olefins project to an area of roughly 800 acres and caused underground water contamination. About 2,200 local villagers had to be relocated as a result. Datang was ***fined for 287,000 CNY*** with roughly ***three months halt in production*** for mitigation, costing the company approximately ***371 million CNY of loss in revenue*** (China Economic Net, 2016). Later in August 2016, a methanol tank explosion occurred at the same site. This led to a direct loss of raw material and equipment of 7.5 million CNY for the company (21st Century Business Herald, 2016).

In 2014, Yunnan Xianfeng Chemical Industry Co., Ltd. received over 177 complaints about air pollution at its coal-to-oil project in Yunnan. The issue had not been resolved and resulted in a suspension in production and a total fine of 550,000 CNY between 2014 and 2016. This, however, was not able to force the company to address the issues and production was resumed without official permission. In November 2016, the provincial government ordered a production suspension again and prosecuted the executives of the company for the "crime of pollution" (China News, 2016).

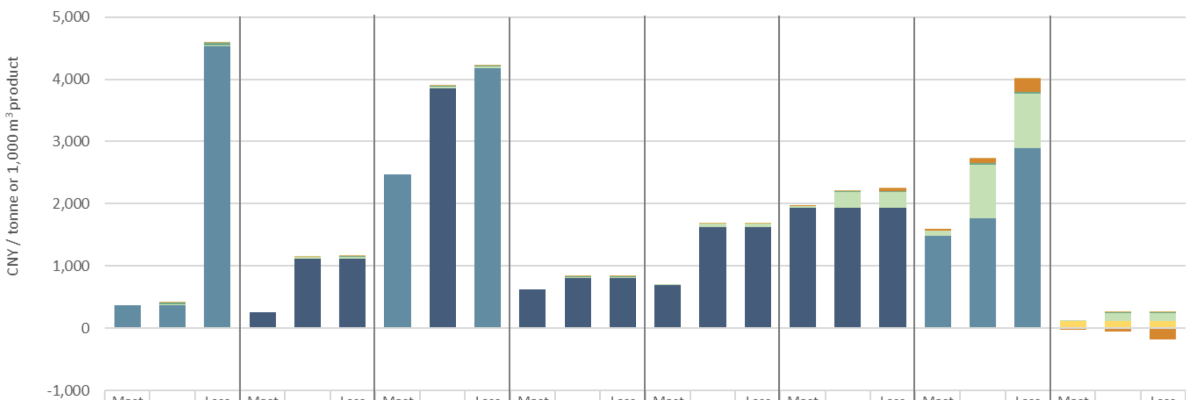
Environmental risks could lead to a financial cost at about 35 - 64% of the unit price of these products on average in the three scenarios.

RESULTS HIGHLIGHTS

Using the methodology described above and regional production data for each product type, Trucost estimates the potential risks in financial terms under three key scenarios. This section aims to provide insights on the risk hotspots across product types, scenarios, and regions, followed by a potential outlook of these risks for coal to oil and coal to gas under the development targets set in the 13FYP. This section concludes with case studies of coal-to-chemical projects to illustrate how these results could be integrated into financial analysis.

ENVIRONMENTAL RISKS COULD MEAN INCREASING COSTS AT 35 - 64% OF UNIT PRICE FOR MOST PRODUCTS. COAL TO OIL (INDIRECT) AND CALCIUM CARBIDE CONSISTENTLY HAVE THE TOP 3 HIGHEST RISK INTENSITIES ACROSS SCENARIOS. COMPARE TO UNIT PRICE, ENVIRONMENTAL RISK INTENSITIES FOR COAL TO OIL (DIRECT), COAL TO OLEFINS AND COAL TO GAS ARE ALSO SIGNIFICANT, WHICH COULD ALSO HAVE NEGATIVE IMPACT ON THE PROFITABILITY OF THE PROJECTS IN THE CURRENT COAL PRICE (AS COST) AND THE COMMODITY MARKETS.

EXHIBIT 11: ENVIRONMENTAL RISK INTENSITY BY PRODUCTS AND SCENARIOS, NATIONAL AVERAGE



	Coal to olefins			Coal to oil (direct)			Coal to oil (indirect)			Coal to gas			Coking			Coal-based ammonia			Calcium carbide			Coal-based methanol		
	Most Likely	Likely	Less Likely	Most Likely	Likely	Less Likely	Most Likely	Likely	Less Likely	Most Likely	Likely	Less Likely	Most Likely	Likely	Less Likely	Most Likely	Likely	Less Likely	Most Likely	Likely	Less Likely	Most Likely	Likely	Less Likely
Pollutant Emission Right Trading System	-	0.1	0.1	-	0.1	0.1	-	0.2	0.2	-	0.1	0.1	-	0.6	0.6	-	1.5	1.5	-	4.9	4.9	-	1.1	1.1
National carbon ETS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	10	40	30	70	220	-30	-60	-180
Water resource tax	-	30	40	-	10	20	-	20	20	-	10	10	-	-	-	-	10	10	-	20	20	-	10	20
Environmental tax	-	10	10	-	20	20	-	20	20	-	10	10	10	60	60	30	260	260	90	870	870	10	130	130
Water stress	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	110	110	110
Water cap compliance	370	370	4,530	-	-	-	2,470	-	4,180	-	-	-	-	-	-	-	-	-	1,480	1,760	2,900	-	-	-
Energy standard compliance	-	-	-	250	1,120	1,120	-	3,860	-	620	810	810	700	1,620	1,620	1,930	1,930	1,930	-	-	-	-	-	-

Exhibit 11 shows the breakdown of environmental risk intensity at the national average level. **Potential loss of production from regulatory compliance accounts for the largest share of environmental risks for most products – over 90% of total cost on average**. Water-related risks also appear to be the most prominent driving force compared to other envrionmental indicators such as GHG emissions, energy use, and pollutant emission. **About 45% of the total environmental risks is related to water use**, such as water resource tax, water cap compliance, and water stress. Water risk is particularly significant to coal-based methanol and coal to olefins, where potential costs from water risks account for nearly all of its environmental risk across many scenarios. **Coal to oil (indirect), calcium carbide, and coal-based ammonia consistently rank in the top four for total risk intensity across scenarios** (see Exhibit 12). Coal to olefins has the highest increase in environmental risks from "Likely" to "Less Likely" scenario, which makes it the product with the highest risk intensity in the "Less Likely" scenario. While coal to olefins may not face as high a risk as other products in the near future, it could be subjected to disruptive rises in risks in the future and brings greater uncertainty for investors.

EXHIBIT 12: RANKING OF TOTAL ENVIRONMENTL RISK INTENSITY BY PRODUCTS

RANKING	MOST LIKELY	LIKELY	LESS LIKELY
1	Coal to oil (indirect)	Coal to oil (indirect)	Coal to olefins
2	Coal-based ammonia	Calcium carbide	Coal to oil (indirect)
3	Calcium carbide	Coal-based ammonia	Calcium carbide
4	Coking	Coking	Coal-based ammonia
5	Coal to gas	Coal to oil (direct)	Coking
6	Coal to olefins	Coal to gas	Coal to oil (direct)
7	Coal to oil (direct)	Coal to olefins	Coal to gas
8	Coal-based methanol	Coal-based methanol	Coal-based methanol

Source: Trucost 2017

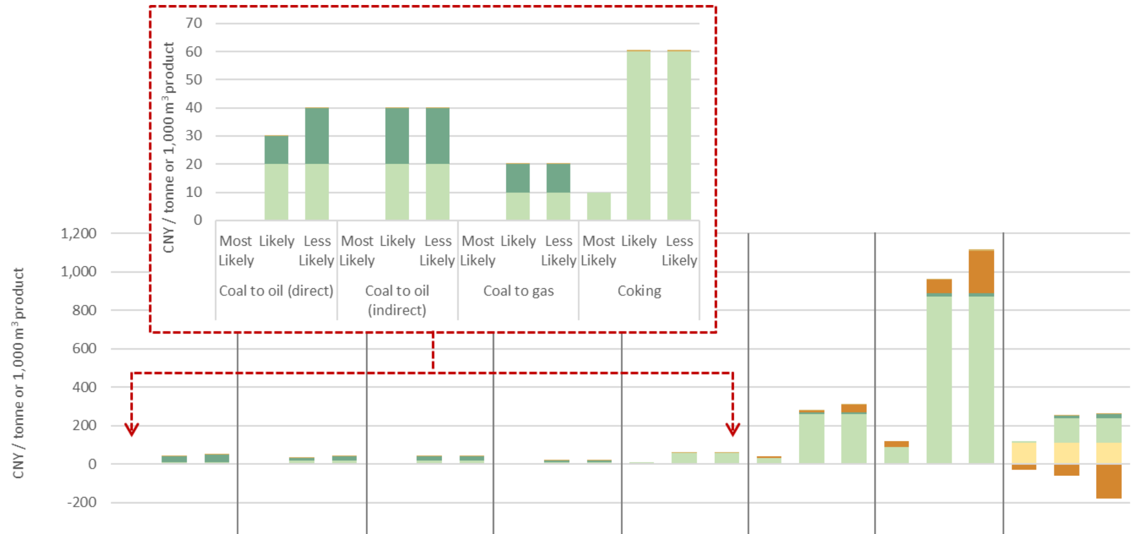
Most products show a steady increase of risks from the "Most Likely" towards the "Less Likely" scenario. This implies that even though some of the risks may seem low in the "Most Likely" scenario, they may increase significantly as risk factors evolve in the future. In particular, **calcium carbide and coal to olefins demonstrate the most significant increase in risk intensity from the "Likely" to "Less Likely" scenario, nearly 50% and 180%, respectively, driven by the increase in a potential loss of production from water cap compliance**.

[6] Environmental risk intensity for coal to gas is measured in CNY per 1,000 m^3 product

In terms of relative magnitude, **environmental risks could lead to a financial cost at about 35 - 64% of the unit price of these products on average in the three scenarios**. The most rapid increase of this risk ratio is between the “Most Likely” and “Likely” scenarios, where the average ratio increased by 1.5 times. For some products, environmental risks could increase so much that it would greatly affect their profitability. For example, the risk ratio for calcium carbide exceeds 100% in the “Less Likely” scenario and the ratio for coal to oil (indirect) reaches 90% in both “Likely” and “Less Likely” scenarios – all driven by risk related to potential production loss from regulatory compliance.

Potentially increasing risks could be of concern, yet there are also possible opportunities in these scenarios. Top-performing companies or assets could not only minimize risks by reducing environmental impacts to create a competitive advantage, they could also benefit from some of the market-based regulations such as national carbon ETS. For example, coal-based methanol has an industry average GHG intensity that is relatively low – possibly below the cap – putting it in the position where businesses could sell permits for additional revenue. Since the emission cap for the chemical industry is yet to be announced, this result is based on the estimated cap. The risks landscape is therefore subject to change when the official cap is announced in the future.

EXHIBIT 13: ENVIRONMENTAL RISK INTENSITY POTENTIALLY MITIGATED BY THOROUGH DUE DILIGENCE



	Coal to olefins			Coal to oil (direct)			Coal to oil (indirect)			Coal to gas			Coking			Coal-based ammonia			Calcium carbide			Coal-based methanol		
	Most Likely	Likely	Less Likely	Most Likely	Likely	Less Likely	Most Likely	Likely	Less Likely	Most Likely	Likely	Less Likely	Most Likely	Likely	Less Likely	Most Likely	Likely	Less Likely	Most Likely	Likely	Less Likely	Most Likely	Likely	Less Likely
Pollutant Emission Right Trading System	-	0.1	0.1	-	0.1	0.1	-	0.2	0.2	-	0.1	0.1	-	0.6	0.6	-	1.5	1.5	-	4.9	4.9	-	1.1	1.1
National carbon ETS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	10	40	30	70	220	-30	-60	-180
Water resource tax	-	30	40	-	10	20	-	20	20	-	10	10	-	-	-	-	10	10	-	20	20	-	10	20
Environmental tax	-	10	10	-	20	20	-	20	20	-	10	10	10	60	60	30	260	260	90	870	870	10	130	130
Water stress	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	110	110	110

For investors who have high confidence in mitigating many of these risks through thorough due diligence, Exhibit 13 shows the breakdown of residual environmental risks if the potential loss of production from regulatory compliance – for both energy and water standards – had been avoided. Water risks remain significant to coal-based methanol and coal to olefins, while tax – environmental tax or water resource tax – is the largest risk for other products. Due diligence may help reduce the potential loss from water stress if water efficiency measures are identified and acted on for the high-risk products and regions. Water stress and regulatory compliance are ongoing and changing risks, therefore, due diligence may only maximize its risk management function under continuous monitoring and review.

Note that the risks from environmental tax for modern coal-to-chemical products are relatively low. This is due to limited availability of comprehensive project-specific LCA data on the extensive list of pollutants as included in the law. Therefore, the estimates on financial risk from environmental tax for these products could in fact be even higher.

PROJECTS IN INNER MONGOLIA, SHANXI, SHANDONG, HENAN, HEBEI, AND SHAANXI WOULD FACE THE HIGHEST ENVIRONMENTAL RISKS

Environmental risk intensity also varies across provinces because some risk factors are region-specific[7]. Three out of the seven risk factors – water cap compliance, water stress, and water resource tax[8] – have regional variations in certain scenarios (see *italic* in Exhibit 8).

In terms of the magnitude of risk regional variation, it mostly remains relatively small and ranges from 1 to 27 CNY / tonne product or 0.1 to 19 CNY / 1,000 m^3 product in the three scenarios. The only exceptions are for coal-based methanol and calcium carbide, where regional risks are skewed by the potential loss of production from water stress in some provinces in the "Most Likely" and "Likely" scenarios.

[7] Regional environmental risk intensity is calculated based on the average risks if a particular type of coal-to-chemical project is to be built in each province. The ranking does not reflect existing capacity in provinces.
[8] Although the water resource tax rate is fixed for all provinces, water use retrieved from ground water and surface water is estimated based on the provincial water supply breakdown, so the total estimated cost will have regional differences.

From the ranking perspectives, regional variation is the most diverse in the "Likely" scenario for two reasons. The first reason is that the "Most Likely" scenario contains two regional risk factors (water cap compliance and water stress), which are usually overwritten by the potential loss of production from energy standards compliance[9]. There is no regional variation for all products in this scenario except for coal-based methanol, in which the high water stress in Beijing, Hainan, Tianjin, and Shandong drives the only regional variation of risks in the "Most Likely" scenario.

The second reason is that most of the regional risk factors evolve towards national standardization in the "Less Likely" scenario. Therefore, the top five provinces for all products in these scenarios are consistently Hebei, Henan, Beijing, Inner Mongolia, and Shanxi. The variation across regions is small and mainly driven by the relatively high water resource tax from ground water use in these provinces. Exhibit 14 lists the top five provinces with the highest environmental risk intensity in the "Likely" scenario, where ranking is the most diverse.

There are two key highlights from the ranking across these scenarios. The ranking shows the same top five provinces across products. Hebei, Henan, Beijing, Inner Mongolia, and Shanxi consistently rank at the top in most of the scenarios, mainly because these provinces have the highest share of water use from ground water, which is subject to a higher water resource tax rate.

EXHIBIT 14: TOP FIVE REGIONAL ENVIRONMENTAL RISK INTENSITIES IN THE "LIKELY" SCENARIO

PRODUCT	1	2	3	4	5
Coal to gas, coal to oil, coal to olefins, coal-based ammonia, coking	Hebei	Henan	Beijing	Inner Mongolia	Shanxi
Coal-based methanol	Beijing	Hainan	Tianjin	Shandong	Heibei
Calcium carbide	Hebei	Inner Mongolia	Shanxi	Liaoning	Shanxi

Besides water resource tax, potential loss of production from water stress also explains some of the top provinces in the ranking. In particular, the high water stress in Beijing, Hainan, Tianjin[10], and Shandong outweighs the risk from regulatory compliance and turns the net gain from national carbon ETS into a net

[9] The aggregated financial cost of all risk factors will only take the highest values of the potential loss of production from either energy standard compliance, water cap compliance, or water stress.
[10] In the "Most Likely" and "Likely" scenarios

cost for coal-based methanol. Water stress is also the driver for the top five provinces – Hebei, Inner Mongolia, Shanxi, Liaoning, and Shaanxi – for calcium carbide in the "Likely" scenario, as shown in Exhibit 14.

Overall, water risks – from either regulation or stress – seem to be the key driver for variation in environmental risk intensity across products and scenarios. For the same reason, the highest risks also concentrate in the North-eastern provinces, where some of the regions currently have the greatest coal-to-chemical production capacity in the country, for example in ***Inner Mongolia, Shanxi, Shandong, Henan, Hebei,*** and ***Shaanxi*** (see blue highlights in Exhibit 15).

EXHIBIT 15: TOP FIVE PROVINCES FOR COAL-TO-CHEMICAL PRODUCTION IN 2015

PRODUCT	1	2	3	4	5
Coal to gas	Inner Mongolia	Xinjiang	N/A	N/A	N/A
Coal to oil	Shaanxi	Inner Mongolia	Yunnan	Shanxi	Ningxia
Coal to olefins	Shaanxi	Inner Mongolia	Ningxia	Ningxia	Zhejiang
Coal-based ammonia	Shandong	Henan	Shanxi	Hubei	Sichuan
Coal-based methanol	Inner Mongolia	Shandong	Ningxia	Shaanxi	Henan
Coking	Shanxi	Hebei	Shandong	Shaanxi	Inner Mongolia
Calcium Carbide	Inner Mongolia	Xinjiang	Ningxia	Shaanxi	Henan

Source: (Anychem, 2017; China Indsutry Information, 2016a; China Indsutry Information, 2016b; China Indsutry Information, 2016c; NRDC, 2016)

OUTLOOK OF ENVIRONMENTAL RISKS UNDER THE 13FYP TARGETS

While the areas of high environmental risks and production hotspots greatly overlap, the situation is likely to intensify in the near future. To provide more insights on how this regional landscape of risks may change, Trucost further investigated two products that are expecting significant growth by 2020 under the 13FYP – coal to oil and coal to gas. The National Energy Administration sets out targets to reach a capacity of 13 million tonnes of coal-based oil per year and 17 billion m^3 of coal-based gas per year by 2020 (National Energy Administration, 2017), which implies roughly a fivefold increase of the existing capacity (see Exhibit 16).

The current capacity and pilot project as proposed in the 13FYP for coal to oil (9.34 million tonnes per year) is below the target of 13 million tonnes per year, whereas the current and pilot capacity for coal to gas together (21.23 billion m^3

per year) well exceeds the 13FYP target of 17 billion m^3 per year. Although it is unclear which projects – either existing, pilot, or backup – would make up the 13FYP targets, it would be useful to look at the maximum potential risk landscape based on all the capacity listed in Exhibit 16.

EXHIBIT 16: EXISTING AND POTENTIAL GROWTH IN CAPACITY, COAL TO OIL & GAS

CAPACITY	COAL TO OIL (MILLION TONNES / YEAR)	COAL TO GAS (BILLION M^3 / YEAR)
Existing (2015)	2.54	3.10
Pilot projects in 13FYP	6.80	18.13
Backup projects in 13FYP	7.00	63.80
Pilot + backup projects in 13FYP	13.80	81.93
Target capacity in 13FYP	**13.00**	**17.00**

Source: (National Energy Administration, 2017)

Based on the three potential sets of projects – "2015 existing," "2015 + pilot," and "2015 + pilot + backup," Trucost estimates the total environmental risks for each of these sets under the three risk scenarios[10] and compares them to the total investment for these projects (see Exhibit 17). **The commencement of the pilot projects will increase the risks by six times on average for both products**, and by 12 times and 26 times, respectively, for coal to oil and coal to gas if all backup projects go into operation.

EXHIBIT 17: TOTAL ENVIRONMENTAL RISK VERSUS INVESTMENT FOR PROJECTS OPERATING IN 2015 AND PROPOSED IN 13FYP, 100 MILLION CNY

PRODUCT	SCOPE OF PROJECTS ESTIMATED	TOTAL CLIAMTE RISKS[11]			TOTAL INVESTMENT
		VERY LIKELY	LIKELY	LESS LIKELY	
Coal to oil	2015	10	25	26	656
	2015 + pilot	90	151	162	3,513
	2015 + pilot + backup	169	274	295	3,377
Coal to gas	2015	12	15	16	385
	2015 + pilot	80	106	106	1,559
	2015 + pilot + backup	307	406	448	5,645

Ratio Legend:

> 8%	6% - 8%	4% - 6%	2% - 4%	< 2%

[11] Total environmental risks are estimated based on production data and assumed production at current average utilization rate (45% for coal to oil and 61% for coal to gas) for pilot and backup projects as proposed in 13FYP.

Source: Trucost 2017, (Anychem, 2017)

Exhibit 17 also compares the total risks against the investment of these projects, in which the range of colors presents different levels of risk to investment ratio. **The risk ratio for coal to oil ranges from slightly under 2% to 9% and ranges from 3% to 8% for coal to gas.** The ratio for coal to oil is subject to a broader range of changes across risk scenarios and growth targets. This is driven by the fact that all projects listed in the 13FYP are coal to oil indirect liquefaction, which is subject to relatively higher risk (as shown in Exhibit 11) and could lead to investment in these projects being more sensitive to the financial implications of environmental risks. While these ratios may not seem significantly high, these costs account for only the environmental risks and could affect profit margins given the current low oil and gas prices.

The 13FYP growth target appears to intensify the cost of environmental risks by increasing capacity in the high-risk areas as well as spreading out distribution of capacity. Exhibit 18 shows where the highest increases in capacity and environmental risks occur based on the pilot and backup coal-to-oil projects listed in the 13FYP. The pilot projects would lead to further growth in some provinces with high environmental risks, such as Inner Mongolia and Shanxi. The project list also implies that the industry will spread out to other provinces with slightly lower environmental risks such as Guizhou, Xinjiang, and Ningxia. **If all of the pilot and backup projects go into operation by 2020, about 35% of this capacity would be located in the high-risk regions.**

Coal to gas shows similar changes in risk landscape with the expected growth in capacity (see Exhibit 19). Nearly half of the capacity from both pilot and backup projects[12] is located in the relatively high-risk regions like Inner Mongolia and Shanxi. Some of the backup projects impose significantly higher risks if they go into operation, for example, new capacity in the province with the highest environmental risk (Hebei).

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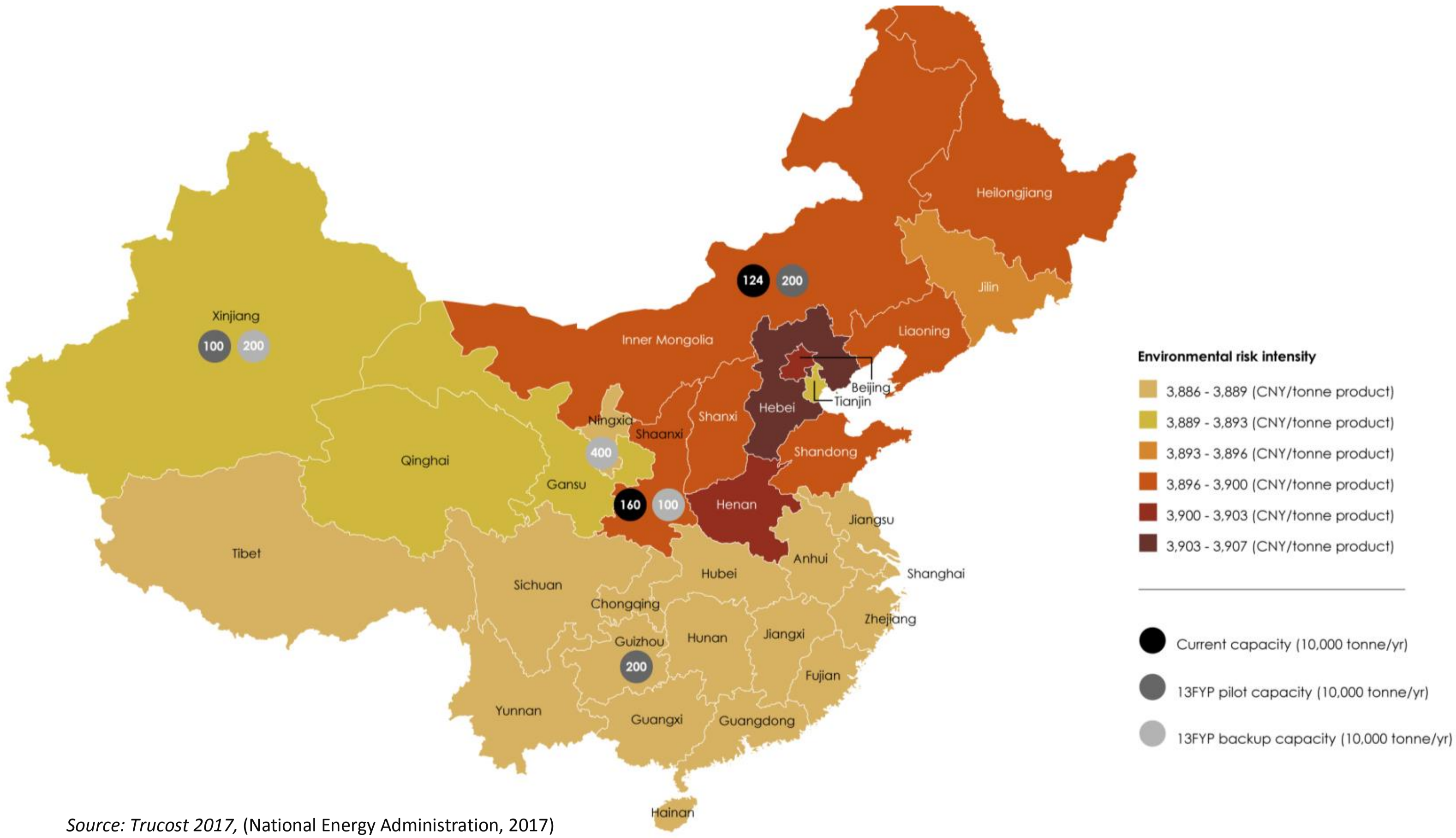
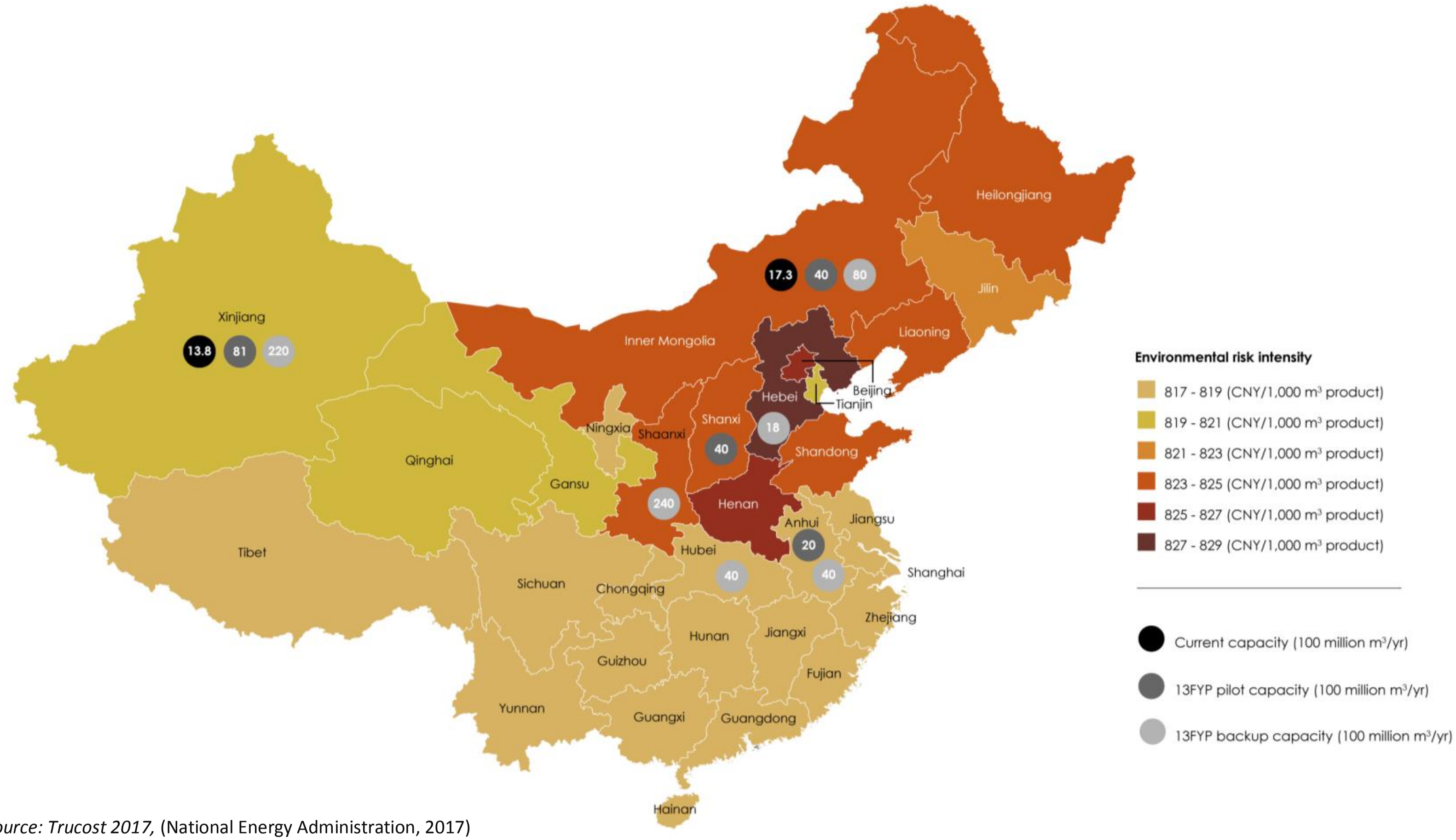
[12] The number of backup projects taken into account for this analysis only include those which are explicitly named in the 13FYP. The backup capacity that is only indicated by region is not included.

EXHIBIT 18: ENVIRONMENTAL RISK HEATMAP WITH POTENTIAL GROWTH FROM 13FYP, COAL TO OIL



Source: Trucost 2017, (National Energy Administration, 2017)

EXHIBIT 19: ENVIRONMENTAL RISK HEATMAP WITH POTENTIAL GROWTH FROM 13FYP, COAL TO GAS



Source: Trucost 2017, (National Energy Administration, 2017)

CASE STUDY: INTEGRATING ENVIRONMENTAL RISKS IN FINANCIAL ANALYSIS

These results could not only be used for materiality risk assessment of investment portfolios, but also for company-specific risk assessment. Trucost selected two existing projects – one coal to oil and one coal to gas – as examples of how these environmental risks impose financial implications on a project level and provide insight on risk management for investment in this sector.

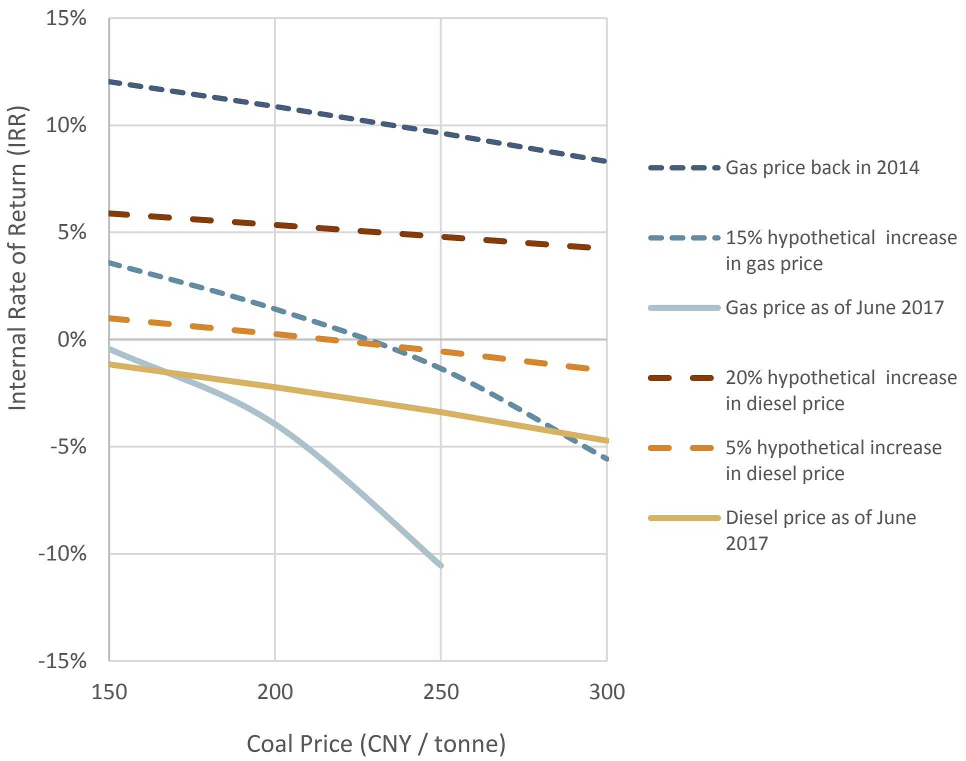
The two selected projects are located in the relatively high-risk areas – Inner Mongolia and Shanxi. Trucost collected relevant financial data for these projects from publically available sources and incorporated environmental risks by adjusting revenue (from potential loss of production) and operational costs. A cash flow analysis was conducted for the three key scenarios, yet the granularity and availability of financial data imposed some limitations on our project-based estimates. For example, these two companies are both vertically integrated, which allows them to enjoy below-market coal prices as an input material cost. These costs were not directly reported and proxies were applied from peers. Another necessary assumption was that current market spot prices of gas and diesel would be applied, although many market players would enter into future or forward contracts to manage market risks. Also, note that environmental risks were captured as a snapshot in time and do not involve any forecast on future changes in risk factors.

Despite the limitations of the financial data, environmental risks show significant impacts, relatively, on the potential profitability of these projects. **The internal rate of return (IRR) of both projects is estimated to be positive (3-5%) while still far from reaching their weighted average cost of capital (WACC) (the two companies have their reported long-term WACC at 8-9%)**. This is mainly due to the low gas and oil prices, the quick rebound of coal price, and the heavy consumption tax on the coal-to-oil project (CoalChem, 2016). However, once environmental risks are factored in, such mere return would be reversed and worsened as the risks become larger in the "Likely" and "Less Likely" scenarios.

Environmental risks also impact the breakeven gas and oil prices for these projects. Based on the risk-adjusted financials, Trucost performed sensitivity analysis on the changes in price for the key input (coal) and output (diesel and gas) to simulate the necessary price level for these projects to breakeven under various risk scenarios. Under the average coal, diesel, and gas prices in June 2017, both projects demonstrate negative IRRs across all scenarios.

Overall, the **breakeven threshold for both projects has become significantly more stringent as environmental risks increase**. They require much higher diesel and gas prices while relying on a low coal price in order to break even (see Exhibit 20). For example, a 5 - 20% increase in diesel or gas price would be necessary for a mere breakeven (IRR > WACC) in the "Most Likely" scenario.

EXHIBIT 20: SENSITIVITY ANALYSIS OF IRR IN THE "MOST LIKELY" ENVIRONMENTAL RISK SCENARIO[13]

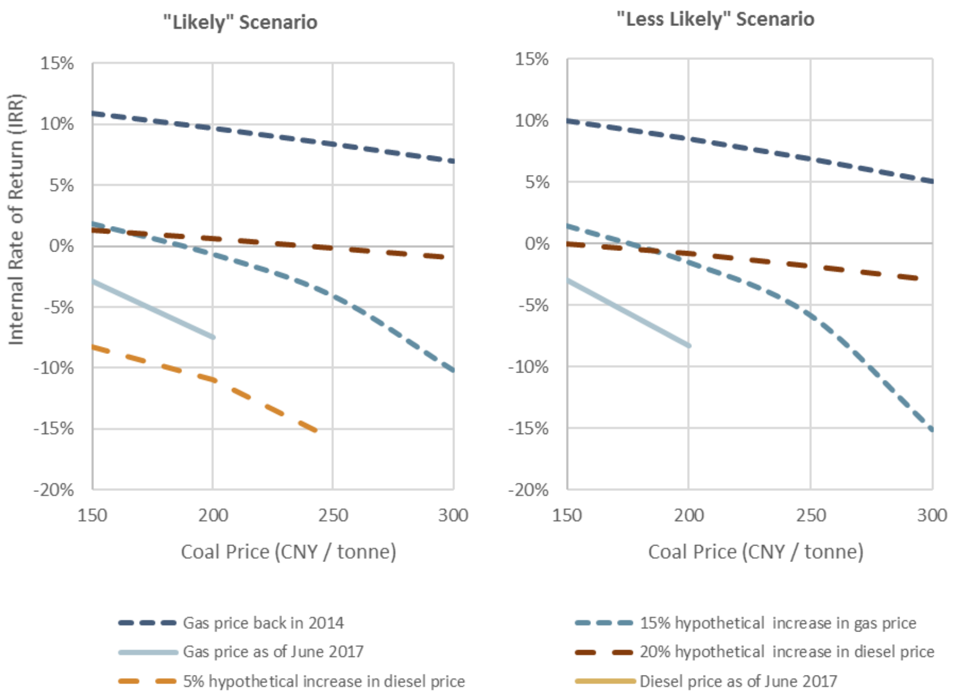


Source: Trucost 2017

The coal-to-oil project appears to receive greater adverse impacts on its breakeven threshold than coal to gas, which is most likely to break even if diesel price is 20% higher than the current price in the "Likely" and "Less Likely" scenarios. This is shown by the negative or invalid (missing values) IRR for both the 5% hypothetical increase in diesel price and the current diesel price in Exhibit 21.

[13] The missing data in the graph represent that cash flow across the entire analysis period is negative

EXHIBIT 21: SENSITIVITY ANALYSIS OF IRR IN THE "LIKELY" AND "LESS LIKELY" ENVIRONMENTAL RISK SCENARIOS[14]



Source: Trucost 2017

The coal–to-gas project is slightly more tolerant to the risks that a 15 - 20% increase in gas price with a coal price of around 150 - 200 CNY / tonne would still leave some room to break even in the "Less Likely" scenario (see the "gas price back in 2014" and "15% hypothetical increase in gas price" in Exhibit 21). For a steady profit, the gas price would need to return to the 2014 level for a chance of obtaining higher IRR than WACC.

These results suggest that not only projects built based on high gas or diesel prices – for example, projects built in 2014 when gas price was high) – would possibly be stranded at the current market conditions, but that they are also likely to be stranded as environmental risks increase in the future. While the current market condition is challenging for most of the projects' economics, environmental risks are likely to intensify the hardship from an investment perspective. As government support and subsidies are not included in this analysis, these results represent a more conservative risk landscape if such support were to be removed in the future.

[14] The missing data in the graph represent IRR that returns as N/A, that the net present values across the entire analysis period are negative

These impacts on profitability could be buffered if the project also includes upstream activities such as coal mining so that the coal price may be much lower than the market price used in this sensitivity analysis. Yet, coal mining activities are likely to face significant environmental risks given the increasing stringency of environmental regulations on that sector as well as the high environmental impacts generated in the production process. Such risks could possibly be passed through and indirectly affect the cost of coal-to-chemical production.

This analysis demonstrates the importance of integrating environmental risks in investment analysis and how this could help investors better understand the risk-adjusted profitability of their investment. Factoring in the potential costs of environmental risks could enhance risk management to avoid projects that could be stranded in the future when environmental risks become much more significant.

CONCLUSION & RECOMMENDATIONS

The potential scale and uncertainty of future changes in environmental risks reinstates the importance of incorporating this into financial analysis for investment.

This study not only illustrates the framework for assessing environmental risks, but also provides insights on the specific hotspots of risk and what financial implications they may have in the coal-to-chemical sector's future development. The key insights on assessing the financial implications of environmental risks for the sector are:

- Environmental risks could mean increasing costs at 35 - 64% of unit price for most products
- Coal to oil (indirect) and calcium carbide prominently rank in the top two products with the highest risk intensities across scenarios. Environmental risk intensities for coal to oil (direct), coal to olefins and coal to gas are also significant, which could also have negative impact on the profitability of the projects in the current coal price (as cost) and the commodity markets.
- Potential loss of production from regulatory compliance and water risks are the prominent drivers of risk for most products across scenarios
- The highest risk intensity concentrates in the north-eastern provinces – Inner Mongolia, Shanxi, Shandong, Henan, Hebei, and Shaanxi – and is mainly driven by water stress
- The 13FYP growth target could increase the total environmental risks for coal to oil and coal to gas by 6 to 26 times, accounting for 2 - 9% of projects' total investment. 35% of the planned capacity in the 13th five-year plan will be located in the high risk regions
- Case studies also demonstrate that environmental risks could greatly increase the breakeven threshold for coal to oil and coal to gas, imposing financial stress on these projects in addition to the unfavorable market conditions
- Environmental incidents – either due to non-compliance of environmental regulations or technical issues – that have previously occurred in the coal-to-chemical sector prove the associated costs could be significant and should be monitored through due diligence processes on the compliance of projects with regulations and their incident management systems.

The results demonstrate that environmental risks could have profound impacts on project profitability and therefore investment decision making. The potential scale and uncertainty of future environmental changes emphasizes the importance of incorporating environmental risks into financial analysis for investments. Based on these findings, Trucost provides some recommendations for policy makers and investors.

RECOMMENDATIONS FOR POLICY MAKERS

By understanding how environmental risks could potentially translate into costs for businesses, policy makers could formulate or strengthen such regulatory systems to internalize environmental impacts and encourage sustainable business decision making.

- Measures to promote robust enforcement of existing policies and regulations. As shown in the results, financial risks from regulatory compliance could create substantial incentives for businesses to reduce their environmental impacts. To leverage this mechanism effectively, policy makers could consider ensuring that regulatory enforcement is robust and consistent. For example, putting in place periodic compliance review and audit processes, and providing clear and systematic guidance for enforcement authorities to handle non-compliance, such as fines and suspension. This could increase the certainty of environmental risks from regulation and therefore increase the motivations for businesses to mitigate their impacts.
- Consider revising current regulations on water, energy, carbon, tax and fees, and so on to fully internalize environmental externalities. Enhancing current regulations would provide a strong signal for businesses to invest in and implement environmentally friendly operations. Such enhancement may include explicitly reflecting and embedding regional ecosystem vulnerability and capacity in regulations – water stress is a good example. Gradually increase the stringency of standards and compliance requirements and strengthen policies and regulations around GHG emissions (as the analysis shows the costs associated with GHGs are relatively low).

RECOMMENDATIONS FOR INVESTORS

Investors could use this framework to conduct materiality assessment of their portfolios, identify risk hotspots, and prioritize hotspots for in-depth company or asset-level analysis. Investors could also consider customizing the framework and scenario settings to fit their own risk appetites and expectations of the market.

- Investors should prioritize environmental risk assessment for these hotspots in their portfolios and incorporate the environmental risk-adjusted financial metrics into their considerations. The results highlight some risk hotspots such as coal to oil (indirect) and calcium carbide, and projects in the north-eastern provinces.
- Investors should consider using scenario analysis, as recommended by the Task Force on Climate-related Financial Disclosures, to assess the possibility and potential scale of such changes and incorporate this practice into regular risk assessment procedures to ensure the financial resilience of their investments is regularly reviewed. Although some of the risks could be relatively low in the "Most Likely" scenario, the financial costs could increase exponentially as these risk factors evolve or when new risk factors occur in the future.
- Investors should also recognize the importance of due diligence for its environmental risk screening and management function. The role of regulatory compliance in environmental risks implies that investors could potentially mitigate and avoid them by ex-ante screening, incorporating environmental risks in financial analysis, and encouraging abatement measures to be taken by investees. It is also recommended to carry out due diligence in a continuous manner for ongoing tracking of investment performance and development in risk factors.

In conclusion, this research represents an innovative step in bringing environmental risks closer to financial analysis, incorporating environmental considerations into investment decision making with the support of the Green Finance Committee in China. Trucost will continue to expand its work and partnerships in this area, refining and expanding its approach to continuously enhance the knowledge and capability of financial institutions in environmental risk-adjusted decision making.

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