

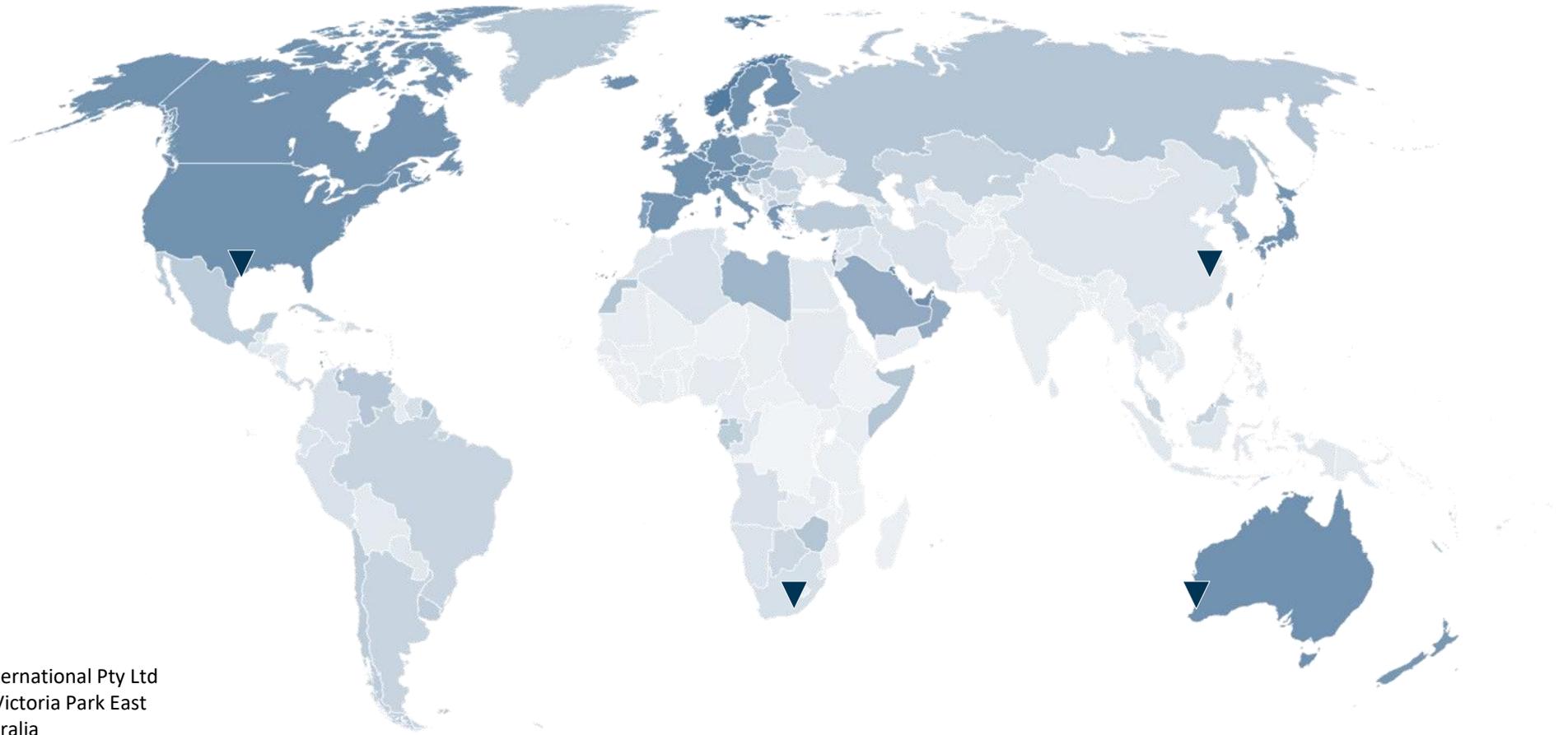


# Executive Summary on China ZOC Industry Australian Strategic Materials

**October 2018**



# Executive Summary on China ZOC Industry



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TZ Minerals International (TZMI) is a global, independent consulting and publishing company which specialises in technical, strategic and commercial analyses of the opaque (non-terminal market) mineral, chemical and metal sectors. Our clients include the worlds largest mining, financing and OEM companies, together with a wide range of existing and new market participants.

With a worldwide presence, including head office in Australia, and offices in the US, Africa and China, TZMI's strength in consulting services is a result of our extensive practical experience across all elements of the industries and from a comprehensive and unique database, which has been built up over many years.

TZMI has proven expertise gained from our consultants having many years of direct operating experience in the industry in chief executive, senior operational, analytical and marketing roles.

TZMI's publications and data services provide additional benefit for our clients and ensure up-to-date, high-quality and comprehensive data, analysis and information across the mineral sands, zircon and TiO<sub>2</sub> pigment industries.

To ensure TZMI provides accurate and up to date advice, TZMI maintains the most comprehensive and current databases of industry production, market information and best practices in the world, including supply and demand models, technical data and operating cost data for all major producers.



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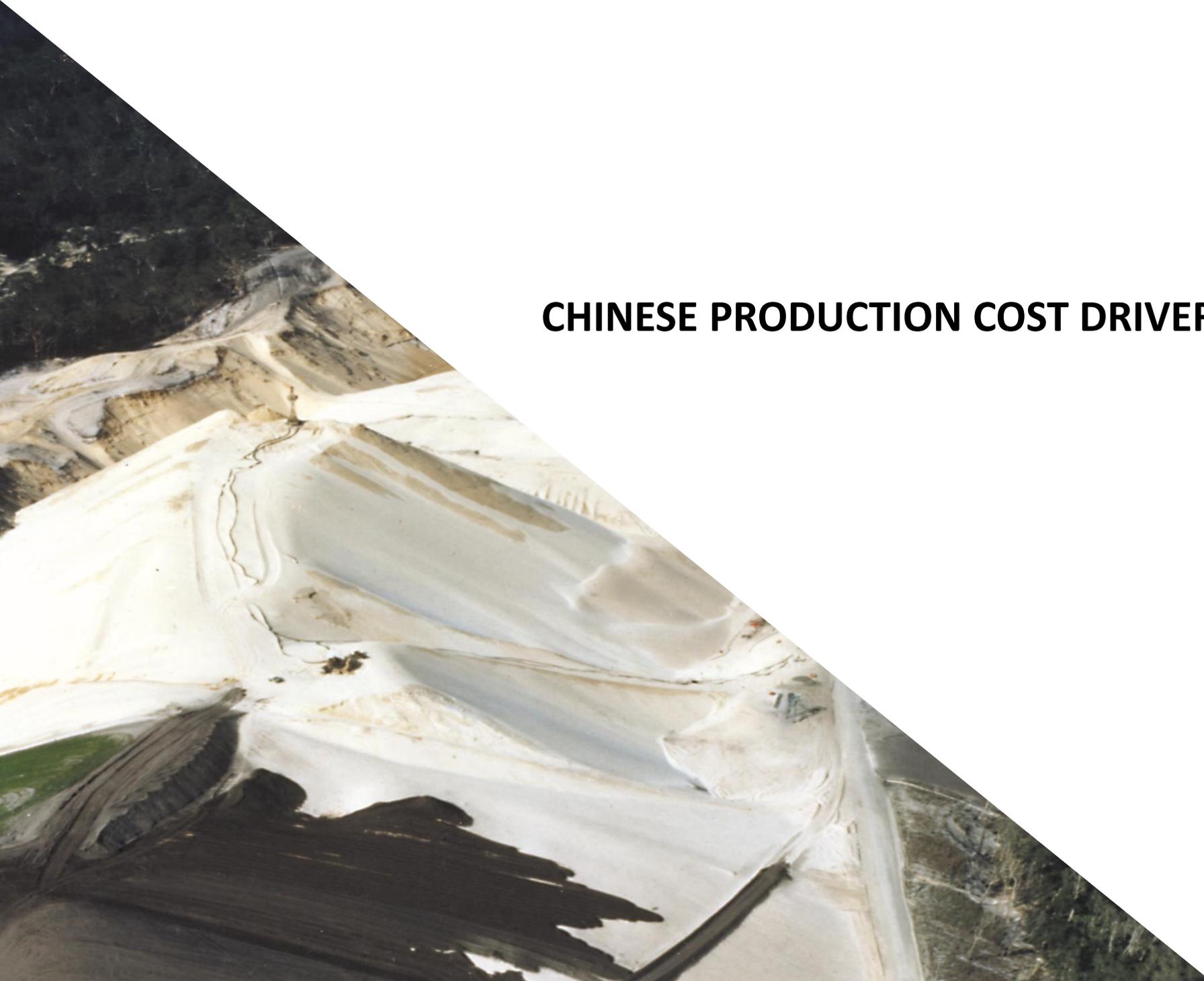
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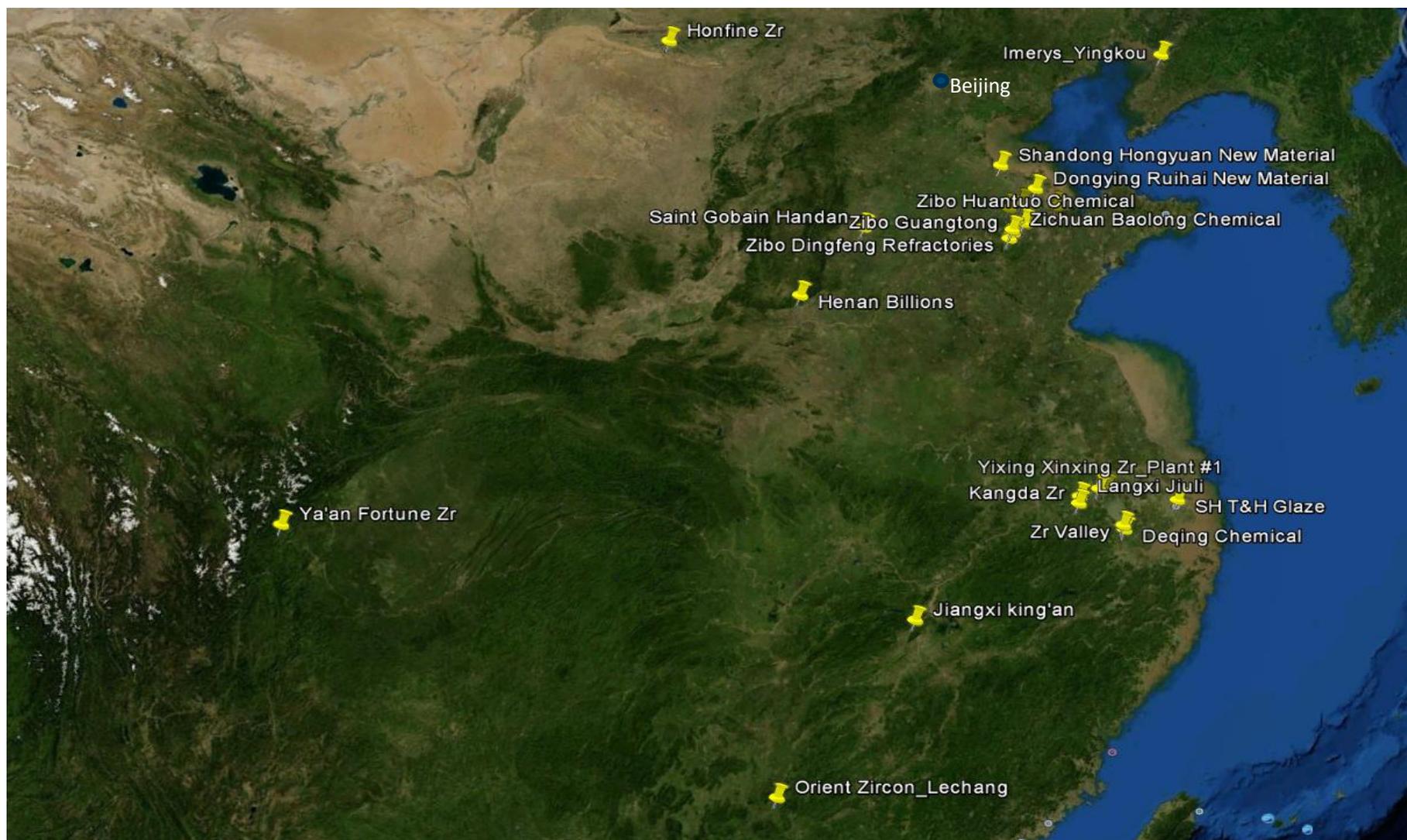
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## CHINESE PRODUCTION COST DRIVERS

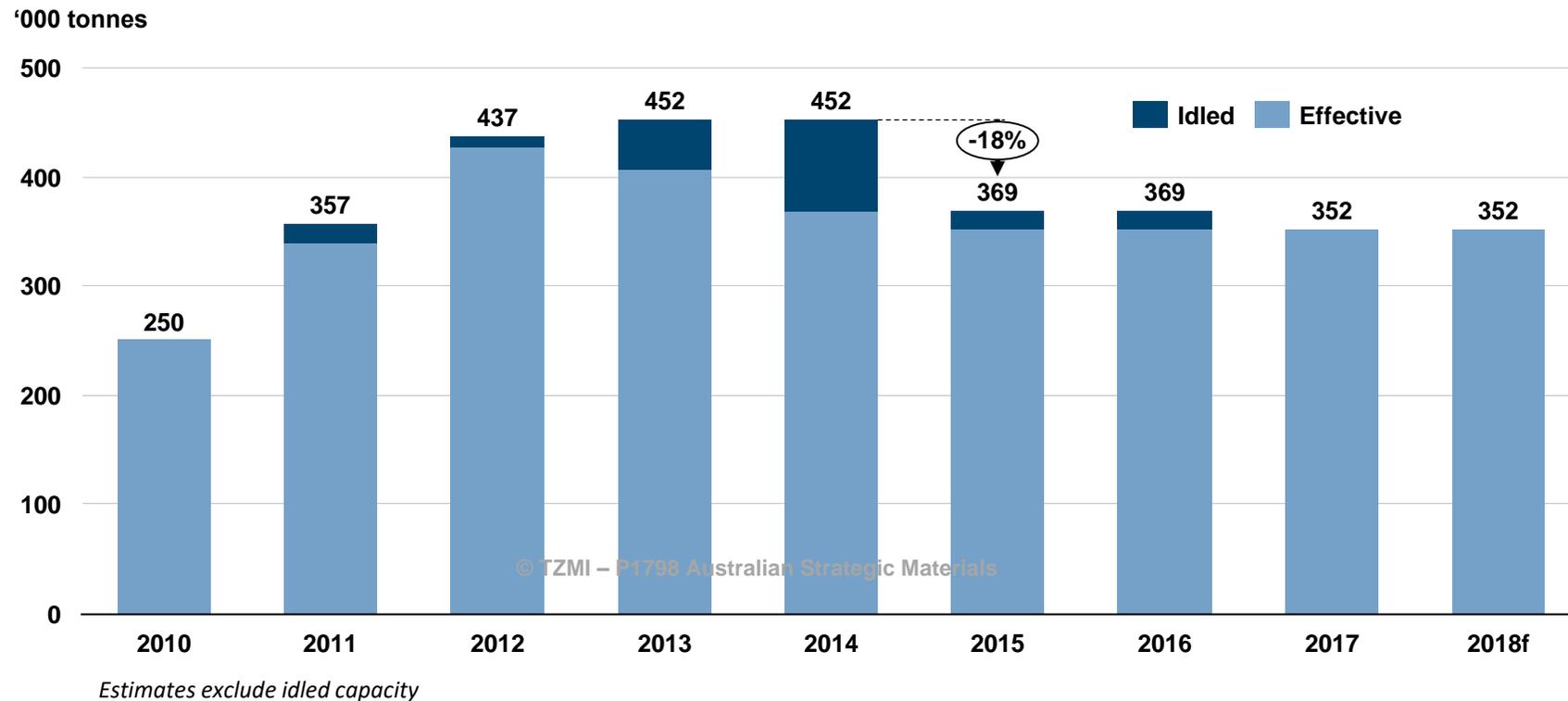
# Distribution of ZOC plants in China



- There are 25 producers (active and idled) of zirconium oxychloride (ZOC) in China. 16 are in the eastern province of Shandong. China national ZOC production is approximately 210,000 tonnes in 2017, while current capacity is 352,000 tonnes per annum.

# ZOC capacity increased considerably after 2010

## ZOC capacity 2010-2018



- The onset of new ZOC plants and capacity expansions following the rapid increase in prices in 2011 has seen total ZOC capacity increasing to approximately 450,000tpa by 2013. The Chinese ZOC market was considerably oversupplied as a result, which saw ZOC prices declining rapidly during 2013.
- However, given the large oversupply and weak prices, capacity was progressively idled during 2014. Sustained weak market conditions led to several producers exiting the sector in 2015, resulting in overall capacity declining by 18% compared to 2014 levels.
- Total ZOC capacity is currently understood to be around 352,000tpa.

# ZOC capacity concentrated in Shandong

- Total ZOC production capacity in Shandong is estimated at 182,000tpa, accounting for approximately 52% of total country production capacity.
- There are 9 active ZOC producers in Shandong, with Zibo Guangtong the largest producer with annual capacity of 100,000tpa. Shandong Feitian is the second largest with total capacity of 18,000tpa and Zibo Huantuo at 15,000tpa, while the rest comprises smaller scale producers with capacity of less than 10,000tpa.
- Production capacity in Jiangxi accounts for 15% of total China's capacity. Jiangxi KingAn accounts for 80% of total capacity in Jiangxi Province.
- Zhejiang Province is another important ZOC producing region, with total capacity of 47,000tpa and is also subject to strict environmental scrutiny given its proximity to Shanghai. Zr-Valley (Shenghua BLOK) and Deqing Xingkang are the two prominent ZOC producers in this province.
- With the tightening of the environmental regulations, the smaller producers are expected to be impacted the most, as these facilities lack proper infrastructure to comply with the environmental standards and do not have the financial means to invest/upgrade their facilities.
- During 2017, the majority of ZOC operations in Shandong and Zhejiang were idled for 1-2 months due to environmental inspections.

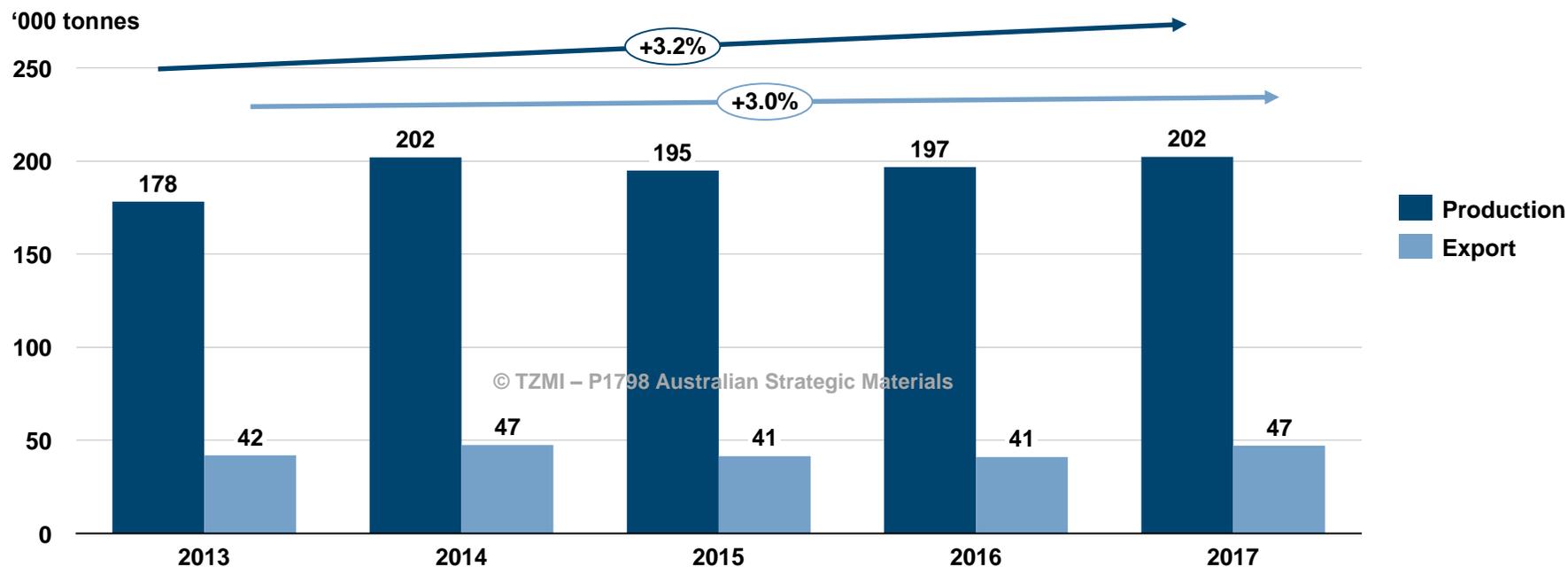
## Breakdown of ZOC effective capacity

Province	ZOC capacity	No producers	Capacity share (%)
Shandong	182,000	9	52%
Zhejiang	47,000	2	13%
Jiangxi	52,000	2	15%
Guangdong	20,000	1	6%
Jiangsu	20,000	1	6%
Henan	16,000	1	5%
Shanghai	15,000	1	4%
<b>TOTAL</b>	<b>352,000</b>	<b>17</b>	<b>100%</b>

*Note: Capacity of inactive producers has been excluded in this update. While there are a total of 16 ZOC producers in Shandong, seven of them have been idled for some years and thus been excluded from the current estimates.*

# Production and exports growth

## ZOC production and exports: 2013 – 2017



- ZOC production and exports are growing at similar rates, 3.2% and 3.0% CAGR respectively, between 2013 and 2017.
- The Chinese ZOC industry is undergoing consolidation. Average operating rate in the sector has increased from 44% in 2013 to 57% in 2017. Uncompetitive plants are being phased out, leaving only those producers with the following attributes:
  - Large scale company
  - Integrated producers with competitive downstream products (most ZOC producers are also engaged in the production of downstream derivatives such as ZBS, ZBC, ZOH etc)
  - Companies with by-product

# Environmental drivers alone have increased ZOC production costs by ~ 10%

- The Chinese government is enacting a 5-year US\$227 billion plan to address environmental concerns, especially industrial pollution.
- Current means of ZOC production in China create pollutants including alkaline waste water, acidic gas, and silicate sludge. Recent changes to Chinese environmental regulations that are profoundly impacting the ZOC industry include 2014 air pollution standards and 2015 emission standards for the inorganic chemical industry. There are also provincial standards that can be stricter than the national standards.
- The Chinese government aims to reduce China's use of energy from coal to 58% by 2020, down from 64% in 2015. Shandong Province, one of the largest ZOC producing regions, is also a primary coal consumer.
- Natural gas is the primary fuel-switching option for industrial boilers used in ZOC production. The government is seeking additional supply and building more pipelines to increase use of energy from natural gas from 6% in 2013 to 10% by 2020.
- Tightening regulations have their greatest impact on smaller ZOC producers who cannot afford to upgrade their emissions, disposal, storage and monitoring practices to comply. Some facilities will also need to pay for water treatment by an external party.
- Producers who do not comply risk permanent closure. Some companies disregard closure orders by continuing to operate, but visits by environmental inspectors frequently force non-compliant operators to suspend production to avoid fines.
- ZOC producers are also bearing the cost of converting coal-fired furnaces to natural gas, as well as paying more for electricity (energy from natural gas is approximately 1.5 times more expensive than coal).

## China's New Five Year Plan to 2020

Total investment of US\$227 billions  
on environmental rectification  
2016-2020 (The 13<sup>th</sup> Five Year Plan)



Soil pollution

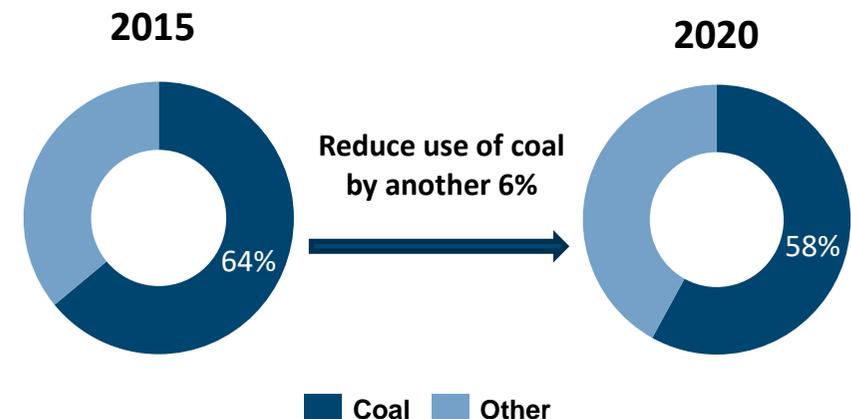


Water pollution



Air pollution

## China's Coal-to-Gas project



# Environmental issues in ZOC manufacture

- Pollutants from zirconium oxychloride (ZOC) production process are mainly alkaline waste water generated from the washing process, along with acidic gas from acidification, primary crystallization, concentration, secondary crystallization and acid washing process, plus silicate sludge from water dissolving process and cooling water & condensation water from acidification and concentration processes, as well as waste water when rinsing the ground in all processes.
  - Alkaline waste water contains excessive NaOH and  $\text{Na}_2\text{SiO}_3$  generated from the caustic fusion process;
  - Sodium chloride waste liquid: While it is not a current issue, the concentration of NaCl in the filtrate from the conversion process is high and may be subject to scrutiny in the future and increase operating costs if ZOC producers have to install proper facilities to treat and recover the water. It should be noted that none of the ZOC producers in China currently has this process step.
  - Silicate waste solid: Silicate sludge is the moisture-containing residual after primary crystallization product is dissolved and filtered, its main ingredient is  $\text{SiO}_2$  with 80-90%  $\text{H}_2\text{O}$ , a little undecomposed zircon sand and undissolved  $\text{ZrOCl}_2$ , plus some impurities containing iron and sodium.
  - Fusion furnace off-gas;
  - Coal waste liquid and solid. If coal gasification is used, then the gasifier will have a water discharge and will need to be incinerated.
- To ensure compliance with environmental standards and regulations, operating costs of ZOC producers are expected to increase as most existing Chinese operations have not been fully compliant in the past despite some having the proper facilities to manage the waste streams.
- In addition, plants subject to environmental supervision will need to install a continuous monitoring system to track the waste discharge from the plant. It is understood that all the ZOC facilities in Shandong have already installed 24-hour automatic emission monitoring systems.

# Capital investments required to build proper facilities

- Plants which do not have the proper facilities will need to spend money to upgrade their production processes. These upgrades may involve:
  - Changing from coal-fired furnace to using natural gas
  - Installation of an off-gas scrubber unit
  - Installation of other proper waste treatment facility
  - Installation of automatic monitoring devices to record emissions
  - Installation of a water purification unit to recover the NaCl in waste water (currently not required). According to industry participants, investment capital for the water purification unit could cost up to RMB30 million for a 10,000tpa ZOC plant.

To date, environmental enforcement has focused on water and gas discharge, but China will need to address the issue of radioactive waste, particularly as future zircon supply is likely to contain a higher proportion of Uranium and Thorium. Producers will therefore bear additional costs associated with safer disposal/treatment of radioactive waste.

# Environmental issues in ZOC manufacture

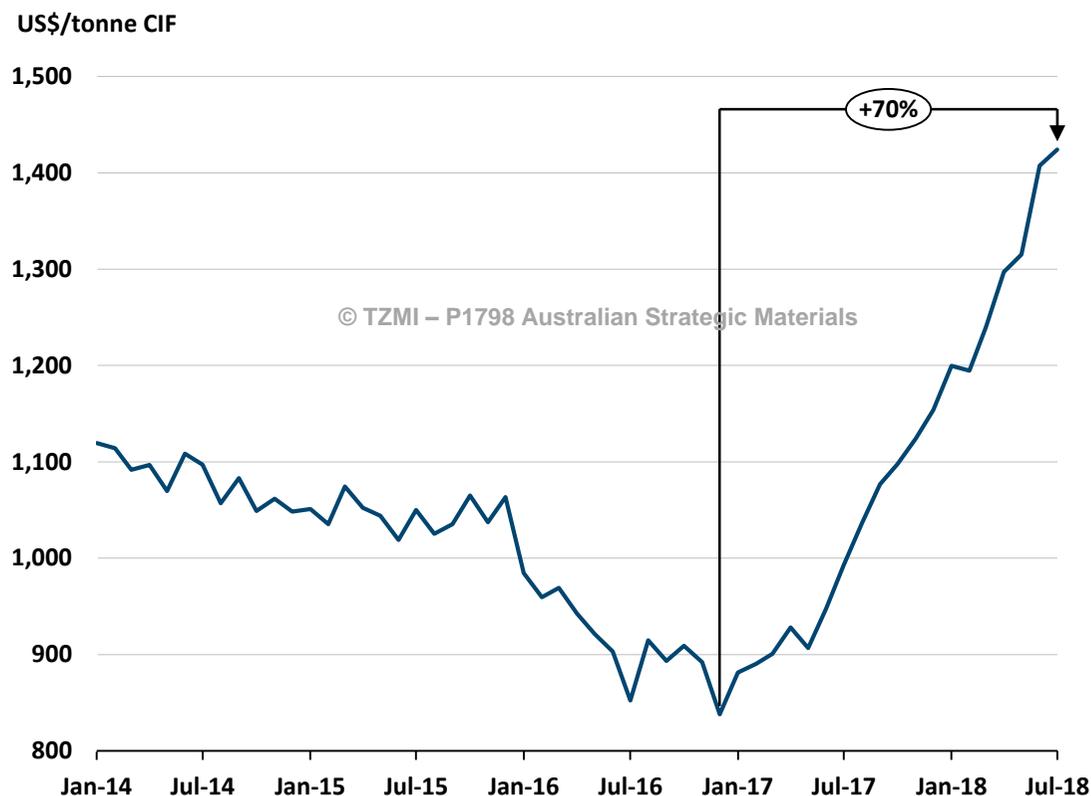
## Waste treatment costs

Item	Waste streams	Processing options
1.	Caustic waste water	Caustic soda in the waste water can be partially recycled. It is understood that most ZOC producers in Shandong are selling the caustic waste stream (post NaOH recycling) to local paper manufacturing plants. An alternative is to recover the $\text{Na}_2\text{SiO}_3$ and sell it to the coating industry, but this is not widely practiced due to the high operating cost.
2.	Sodium chloride waste liquid	There is no clear regulation currently specifying the limits of NaCl in waste water discharge but this could be subject to increased scrutiny in the future. It is understood that none of the ZOC producers in China have a proper treatment facility to address this waste stream. If a proper NaCl treatment circuit is included, this is expected to increase the operating cost by RMB500-1,000 per tonne of ZOC.
3.	Silicate waste solid	The method of handling silicate sludge varies by plant, a common practice is to discard the silicate sludge in a tailings dam or send it to nearby cement or brick plants for use as refractory. It is indicated that this is not a major concern for ZOC producers as most facilities have a way to deal with the disposal that should not result in increased operating costs.
4.	Fusion furnace exhaust gas	Inclusion of an off-gas scrubber unit to neutralize the exhaust gases before release to atmosphere.
5.	Water treatment	Some facilities will need to pay for water treatment fees by an external party despite having the facilities to decrease the COD to less than 50 mg/L. The fee varies by region but is expected to be minimal.

# Consequently, the price of ZOC is increasing

## Prices of zircon imports into China: Jan 2014 – Jul 2018

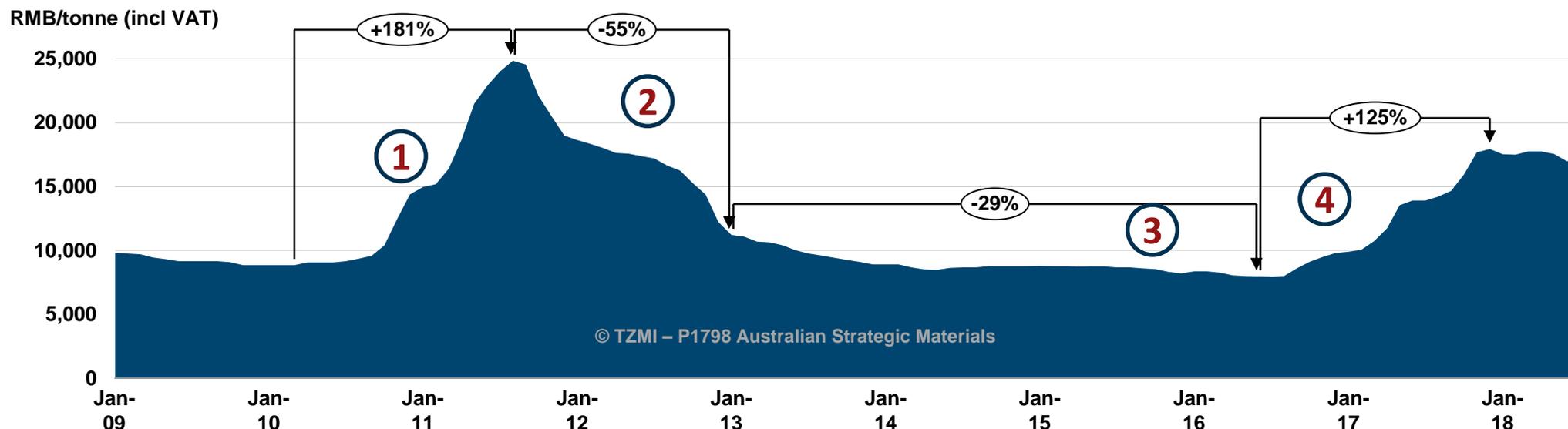
- Average production cost for ZOC increased by 47% from mid-2016 to end-2017, mostly due to price increases for zircon – the raw material for ZOC production – and caustic soda, which is used in the extraction process.
- As a result of environmental clamp-downs constraining local supply, domestic prices for caustic soda have risen by more than 100% since mid-2016.
- Four consecutive price increases were announced by major zircon producers in 2017, with combined increases up to US\$300 per tonne (~30%).
- In first-half 2018, some zircon producers announced price increases of US\$180-US\$300 per tonne. Prices are expected to trend higher after some major producers announced up to US\$175 per tonne increase for second-half 2018.
- Following several years of weak market conditions, with huge stockpiling in the supply chain and declining prices, ZOC prices recovered strongly in 2017.
- The profit margin for ZOC producers is much greater than the margins of downstream users. Surveyed Chinese producers indicated that they could reduce their margin if prices become unacceptable to customers.
- However, ZOC consumers have indicated that since there are currently no substitutes for ZOC, they will be forced to accept any price increases and pass the cost on to their customers.



Source: China custom data

# Review of China ZOC prices

Shandong ZOC prices: Jan 2009 – September 2018



- Prices increased sharply driven by increased demand, tight supply and increasing **zircon prices**.
- ZOC producers enjoyed high profit margins that led to new investment as well as expansion of existing producers.
- Capacity increased by over 20% while the profitability was as high as 40%.
- Zircon sand prices peaked in 2H 2011. 2012 was a turning year for most commodities including other raw materials of ZOC. As **new capacity** was commissioned, ample ZOC supply was available. Incremental availability of ZOC supply and **declining feedstock prices** led to ZOC prices falling in August 2011.
- Profitability started dropping from 40% to 20% and further to 5% in 2013.
- ZOC prices continued to decline during this period but at a slower rate as profitability of ZOC producers was already at historical lows (~20% for some producers).
- In addition to ZOC surplus and zircon prices remaining subdued, the sector was negatively impacted by **increasing costs of environmental protection** and labor, and other miscellaneous charges, further eroding profit margin.
- Some small producers left the market, while some maintained low operating rates.
- Driven by increasing **zircon price** and impact of **environmental protection enforcements**, which not only increased the cost but also limited operating rates, ZOC prices rose rapidly after April 2017.
- **Temporary supply shortage** occurred and triggered panic buying by customers, pushing ZOC prices higher.
- ZOC prices stabilised after November 2017, as producers resumed normal operations, providing supply relief to the market.

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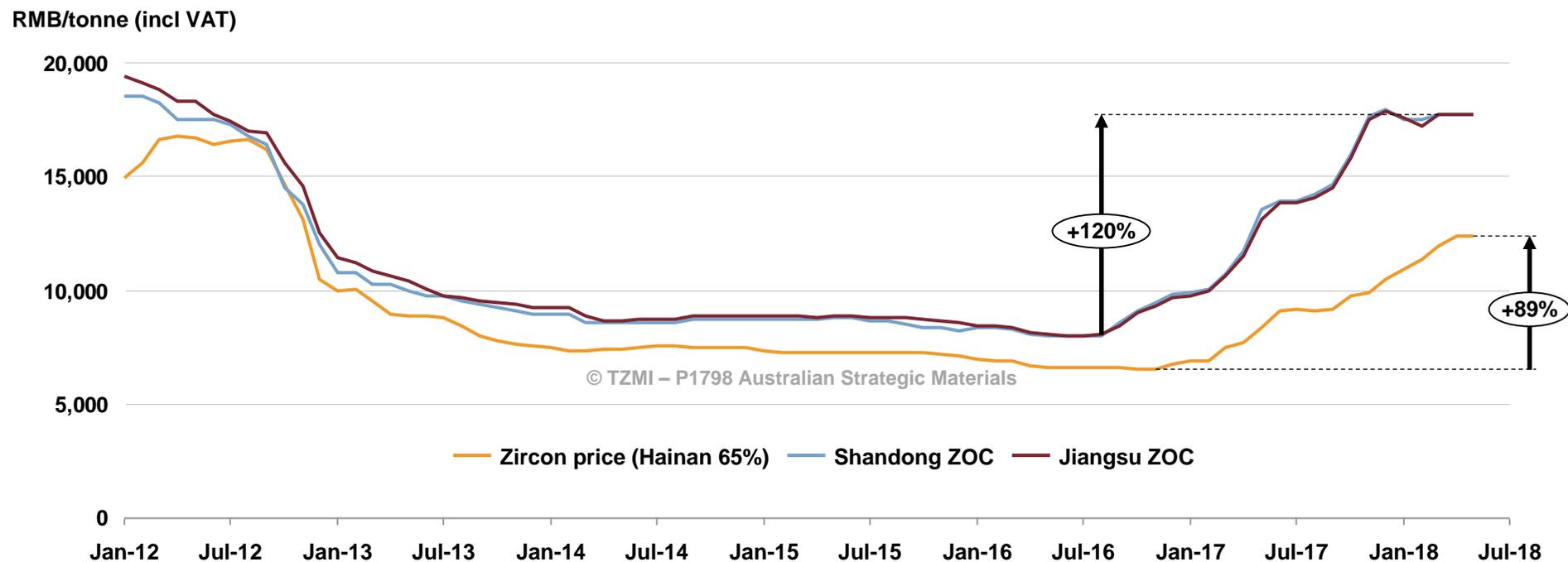
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# ZOC prices increase sharply since Q3 2016

## ZOC prices in China: Jan 2012 – May 2018



Source: [www.cnfeol.com](http://www.cnfeol.com), all prices shown include VAT

- Domestic China ZOC prices rebounded strongly in 2H 2016, increasing by 120% before stabilizing at RMB17,750 per tonne (incl VAT). This is still well below peak pricing recorded in during Q3 2011.
- The increase in ZOC prices was partially attributed to the increase in zircon and caustic soda prices. In addition, environmental inspectors have been making rounds at several provinces and ZOC production has been negatively impacted, resulting in a tightening of ZOC supply.

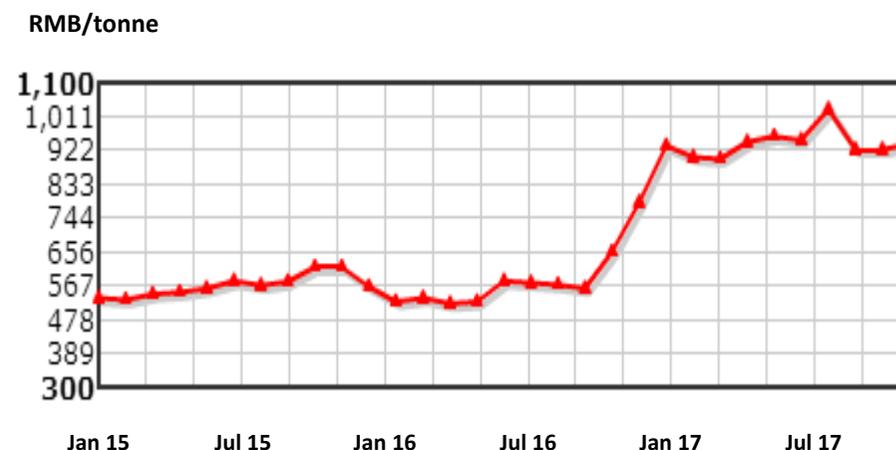
# Increase in operating costs

- To ensure environmental compliance, ZOC producers will need to adhere to strict emission limits during the production process. This will include better disposal and storage practices, neutralization of alkaline waste water and off-gas. All these procedures will increase operating costs as not all producers have been strictly following the standard operating procedures.
- The adoption of natural gas instead of coal will also add to the operating cost. The use of natural gas is said to be 1.5 times more expensive than using conventional coal as the source of energy.
- Some ZOC producers also incur water treatment charges, despite maintaining the Chemical Oxygen Demand (COD) below 50 mg/l. It is understood that the water treatment charges vary from region to region.
- In addition, prices of zircon have been increasing since the start of 2017. Global major zircon producers have announced a series of price increases since Q1 2017. Iluka Resources announced a series of price increases to its zircon reference price, with the latest announcement of a US\$170 per tonne increase effective October 1, 2018 for a period of 6 months, taking the reference price to US\$1,580 per tonne CIF.
- At the same time, prices of caustic soda have increased significantly since August 2016, as a result of environmental clamp down constraining local supply. Domestic prices for caustic soda have risen by more than 100% since June 2016.

## Prices of imported zircon into China: Jan 2011 – Jul 2018



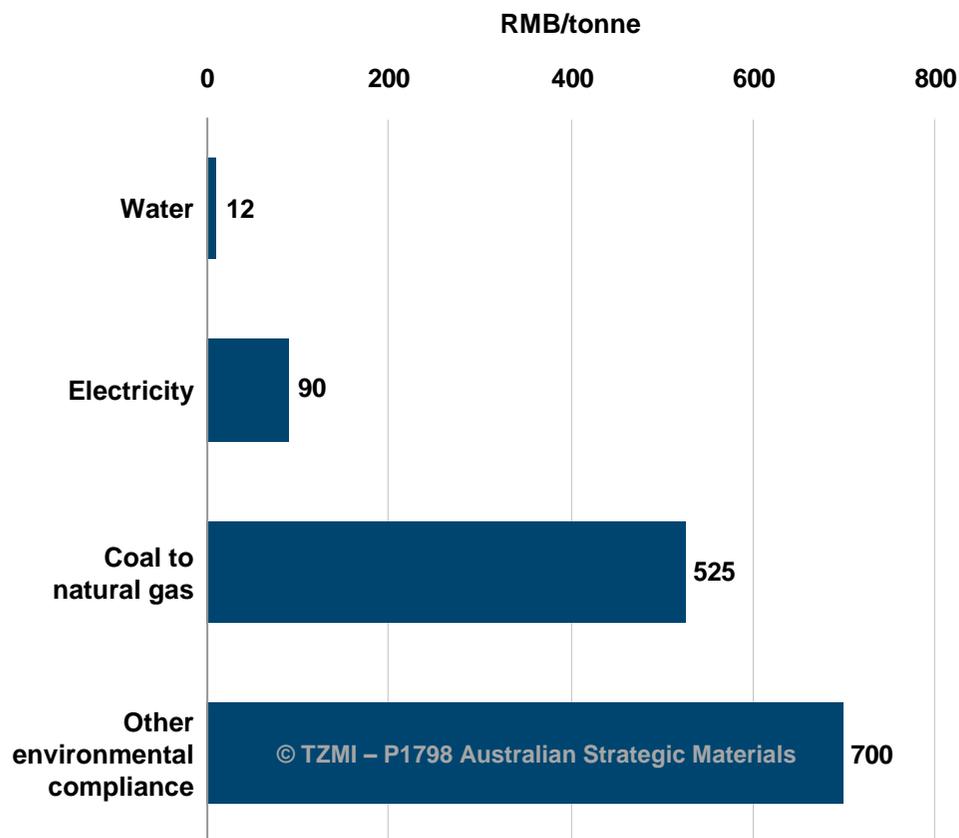
## Northern China caustic soda prices –32% concentrate



Source: [www.ccaon.com](http://www.ccaon.com)

# Cost associated with environmental compliance

## Impact on production cost attributed to environmental compliance

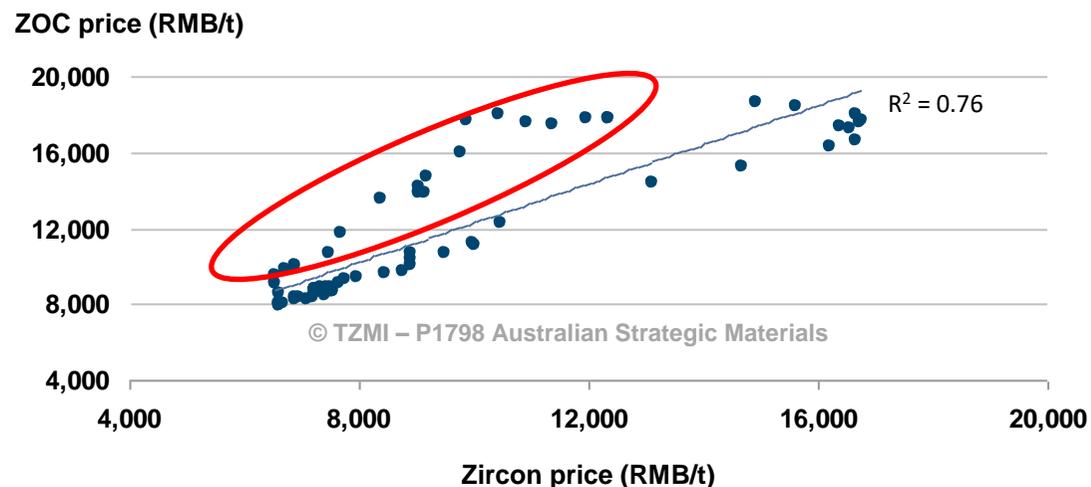


- The strengthening of Chinese environmental regulations has led to increased operating costs for Chinese ZOC producers. The key areas impacted by the tightening of environmental regime are:
  - Use of natural gas as fuel source instead of coal.
  - Increased electricity cost due to the conversion from coal to natural gas as the source of power supply.
  - Higher water costs due to stricter environmental regulations.
  - Other costs associated with emission controls. These costs vary widely between individual operations but TZMI's conversations with various industry participants indicate an average increase of RMB500-1,000 per tonne ZOC would be applicable.
- Overall cost impact attributed to environmental compliance is estimated at RMB1,300-1,500 per tonne.
- That said, the cost impact reflected does not include costs associated with the disposal/treatment of radioactive waste. The focus of the environmental enforcement thus far has been on water and gas discharge from the plant.
- As the environmental regulations become stricter, one can expect that China will need to address the issue of radioactive waste, particularly if the grade/quality of future zircon supply is likely to contain a higher proportion of U and Th. It is difficult to quantify the cost impact for radioactive waste management, but TZMI has made some provisions in the high case scenario (RMB1,700/tonne of ZOC) to cater for this requirement.

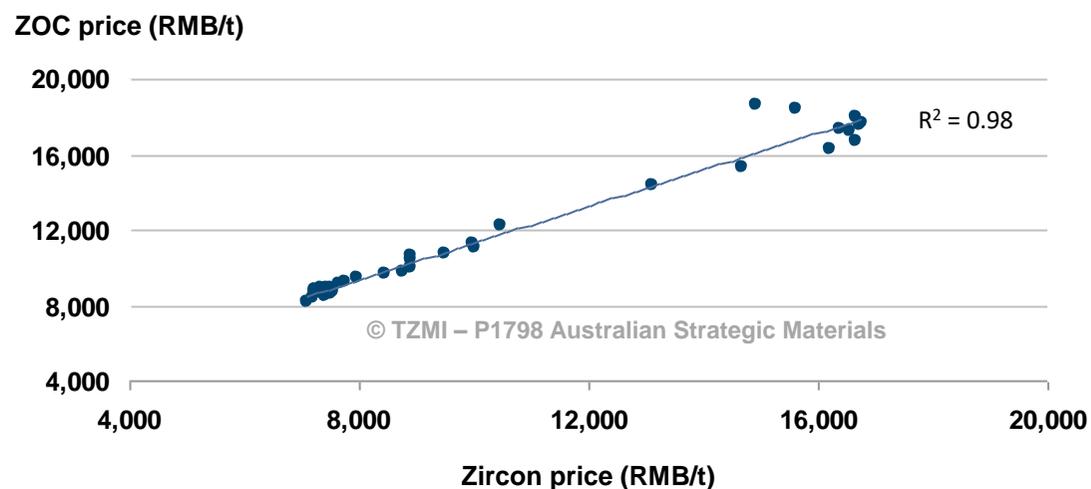
# Strong correlations between ZOC and zircon prices

- Strong correlations between ZOC and zircon prices were noted up to December 2015, with  $R^2$  estimated at 0.98. The ZOC price at the time was predominantly a function of zircon price given the relative importance of zircon in the production cost structure.
- However, the correlation appears to weaken if prices in recent years are included (with  $R^2$  estimated declining to 0.76), likely to be attributed to the increasing influence of environmental impacts, driving up operating costs associated with environmental compliance.
- As such, ZOC prices in the sector have been growing at a much faster rate compared to the rate of growth of zircon prices.
- Going forward, TZMI expects future zircon prices will continue to have an influence on ZOC pricing, although not to the same extent as what was seen prior to 2016.

## ZOC vs zircon prices: Jan 2012 – May 2018



## ZOC vs zircon prices: Jan 2012 – Dec 2015

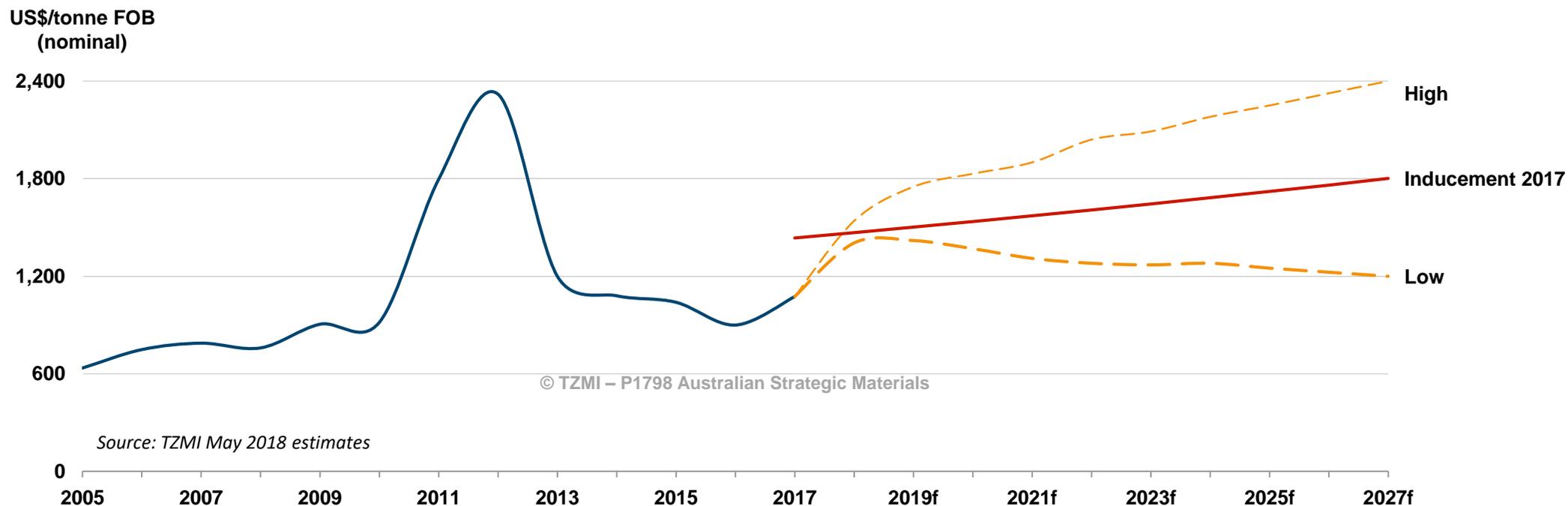




# PRICE FORECAST FOR ZOC

# Zircon price outlook

## Zircon (premium grade) price and outlook to 2027

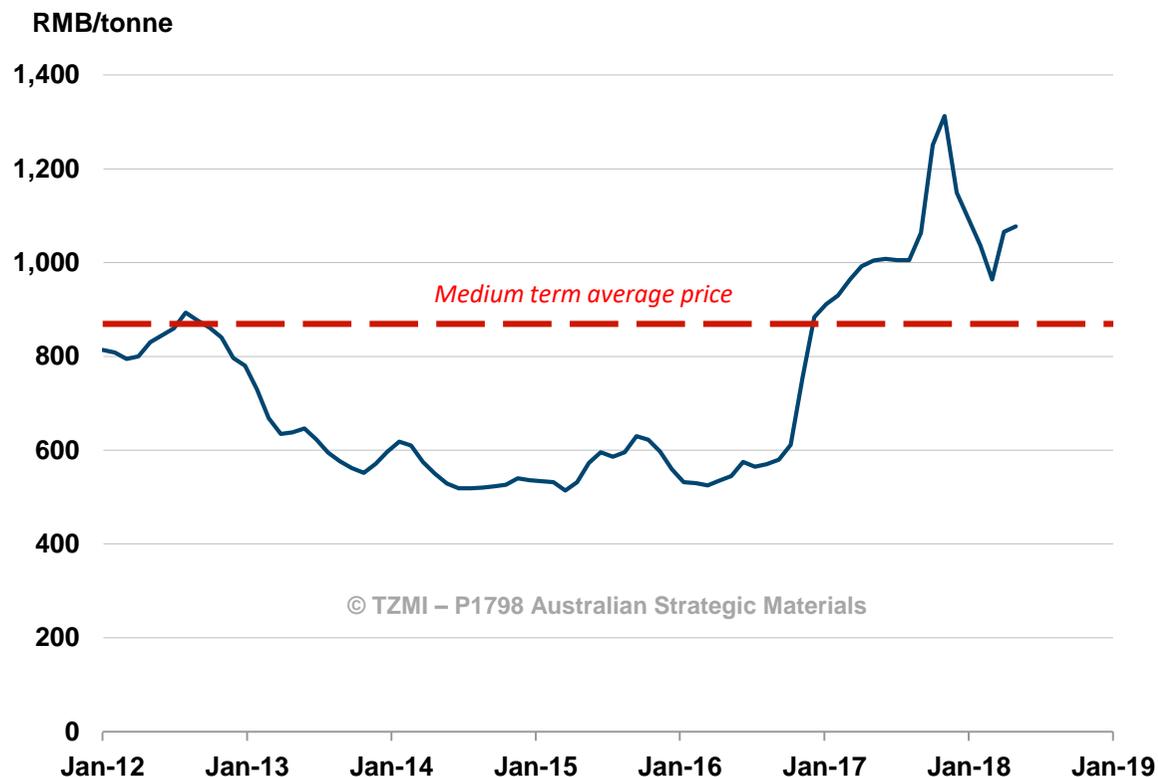


- The global weighted average price is estimated at US\$1,465 per tonne FOB for 2018, reflecting lower average prices in the first half.
- For 2019, TZMI's supply/demand estimates suggest that the market will be more or less balanced, with new supply from projects to be commissioned and response from swing producers able to meet demand growth. At the same time, TZMI believes zircon producers will exercise caution with implementing further price increases given that current price levels are already historically high.
- As such, some minor corrections to zircon pricing are anticipated in 2019, although the weighted average price for the year is still expected to be higher than that in 2018.
- The decline in prices is anticipated to be temporary, as prices are expected to pick up again in 2020 due to the emerging supply gap. A number of existing operations are expected to close due to depletion of mine life.

# Prices of caustic soda spiked in 2017

- Like most chemical sectors, the caustic soda market experienced a downturn after 2012 due to weaker macroeconomic conditions and partially reflected government interventions to cool down the overheating economy.
- Prices of caustic soda (for 30% NaOH liquid) in the domestic China market fell below RMB600 per tonne in 2013 and remained at this level until late 2016, after which prices recovered sharply by more than 100% as a result of environmental clamp-downs constraining local supply.
- The recovery in prices was attributed to the recovery in the domestic alumina, paper making, printing and dye industries, boosting demand for NaOH products. Caustic soda prices (30% NaOH liquid) were more than RMB1,200 per tonne by end 2017 but have been since declined due to increased supply.
- The current base case outlook for caustic soda assumes for slightly weaker pricing, as prices are expected to trend below RMB900 per tonne in the medium term and remain steady for the remainder of the forecast period.

Caustic soda prices (liquid 30% NaOH): Jan 2012 – Apr 2018



Source: [www.100ppi.com](http://www.100ppi.com)

# Base Case assumptions

Category	Assumptions
<b>Zircon</b>	<ul style="list-style-type: none"> <li>Near term pricing correction anticipated for 2019, but the weighted average price for the year is still expected to be higher than that of 2018. TZMI estimates that the weighted average price in 2019 at US\$1,580 per tonne FOB (premium grade zircon).</li> <li>It is anticipated that new supply from to be commissioned projects will keep the market in balance during the forecast period.</li> <li>No major substitution/thrifting to occur that results in considerable demand destruction.</li> <li>Long term zircon price remains unchanged at US\$1,435 per tonne FOB (real 2017 dollars).</li> </ul>
<b>Reagents</b>	<ul style="list-style-type: none"> <li>Prices of caustic soda (30% liquid) to decline below RMB900 per tonne (long term average) over the next 5 years.</li> <li>Minor increases in HCl pricing but this is expected to have negligible impact on ZOC production costs.</li> </ul>
<b>Environmental</b>	<ul style="list-style-type: none"> <li>Incremental cost associated with environmental compliance, adding approximately RMB1,000/tonne by 2027, or 10% CAGR from the 2018 base.</li> <li>No cost provision made for disposal/treatment of radioactive waste.</li> </ul>
<b>Other</b>	<ul style="list-style-type: none"> <li>Modest increase in gas and steam prices as demand increases.</li> <li>Assume labour cost to grow at 3% CAGR through to 2027.</li> </ul>
<b>Margin</b>	<ul style="list-style-type: none"> <li>The ZOC market stays in balance and ZOC producers are expected to maintain 20% profit margin during the forecast period.</li> </ul>

# Low Case assumptions

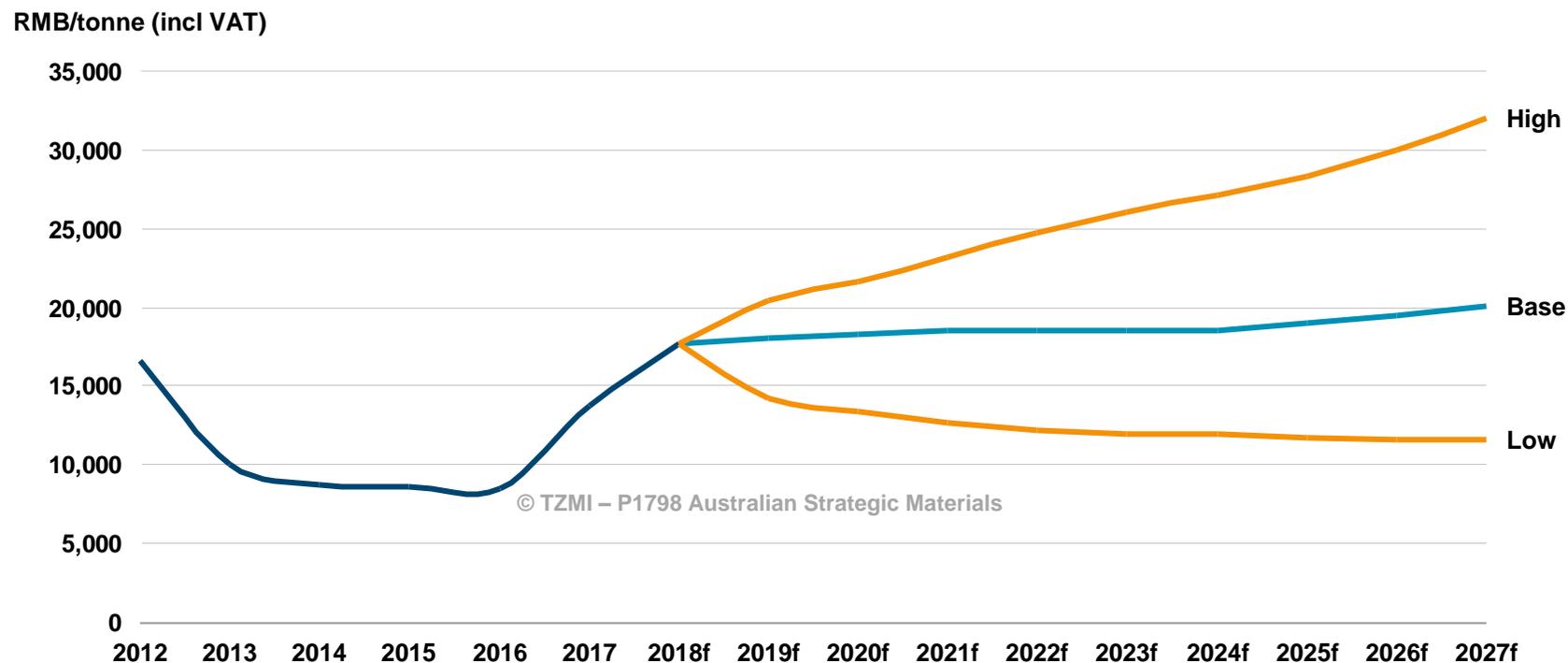
Category	Assumptions
<b>Zircon</b>	<ul style="list-style-type: none"> <li>Zircon pricing adopts the low case scenario in TZMI's forecast, underpinned by modest demand destruction in the ceramic sector and greater than anticipated new supply coming online.</li> <li>Global weighted average zircon (premium grade) price is estimated to trend towards US\$1,250 per tonne FOB by 2027.</li> </ul>
<b>Reagents</b>	<ul style="list-style-type: none"> <li>Prices of caustic soda to decline to 2013/14 levels, down approximately 50% from current levels.</li> <li>Minor increases in HCl pricing but this is expected to have negligible impact on ZOC production costs.</li> </ul>
<b>Environmental</b>	<ul style="list-style-type: none"> <li>Cost associated with environmental compliance remains flat at RMB700 per tonne of ZOC.</li> <li>No cost provision made for disposal/treatment of radioactive waste.</li> </ul>
<b>Other</b>	<ul style="list-style-type: none"> <li>Modest increase in gas and steam prices as demand increases.</li> <li>Assume labour cost to grow at 1% CAGR through to 2027.</li> </ul>
<b>Margin</b>	<ul style="list-style-type: none"> <li>The ZOC market is oversupplied, leading to margin erosions among ZOC producers. Under this scenario, it is assumed that producers' margin declines to 0% during the forecast period, although history has shown that Chinese ZOC producers are able to operate at negative margin for a number of years.</li> </ul>

# High Case assumptions

Category	Assumptions
<b>Zircon</b>	<ul style="list-style-type: none"> <li>Zircon pricing adopts the high case scenario in TZMI's forecast. This scenario is underpinned by stronger than expected demand in the sector and fewer supply from likely new projects able to come on stream during the forecast period.</li> <li>Global weighted average zircon (premium grade) price is estimated to trend towards US\$2,250 per tonne FOB by 2027.</li> </ul>
<b>Reagents</b>	<ul style="list-style-type: none"> <li>Prices of caustic soda are assumed to remain largely unchanged at current levels, which are historically high.</li> <li>Minor increases in HCl pricing but this is expected to have negligible impact on ZOC production costs.</li> </ul>
<b>Environmental</b>	<ul style="list-style-type: none"> <li>Considerable incremental costs associated with environmental compliance, increasing from RMB700 per tonne in 2018 to RMB1,700 per tonne of ZOC by 2027. This also includes provisions for disposal/treatment of radioactive waste.</li> </ul>
<b>Other</b>	<ul style="list-style-type: none"> <li>Modest increase in gas and steam prices as demand increases.</li> <li>Assume labour cost to grow at 1% CAGR through to 2027.</li> </ul>
<b>Margin</b>	<ul style="list-style-type: none"> <li>The ZOC market is in supply deficit. High costs associated with environmental reform result in some producers exiting the sector.</li> <li>Supply deficit in ZOC market will lead to higher prices being achieved, together with margin expansion at ZOC producers' end.</li> </ul>

# ZOC price forecasts

## China ZOC price forecasts to 2027 (nominal terms)



- For the Base Case, TZMI anticipates Chinese ZOC prices to remain relatively stable at RMB18,000-20,000 per tonne during the forecast period, with increases in zircon pricing offset by a slight decline in caustic soda prices. There will be incremental cost impact associated with environmental compliance, increasing the production cost base.
- In the Low Case, low zircon prices drive lower production costs. Weak market demand results in an oversupply of ZOC, leading to margin erosion. In this scenario, Chinese ZOC prices are expected to trend towards RMB11,500 per tonne by 2027.
- In the High Case, higher zircon and reagent pricing drive production cost higher. As China gets tough on environmental reforms, some producers are expected to exit the sector, leading to a supply deficit and margin expansion at remaining producers. Under this scenario, the Chinese ZOC price is expected to reach RMB32,000 per tonne by 2027.

# Uncertain supply, growing demand

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- The Chinese ZOC industry is consolidating. Uncompetitive plants are closing, leaving large scale companies, integrated producers with competitive downstream products, and companies with by-products.
- In addition, a number of existing operations are expected to close due to end of mine life.
- Global supply of zircon from existing operations is predicted to decline rapidly, down 4-5% per annum to 2025, to approximately 800,000 tonnes.
- Global demand for zircon was 1.1-1.2 million tonnes in 2017 and is expected to rise beyond this in 2018. The ceramic sector is expected to underpin global zircon consumption growth in the future.



# End of document

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