ILUKA

BRIEFING PAPER
MODERNISATION, THRIFTING & SUBSTITUTION IN THE MANUFACTURE OF TILES

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SUMMARY AND MAIN CONCLUSIONS

Modernisation, thrifting and substitution (MTS) practices in the manufacture of porcelain tiles have been evident in recent years, particularly in China (the largest tile manufacturing country). These practices, in large measure, follow trends which have been evident in other more advanced tile-making locations (such as Europe) at earlier stages. Zircon in the use of ceramics has constituted approximately 55% of global demand.

Iluka has committed resources since early 2011 to researching and assessing these trends globally and has referenced this in various presentations. This work has included: engagement with ceramic industry players, such as tile manufacturers, raw material producers and ceramic equipment manufacturers; visits to most of the major ceramic manufacturing areas in China and elsewhere; engagement with ceramics research institutes and other research and technical bodies; and more recently the company's own technical work which has involved, amongst other things, sampling of tiles and ceramics to determine trends in zircon intensity of use. Similar work has been undertaken in relation to titanium dioxide usage trends and technical developments and is part of Iluka's broader approach to deepening its analytical base related to industry trends and developments.

Estimates of ceramic tile production in China span a wide range (varying by over 1 billion square metres per annum). Estimates of changes in zircon consumption are similarly challenging. In addition, in 2012 especially, the industry has seen three demand effects at work: destocking, lower manufacturing output and MTS practices.

While Iluka's work is ongoing, the main conclusions in relation to zircon use in tile manufacturing are:

- the adoption of modern tile manufacturing technologies (mainly the "double charging" process) for porcelain tiles has had the most significant impact on the reduction of zircon use in this segment over the last two years - constituting approximately 90% of the assessed decline in zircon use in China ceramics, and accounting for approximately two thirds of the estimated total global impact from MTS practices;
- this manufacturing modernisation represents a structural shift, which in Iluka's view is largely complete;
- these practices follow a trend that has been evident in Europe for at least a decade;

- adoption of the modernisation practices has been inevitable, in many respects, and is considered to have been stimulated initially by lack of availability of zircon-based opacifier products; more recently by higher zircon prices representing a higher proportion of the input costs of tile manufacturers, the impact of increases in other input costs (such as power, labour and other raw materials), as well as the inevitable trend evident in most industries to improve efficiency and reduce costs by investment in new technology;
- representative surveys of porcelain tile products from the major ceramics production provinces in China, as well as in other provinces, undertaken on separate occasions in late 2012 (by Iluka and an externally-commissioned organisation) showed that double charged porcelain tiles are now the norm;
- other approaches to lowering zircon usage, such as through outright substitution (in some cases and in some forms of tiles only) and thrifting (changing formulations to use less zircon or more of alternative products) are also well advanced in Iluka's assessment; and
- Iluka expects higher output of ceramics in developing economies, particularly China, will offset the lower loadings of zircon per square metre of tile in the next few years, along with substantial growth in zircon consumption in other sectors, including zirconia chemicals, as well as new applications for zircon usage.

Accordingly, while Iluka estimates that MTS practices have had an impact on overall zircon consumption levels in 2011 and 2012, in particular, this aspect of the zircon market needs to be seen also in the context of the effects of inventory de-stocking (mainly at the finished ceramics end) and lower demand influenced by global economic performance and associated business confidence levels. It is Iluka's assessment that these latter two, largely cyclical forces, will unwind in future periods, resulting in an increase in zircon demand.

Zircon in Ceramics

Zircon is used in the manufacture of ceramic products (floor and wall tiles, sanitary ware, table ware, as well as a range of industrial and high-end ceramics applications). In ceramics, zircon's highly-valued property is its high refractive index for opacification and whiteness. Its ancillary benefits, including its ability to impart greater mechanical strength, toughness and durability to ceramic bodies and glass matrices, are established attributes and valued by specific segments in the ceramic industry catering to markets with a preference for these attributes.

The uses of zirconium dioxides in advanced ceramics are well accepted, particularly for their heat, electrical and wear properties. Areas of application include high performance engineering ceramics, such as zirconium dioxide ceramic thermal-barrier coatings that insulate and protect aircraft and industrial gas-turbine engine components from extremely high temperatures. Zirconium oxide, the most commonly utilised type of zircon derivative in technical ceramics, has the lowest thermal conductivity of any advanced ceramic, along with high impact strength and high resistance to chemicals.

Forms of Tiles and Zircon Component

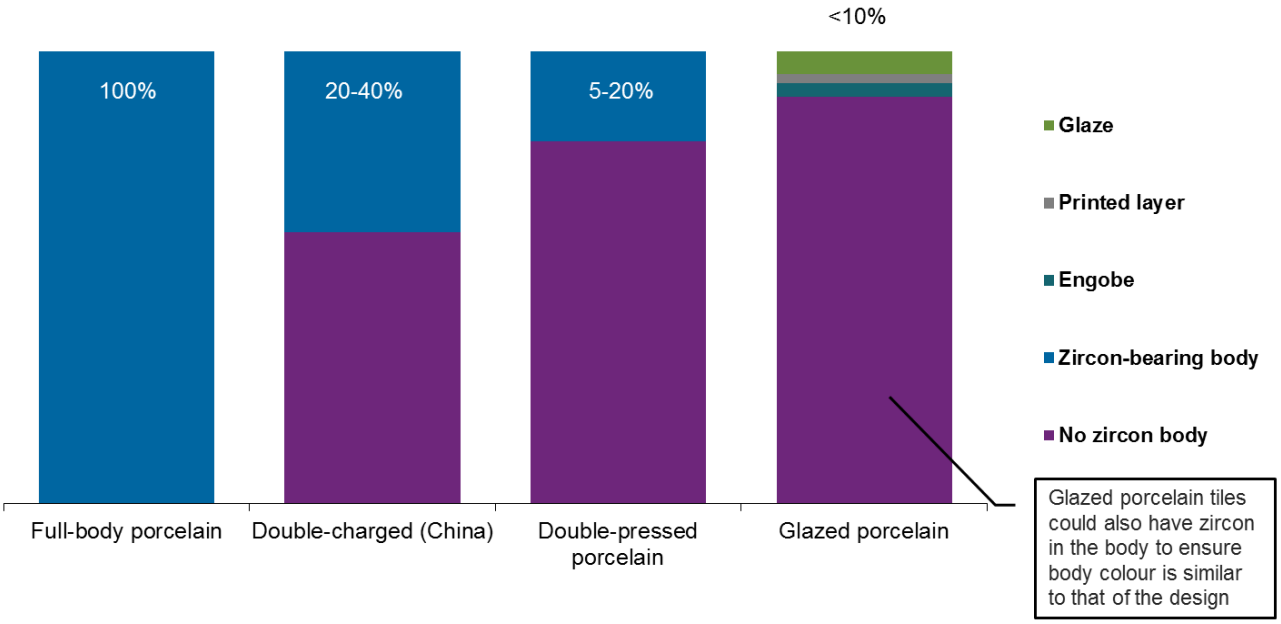
Zircon content in ceramic tiles varies according to several factors, including:

- type of tiles – that is, polished porcelain tiles, glazed porcelain tiles, glazed ceramic tiles;
- production region - that is Italy, Spain, China, India etc; and
- production process - that is full body, double pressed, double charged, thin tiles etc.

As such, it is important to note that zircon usage is not uniform across ceramics – glazed tiles may use no or minimal amounts of zircon while some forms of porcelain tiles can also use no or minimal zircon. On the other hand, some forms of porcelain tiles can use very large amounts or median amounts of zircon. This makes interpretations, drawn from unrepresentative sampling procedures or based on an inadequate knowledge of tile constituent products, potentially highly misleading.

In terms of ceramics' production, the following chart shows an indicative split of zircon in varying forms of tiles.

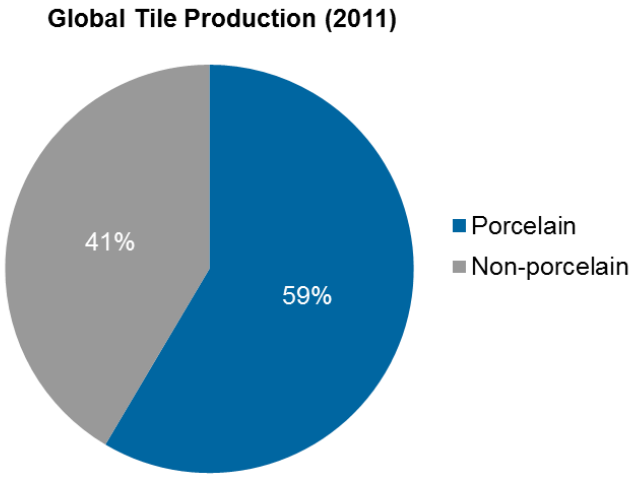
Figure 1 Zircon Containing Layers of Various Tile Types



Porcelain tiles use the highest zircon density amongst ceramics products (and constitute approximately 70% of global zircon consumption for tiles). Porcelain tiles constitute approximately 60% of total ceramics manufacture, based on the production categories of the top 11 tile producing countries in the world in 2011. Based on sampling and testing of tiles from various tile producing countries, Italian polished porcelain tiles typically have the highest amount of zircon (300 – 1,000 grams per square metre) while polished porcelain tiles in China fall within the range of 10 – 540 grams of zircon per square metre.

In terms of total tile manufacturing the following diagram shows the global volumetric split, with the main centres of porcelain tile manufacture globally being Italy, China, Indonesia and Spain.

Figure 2 Percentage of Porcelain Type in Top 11 Tile Producing Countries



Source: Asian Ceramics

Within porcelain tiles, there are glazed and polished tiles. In China almost all porcelain tiles are polished. Polished tiles typically require higher amounts of zircon than glazed porcelain tiles. Increasing affluence and quality appreciation and higher disposable incomes are expected to reinforce this preference.

For glazed porcelain and glazed ceramic tiles, generally zircon is contained only in the engobe and the opaque glazes, with typical zircon content appreciably lower than polished porcelain tiles. However, it is also a practice of tile producers, especially those that produce high quality products, to add opacifier to the bodies of glazed

porcelain to ensure that the colour of the body is close to the colour of the design. Doing this prevents unsightly marks when deep scratches occur on the tile that may allow the colour of the underlying body to be seen.

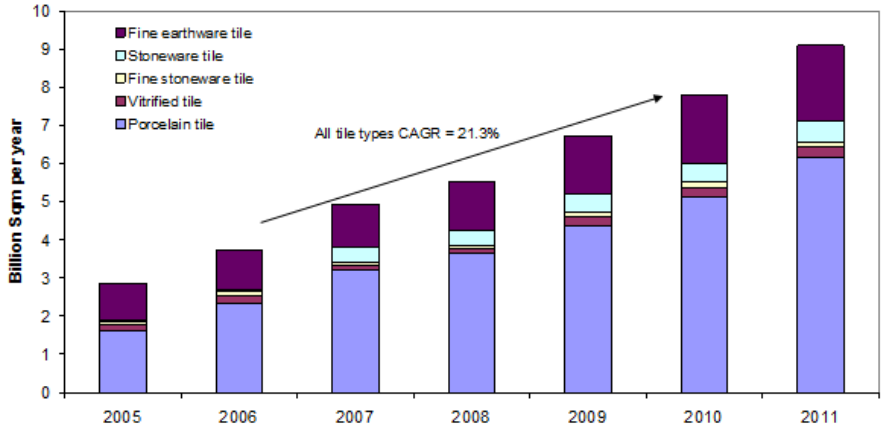
It can be assumed that zircon demand will benefit from both increases in floor space in developing economies, together with increasing consumer preference towards porcelain tiles and those that require higher zircon loadings.

Ceramics Production Trends in China

The following table shows ceramic tile production trends in China, the largest global consumer of zircon currently. Within China, ceramics (in all of its applications) has accounted for approximately 55% of demand. Data from Asian Ceramics and China Building and Sanitary Ceramics Association show that Chinese tile production has been increasing by 21.3% CAGR with a target to exceed the 10 billion square metre mark by 2015.

In 2011, production was 8.7 billion square metres.

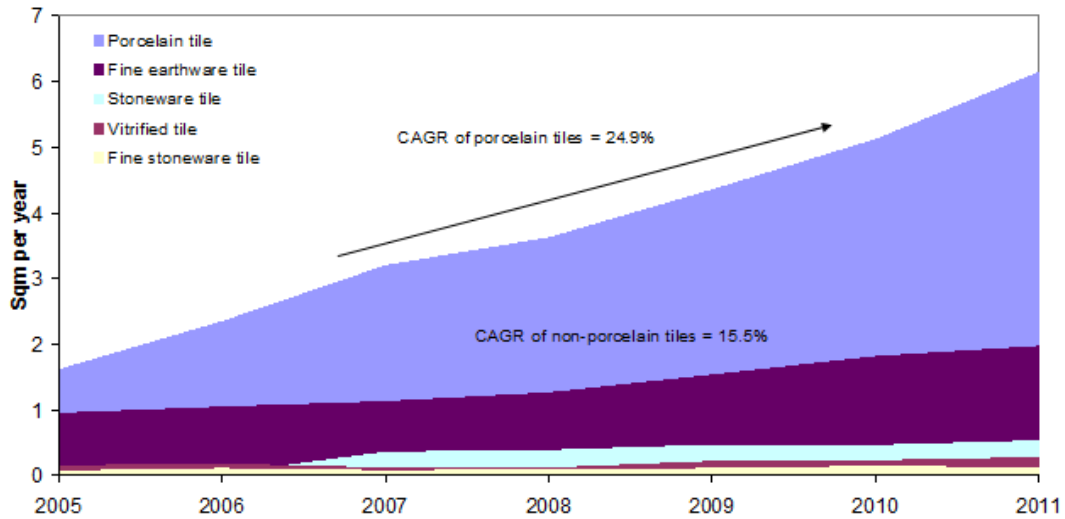
Figure 3 Chinese Ceramic Tile Production



Source: Asian Ceramics

The following chart shows the historical growth rate of porcelain and non-porcelain tiles in China since 2005.

Figure 4 Chinese Ceramic Tile Production



Source: Asian Ceramics

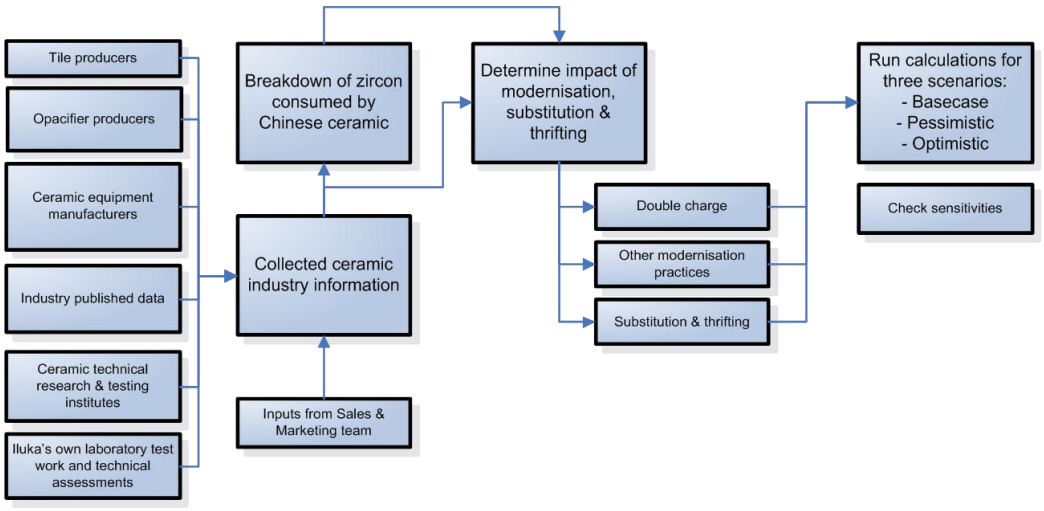
Porcelain tiles, which consume the largest part of zircon in the ceramics sector, have had a CAGR of ~25%, relative to non-porcelain tile CAGR of ~15%.

Iluka's Investigation into Modernisation, Thrifting and Substitution Practices

As with any industry undergoing change in terms of increasing sophistication of production processes, as well as a focus on reduction of raw material input costs, for both direct customers and for ceramics' manufacturers, thrifting and substitution practices will be part of the evolving zircon demand landscape. Iluka has devoted resources to this area to understand the nature of these practices; to determine the likely volumetric effect on this one specific sector of zircon end demand (ceramics tile manufacture); and to utilise this data to forecast zircon demand in this sector via estimates of average zircon intensity of use in various forms of ceramics tiles and of the overall volumetric growth of square metres of tiles manufactured and consumed. Due to both commercial considerations (for example cost structure data for ceramics manufacturers) and proprietary intelligence considerations, the paper does not disclose detailed data in a number of areas of Iluka's work.

Iluka undertakes similar work in other areas of zircon application, where MTS is not considered a major influence, as well in the area of titanium dioxide usage, where again MTS implications are assessed as marginal. In addition, the company supports industry initiatives, such as the Zircon Industry Association, to promote the attributes of zircon and research into new and varying end applications.

The following diagram indicates the areas of Iluka's investigation.



Iluka's analysis has entailed detailed work on the main cost inputs to the manufacture of both porcelain and ceramic tiles in different locations, and on the quality of tiles manufactured within the various product categories.

In seeking to reduce the input cost of zircon, tile manufactures have experimented with a number of approaches, which are categorised by Iluka as: modernisation, thrifting and substitution, defined below. These practices have been most prevalent in China over the recent period.

Modernisation

This mainly refers to a process of "double charging" or "double loading" where porcelain tiles are produced in two layers or two passes, enabling zircon content which would otherwise have been throughout the entire body of the tile to be contained only in the upper layer. This practice has been in existence in Europe for over a decade. In China, this technology has also been in place for more than six years but implementation was not extensive across the industry. Since early 2011, many Chinese tile manufacturers have installed the necessary machinery (typically sourced from local Chinese equipment manufacturers) to adopt this practice. It should be noted that these techniques have long been available in the industry, but the adoption of such techniques has accelerated in the past two years influenced by zircon opacifier availability issues initially and, subsequently, higher zircon pricing, as well as increases in other input. The practice, as displayed in Figure 2, has reduced materially zircon traditionally used in full bodied porcelain tiles. In Iluka's view, this practice is now widely established amongst the major porcelain tile manufacturers.

Thrifting and Substitution (or partial substitution)

These entail lower usage of zircon in tile formulations by, in rare cases, outright substitution of zircon or more commonly by reduction in zircon content by mixing with other products, including body whiteners, such as white

clay, kaolin, floated feldspar, calcined alumina and so on. The knowledge of such materials and their use has been evident for an extended period in tile manufacturing and they have long formed part of some ceramic formulations. The use of alternative products is dependent in part on their physical availability (in some regions they are not readily available or cost-effective to procure) and efficacy in usage. As with the double charging approach, Iluka's observations suggest that such changes in formulations in the main tile manufacturing centres and with the main ceramics manufacturers are well advanced. Based on the company's observations, it has not seen any new practices in modernisation or thrifting approaches or in the use of substitutes since the September quarter 2012. The trend to using substitute whitening materials may be considered reversible as there are no significant impediments to switching back, with any such trend likely to be influenced by zircon pricing as well as the performance characteristics of tiles of lower zircon content.

In Iluka's assessment modernisation initiatives, particularly double charging, have resulted in the vast majority of the demand reduction impact relative to previous levels, over the last two years.

Since 2010 (and most likely before this date) China has pursued a trend similar to that adopted in European ceramics manufacturing centres where the intensity of zircon usage has decreased. This trend has been influenced, in Iluka's assessment by:

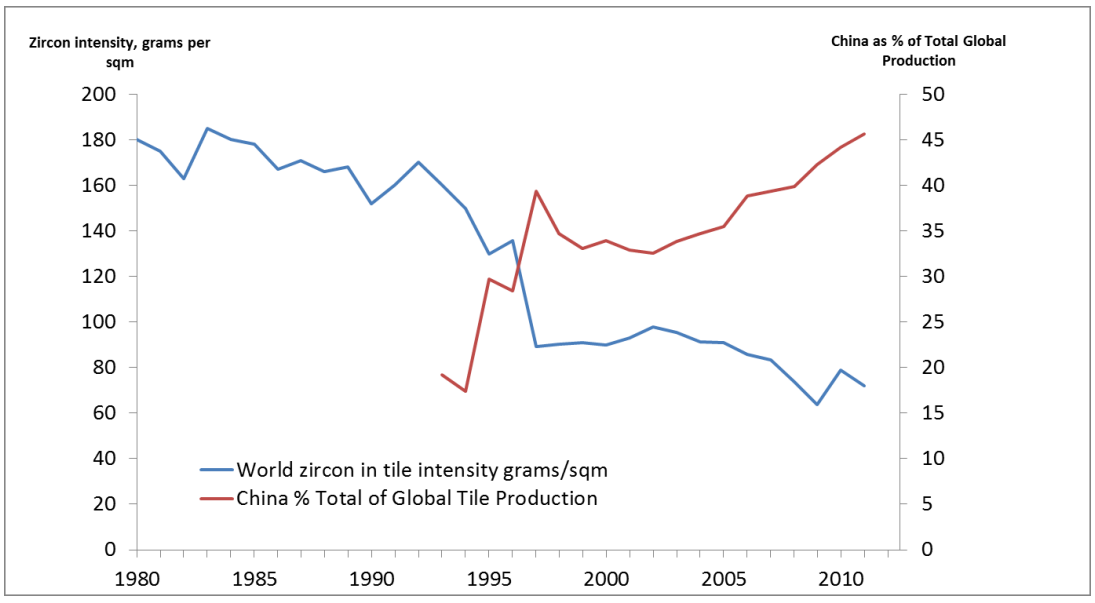
- initial supply restrictions on the availability of zircon-based opacifiers during 2010 and 2011;
- lower profit margins for Chinese tile manufacturers, which despite input price increases, were associated with the factory selling price of porcelain tiles in China reducing by an estimated ~6% per year between 2009 and 2011;
- the attendant desire to reduce raw material costs such as zircon, particularly in porcelain tile manufacturing;
- increased other input costs, including power, labour and other raw materials; and
- the local availability of established modern tile manufacturing technology (at a capital investment cost) and alternative partial substitute inputs.

Iluka's work in this area is ongoing, including detailed analysis of zircon content of various forms of tiles.

Historical Zircon Usage Trends

The following chart indicates that the trend, particularly since the mid-1990s, of zircon intensity in ceramics has been declining. This has been influenced by two main factors: the adoption of modern tile manufacturing techniques in Europe which has reduced zircon intensity of use, as well as China's rise in tile production, with its significant element of lower quality and low zircon intensity tiles. Over this period, while varying from year to year in line with global economic forces, the global usage of zircon in ceramics has shown a dramatic increase. While compression in zircon intensity in tiles has been evident, based on the factors discussed in this briefing paper, Iluka expects world zircon usage in ceramics to continue to increase, albeit off a lower 2012 level.

Figure 5 Zircon Intensity in Ceramic Tiles

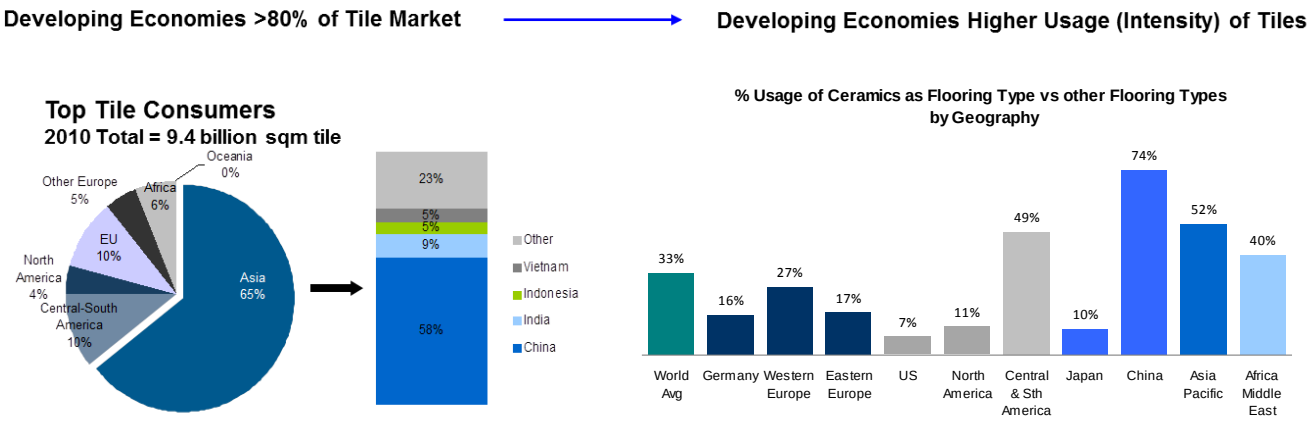


Source: TZMI and Ceramic World Review

On Iluka's assessment, zircon usage in tiles will increase and re-establish itself above 2011 levels in the short to medium term based on the developing economy phenomenon of urbanisation and increases in floor space and, with it, higher levels of ceramics usage.

As shown in the following charts, the developing economies constitute over 80 per cent of global tile consumption. Such countries have a cultural and/or climatic preference for ceramic-based flooring. Given economic growth levels from developing economies are forecast to exceed more mature economies, there is a potential "leveraging" effect upon tile growth, and zircon demand in this application, in developing economies.

Figure 6 Zircon Intensity of Use – Dominated by Developing Economies



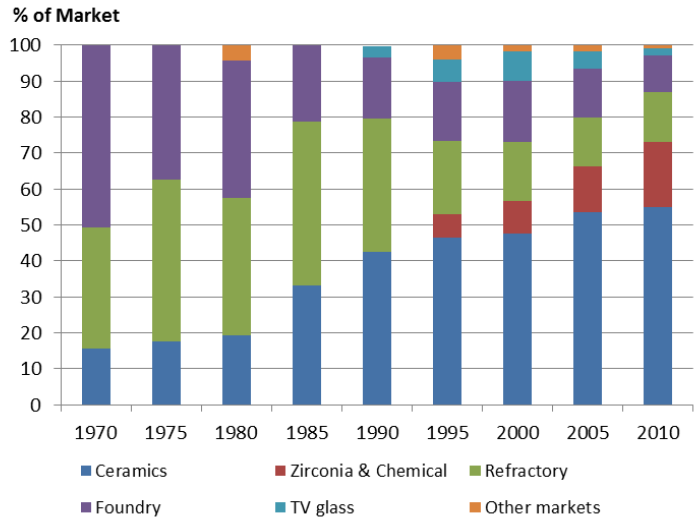
Overlaying this area of sector demand is an expected growth trend in non-ceramic demand, which is likely to exceed that for ceramics historically and will, in all likelihood, result in a greater level of zircon used in non-ceramic applications**.**

Overall Demand Trends for Zircon – All Sectors of End Demand

Historically, zircon's use in differing applications has varied in different historical periods. In the 1970s, zircon's major use was in foundry applications; in the 1980s it was in refractories; and in the 1990s and 2000s predominantly in ceramics.

However, the fastest growing sector for zircon use in recent years has been in the zirconia chemicals sector. The current trend towards zirconia chemicals use is expected to continue to be reflected in strong demand, influenced by supply to a range of high technology industries and a myriad of end use and niche applications. It is possible that zircon's use in zirconia chemicals may supplant its use in ceramics over the next five years.

Figure 7 Historical Demand by End Segments for Zircon



Source: TZMI, Roskill, USGS & Iluka

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