Horizon 2020 Programme

SCRREEN2

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958211.

Start date: 2020-11-01 Duration: 36 Months

SCRREEN

Solutions for CRitical Raw materials - a European Expert Network

FACTSHEETS UPDATES **BASED ON THE EU FACTSHEETS 2020**

FELDSPAR

AUTHOR(S):

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FELDSPAR

OVERVIEW

Feldspars (and feldspathoids) are a group of rock-forming minerals, which are alumino-silicates of sodium, potassium, calcium or combinations of these elements. They constitute as much as 60% of the Earth's crust and are recovered from a wide range of rocks, which are the actual raw materials used by industry. In fact, the amount of feldspars and feldspathoids in commercial products rarely exceeds 85% and is usually in the 30-80% range. Such feldspathic rocks encompass igneous (e.g., aplite-pegmatite, nepheline syenite), sedimentary (e.g., arkosic sand) and metasomatic types (e.g., albitite) along with their metamorphic equivalents (Potter, 2006; McLemore, 2006; Dondi, 2018).

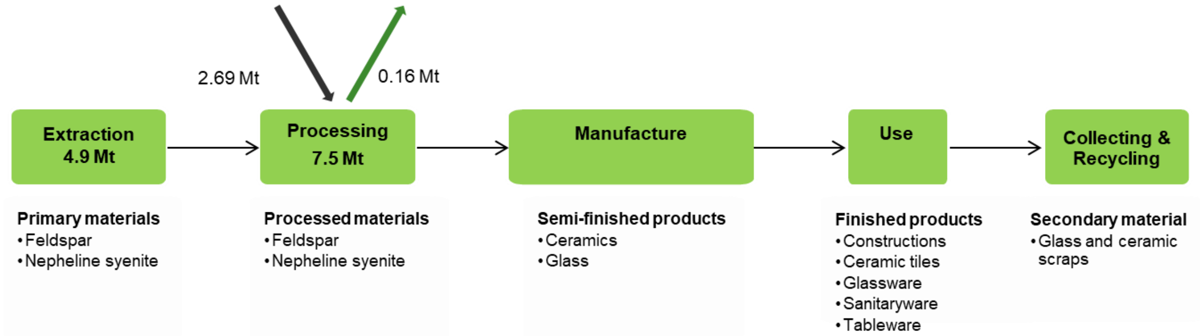

Figure 1. Simplified value chain for RM in the EU[1]

Table 1. RM supply and demand in metric tonnes, 2016-2020 average

Global production	Global Producers	EU consumption	EU Share	EU Suppliers	Import reliance
31.8 Mtonnes	Turkey 32% India 20% China 8% Italy 7% Iran 5% Thailand 4% Indonesia 3%	9.8 Mtonnes	30.7%	Turkey 93% Norway 6%	54%

Prices: Feldspar prices vary across countries. From 2007 to 2018, the most significant rate of growth in export price was achieved by China, while the other players experienced more moderate paces of growth. The average feldspar export price was USD 44 per tonne in 2018, rising by 6.8% compared to the previous year. In 2018, India had the highest export price at USD 73 per tonne while Turkey (USD 31 per tonne) was amongst the lowest. In 2018, the average feldspar import price was USD 51 per tonne, approximately reflecting the previous year.

[1] JRC elaboration on multiple sources (see next sections)

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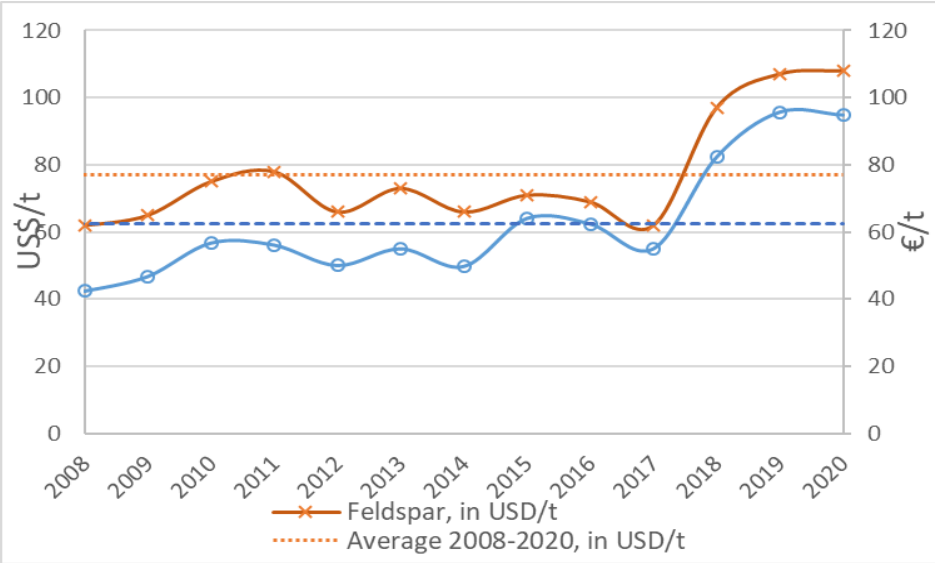

Figure 2. Annual average price of RM between 2000 and 2020 (USGS, 2021)[2].

Primary supply: Turkey and India are the major producers, with 10 and 6.2 Mt respectively, in 2020 (WMD, since 1984). A notable feldspar production is taking place also in China, Italy and Iran, with 2.4, 2.2 and 1.9 Mt, respectively.

Secondary supply: Feldspars (and feldspathoids) are mainly used as fluxes in ceramic and glass production (98.5%). In these applications, they are melted and no feldspars exist in the finished products (Dondi, 2018; IMA-Europe, 2018). Thus, recycling entails end-of-life glass and ceramics (containing the original feldspars transformed in a vitreous phase) that can act as flux. Feldspars and feldspathoids used as fillers and extenders are englobed into paints, glues, plastic and rubber products, so no recycling is possible.

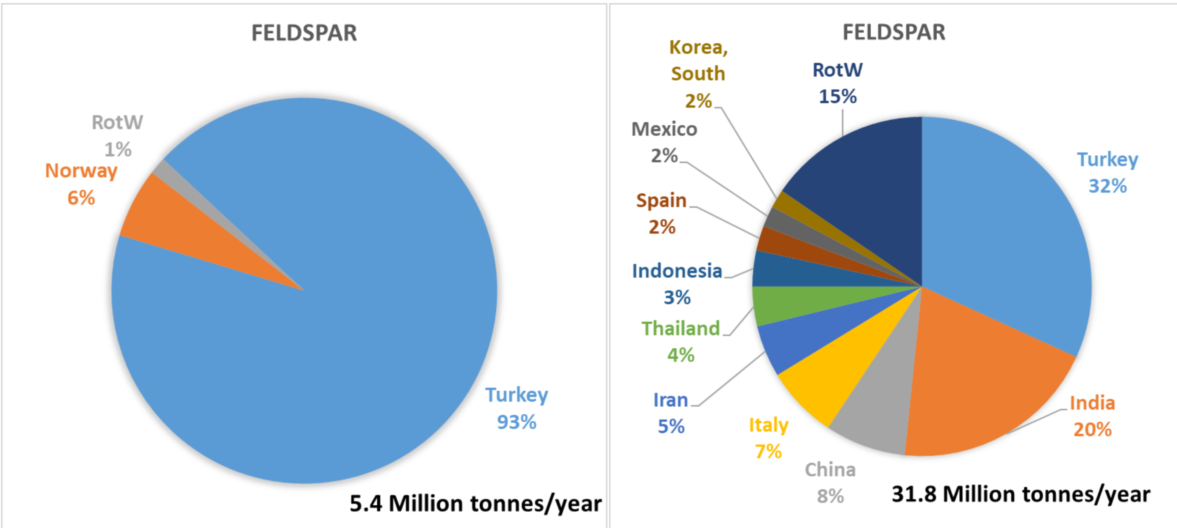

Figure 3. EU sourcing of RM and global mine production (2016-2020)

[2] Values in €/kg are converted from original data in US$/kg by using the annual average Euro foreign exchange reference rates from the European Central Bank (https://www.ecb.europa.eu/stats/policy_and_exchange_rates/euro_reference_exchange_rates/html/eurofxref-graph-usd.en.html)

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Uses: Feldspars are used widely in the glass and ceramics industries. Alkali feldspars are more commonly used commercially than plagioclase feldspars. Albite, or soda spar as it is known commercially, is used in ceramics. The feldspar-rich rocks larvikite and a few anorthosites are employed as both interior and exterior facing slabs. In addition, several feldspars are used as gemstones.

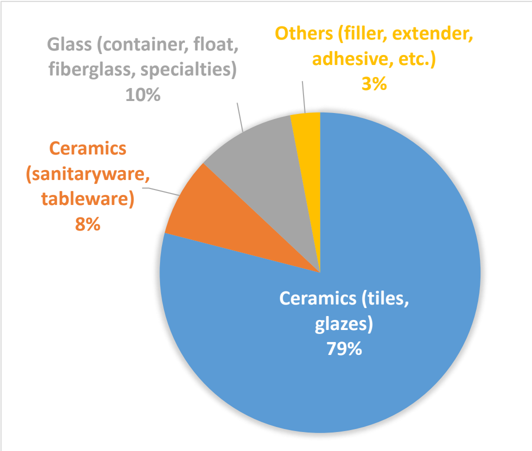

Figure 4: EU uses of RM

Substitution: There is a large range of substitutes in these applications, including calcium carbonate, talc, wollastonite, kaolin, mica, pyrophyllite, silica, diatomite, and bentonite (IMA-Europe, 2018; Kogel, 2006; SCRREEN workshops, 2019, 2022).

Table 2. Uses and possible substitutes

Use	Share*	Substitutes	Sub share	Cost	Performance
Ceramics (tiles, glazes)	79%	Talc	2%	Slightly higher costs (up to 2 times)	Reduced
Ceramics (tiles, glazes)	79%	Dolomite	1%	Similar or lower costs	Reduced
Ceramics (tiles, glazes)	79%	Wollastonite	1%	Very high costs (more than 2 times)	Similar
Ceramics (tiles, glazes)	79%	Pottery stone, Phyllite	1%	Similar or lower costs	Reduced
Ceramics (tiles, glazes)	79%	no substitute	95%		No substitute
Ceramics (sanitaryware, tableware)	8%	Lithium silicates	5%	Very high costs (more than 2 times)	Similar
Ceramics (sanitaryware, tableware)	8%	no substitute	95%		No substitute
Glass (container, float, fiberglass, specialties)	10%	Kaolin	5%	Slightly higher costs (up to 2 times)	Reduced
Glass (container, float, fiberglass, specialties)	10%	no substitute	95%		No substitute
Others (filler, extender, adhesive, etc.)	3%	Lime (calcium carbonate)	5%	Similar or lower costs	Similar
Others (filler, extender, adhesive, etc.)	3%	Talc	5%	Slightly higher costs (up to 2 times)	Similar
Others (filler, extender, adhesive, etc.)	3%	Wollastonite	5%	Very high costs (more than 2 times)	Similar
Others (filler, extender, adhesive, etc.)	3%	Kaolin	2%	Slightly higher costs (up to 2 times)	Similar

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Others (filler, extender, adhesive, etc.)	3%	Mica	2%	Slightly higher costs (up to 2 times)	Similar
Others (filler, extender, adhesive, etc.)	3%	Pyrophyllite	2%	Similar or lower costs	Similar
Others (filler, extender, adhesive, etc.)	3%	Silica	2%	Similar or lower costs	Similar
Others (filler, extender, adhesive, etc.)	3%	Diatomite	1%	Similar or lower costs	Similar
Others (filler, extender, adhesive, etc.)	3%	Bentonite	1%	Slightly higher costs (up to 2 times)	Similar
Others (filler, extender, adhesive, etc.)	3%	no substitute	75%		No substitute

*based on EU end use share of feldspar, 2020 (SCRREEN Experts, 2022)

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MARKET ANALYSIS, TRADE AND PRICES

GLOBAL MARKET

Table: Feldspar (extraction) supply and demand in metric million tonnes, 2016-2020 average

Global production	Global Producers	EU consumption	EU Share	EU Suppliers	Import reliance
31.9 Mtonnes	Turkey 32% India 20% China 8% Italy 7% Iran 5% Thailand 4% Indonesia 3%	9.8 Mtonnes	18.9%	Turkey 93% Norway 6%	55%

Feldspar is recovered from different geological sources: albitites (37%), pegmatites and aplites (24%), granitoids (16%), feldspathic arenites (11%), nepheline syenites (6.5%), rhyolites and porphyries (2.5%), metamorphics and epithermal alterations (1.5% each).

Extracted feldspar and nepheline syenite comes mostly from Turkey. Other producers are India, China, Iran, and Italy (USGS, 2022). In the EU, the major producers in the EU are Italy and Spain (SCRREEN2 workshops, 2022). Though Turkey remains a major producer, the economic importance related to feldspar is limited (SCRREEN2 workshop, 2022).

The world market of feldspar was on average 31.9 Mt in the period 2016-2020 (WMD, 2022 quite stable on the period, after a continuous growth over the last 30 years. It worth 2 billion euros. Most of the feldspar is sold on the open market and only some users signed annual contracts of supply (Dondi, 2018).

The key vendors are Imerys Minerals, Eczacibasi Esan, Gimpex, EP Minerals, Micronized Group, Minerali Industriali, Sibelco, Pacer Minerals, Asia Mineral Processing, Sun Minerals, The Quartz Corp. and Polycor.

Overall, reserves are thought to be “large”, simply because of the feldspar abundance in the Earth’s crust, even though their quantification is missing in most cases (Dondi, 2018). Reserves could be significant for Iran, India, and Turkey (USGS, 2022).

Main applications include ceramics, for uses in tiles and glazes (79%), and for sanitaryware and tableware (8%). Glass is also an important application (10%) as it is used for containers, float, fiberglass, and specialties. Other applications encompass filler, extender, adhesive among others (3%) (SCRREEN2 workshop, 2022).

The global feldspar is estimated to grow at a compound annual growth rate of 4.9% from 2020 to 2027 (Grand View Research, 2022).

Feldspar growth was mostly due to a shift in demand towards porcelain tiles. The production of porcelain tiles has increased and is globally 250 million tonnes a year (SCRREEN2 workshop, 2022). The Ukraine war might trigger substitution in certain applications (SCRREEN2 workshop, 2022).

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EU TRADE

Feldspar is assessed at Mining and concentrate level. The following table lists relevant Eurostat CN trade codes for Feldspar.

Table 3: Relevant Eurostat CN trade codes for Feldspar.

Mining	
CN trade code	**title**
252910	Feldspar
25293000	Leucite, nepheline, and nepheline syenite

The listed CN codes that refer to Feldspar are: 252910-Feldspar and 25293000-Leucite, nepheline, and nepheline syenite.

Figure 5 shows the import and export trend of feldspar. The EU is a net importer of Feldspar. The EU exports lower quantities of Feldspar compared to imports. It was stable during 2000-2021 without any fluctuation. While the import of Feldspar had an increasing trend with some fluctuations in 2000 to 2010 and 2018 to 2020. The decline in 2020 can be related to Covid-19 impacts during those years. Overall, the import of Feldspar to EU increased around 4 times from 1,954,907 tonnes in 2000 to 7,144,678 tonnes in 2021.

Figure 6 illustrates the share of import in EU for Feldspar from various countries. The main import partner of EU is Turkey by share of 97% in all years. Norway, Morocco and the rest of world, each contributed only by 1% in the import to EU.

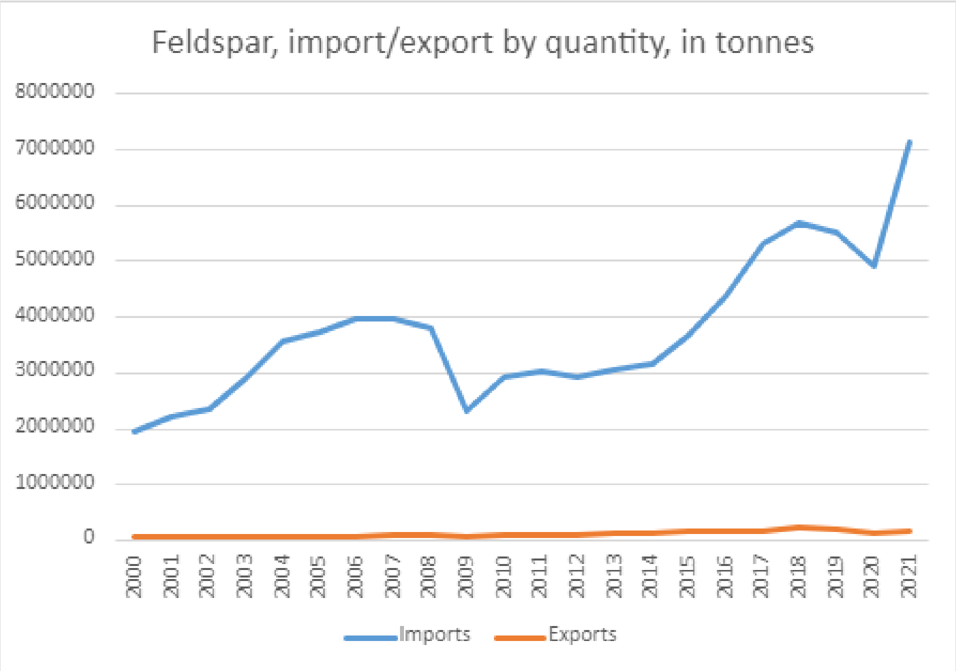

Figure 5. EU trade flows of feldspar (CN 252910) from 2000 to 2021 (Eurostat, 2022)

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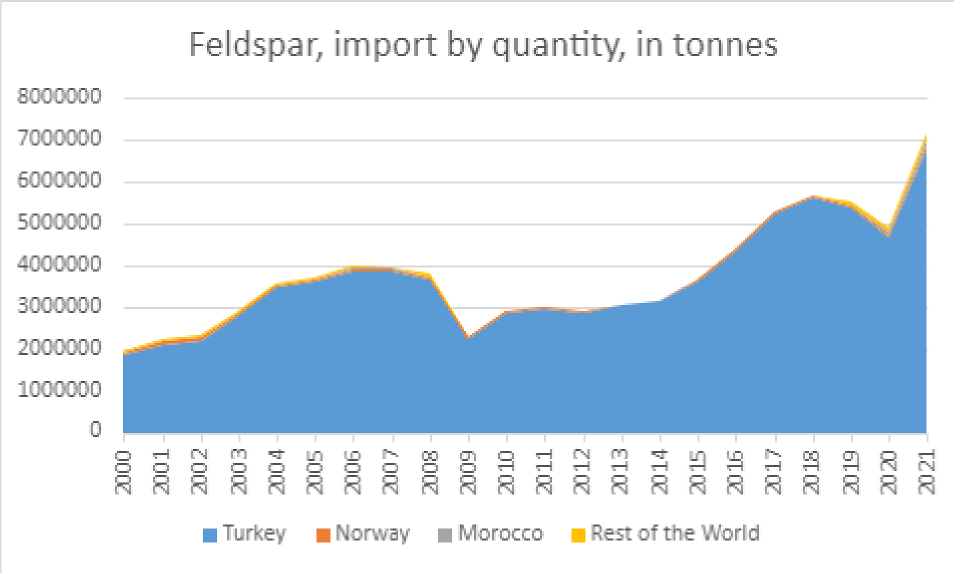

Figure 6. EU imports of feldspar (CN 252910) by country from 2000 to 2021 (Eurostat, 2022)

Figure 7 shows the import and export trend of leucite, nepheline, and nepheline syenite. The EU is an also net importer of this commodity. The import data shows a gradual declining trend with some fluctuations from 2000 to 2021. The import in 2021 was 305,795 tonnes compared 373, 486 tonnes in 2000. EU also exports comparatively minor quantity of leucite, nepheline, and nepheline syenite. The export increased from 2664 tonnes in 2000 to 9530 tonnes in 2021.

Figure 8 presents the share of import in EU for Leucite, nepheline, and nepheline syenite from various countries. The main suppliers of EU are Norway (76%), Canada (20%) and Russia (2%). Norway was always the main supplier of Leucite, nepheline, and nepheline syenite to EU over the 21-years period. The import from Russia increased more than 18 times in 2013 (from 703 tonnes in 2012 to 13,243 tonnes in 2013), While the import from Canada shows declining.

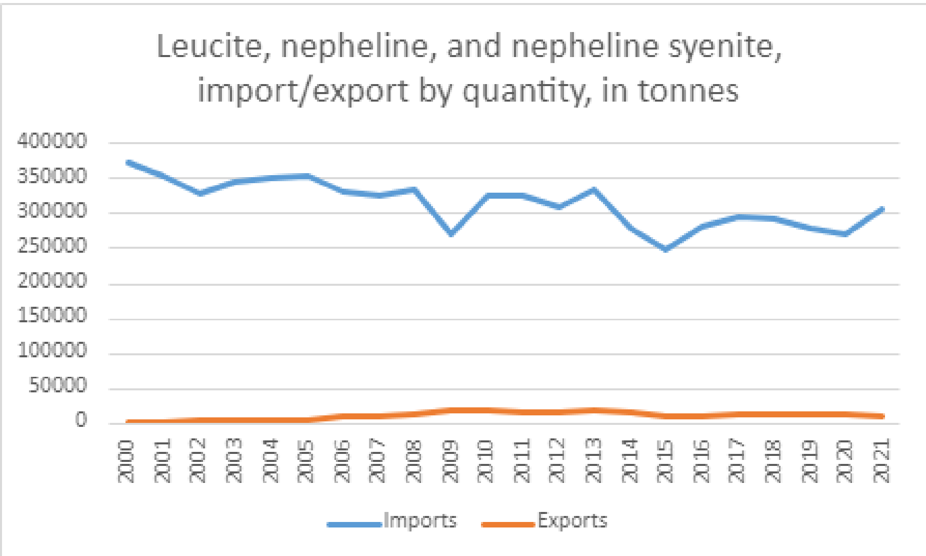

Figure 7. EU Trade flows of leucite, nepheline, and nepheline syenite (CN 25293000) from 2000 to 2021 (Eurostat, 2022)

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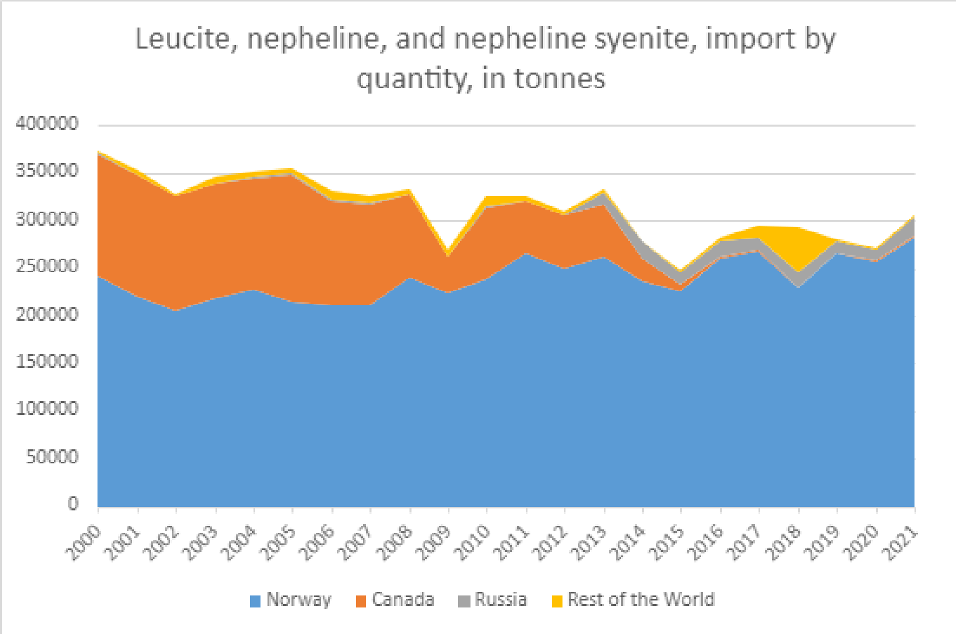

Figure 8. EU imports of leucite, nepheline, and nepheline syenite (CN 25293000) by country from 2000 to 2021 (Eurostat, 2022)

PRICE AND PRICE VOLATILITY

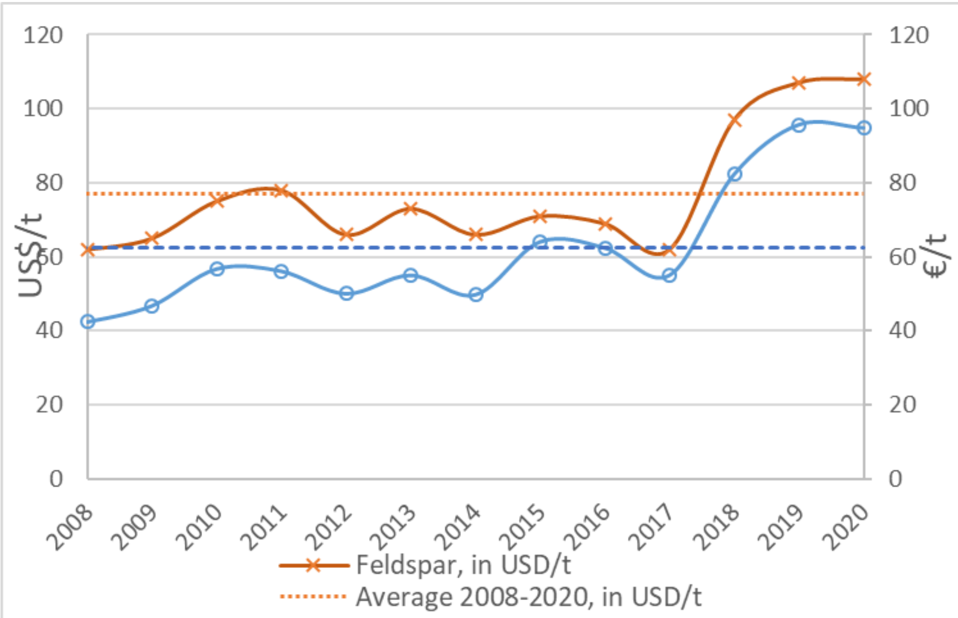

Figure 9. Annual average price of feldspar between 2008 and 2020, in US$/t and €/t[3]. Dash lines indicates average price for 2008-2020 (USGS, 2022)

[3] Values in €/kg are converted from original data in US$/kg by using the annual average Euro foreign exchange reference rates from the European Central Bank (https://www.ecb.europa.eu/stats/policy_and_exchange_rates/euro_reference_exchange_rates/html/eurofxref-graph-usd.en.html)

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Feldspar prices vary across countries. From 2007 to 2018, the most significant rate of growth in export price was achieved by China, while the other players experienced more moderate paces of growth. The average feldspar export price was USD 44 per tonne in 2018, rising by 6.8% compared to the previous year. In 2018, India had the highest export price at USD 73 per tonne while Turkey (USD 31 per tonne) was amongst the lowest. In 2018, the average feldspar import price was USD 51 per tonne, approximately reflecting the previous year. From 2007 to 2018, Indonesia had the most notable growth rate in import prices, while other global players experienced mixed trends in import price figures. Indonesia had the highest import price at USD 89 per tonne in 2018 while Spain at USD 37 per tonne was amongst the lowest (IndexBox, 2020). Competitive pricing strategy is key for feldspar producers. For instance, in October 2019, The US based Quartz Corp company, one of the biggest players in the market, declared a rise in prices of feldspar on an average of 5% to 10%, effective from 1st January 2020. This was implemented through changes in packaging and product prices (Future Market Insights, 2020).

OUTLOOK FOR SUPPLY AND DEMAND

The global feldspar market was valued at USD 564.69 million in 2021 and is expected to reach USD 899.36 million by 2029, registering a CAGR of 5.99% during 2022 to 2029 (Data Bridge Market Research, 2022). Future Market Insights (2020) states that the main factors driving growth of the feldspar market include the increasing demand for glass and ceramic products and coatings and fillers in the paint industry. Furthermore, an increase in construction activities and expanding demand for electronics are expected to strengthen the market up to 2029. Asia Pacific was the most dominant player in the global feldspar market in 2020, accounting for 44.5% market share in terms of volume, followed by Europe and North America (Coherent Market Insights, 2021). Europe is expected to remain at the forefront of the global feldspar market, accounting for the most significant portion of total revenue.

The feldspar market in Europe will continue to mark a substantial growth rate because of the rising demand for feldspar in widespread applications (Future Market Insights, 2020). The outbreak of the COVID-19 pandemic in 2020 negatively impacted mining activities for feldspar. However, mining was able to resume relatively quickly due to several factors such as the effectiveness of vaccines (Technavio, 2022). Some challenges foreseen for the market is the recycling of glass and ceramics which requires lesser use of feldspar which in turn creates limits the demand for feldspar. In addition, mining costs, volatile logistics and stringent environmental regulations on feldspar mining are also likely to hamper the growth of the market (Technavio, 2022).

DEMAND

GLOBAL AND EU DEMAND AND CONSUMPTION

Feldspar demand varies upon the type of feldspar and feldspathoid minerals. However, there is no general definition of "feldspar" as industrial mineral and single countries adopt their own classification (Dondi, 2019).

Feldspar consumption is analysed at extraction stage. Feldspar extraction stage EU consumption is presented by HS codes CN 25291000 – Feldspar and CN 25293000 - Leucite, nepheline and nepheline syenite. Import and

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export data is extracted from Eurostat Comext (2022). Production data is extracted from WMD (2022), IMY (2017-2020), GTK (2016-2020), EME (2016-2020) and CEIC data (2016-2020).

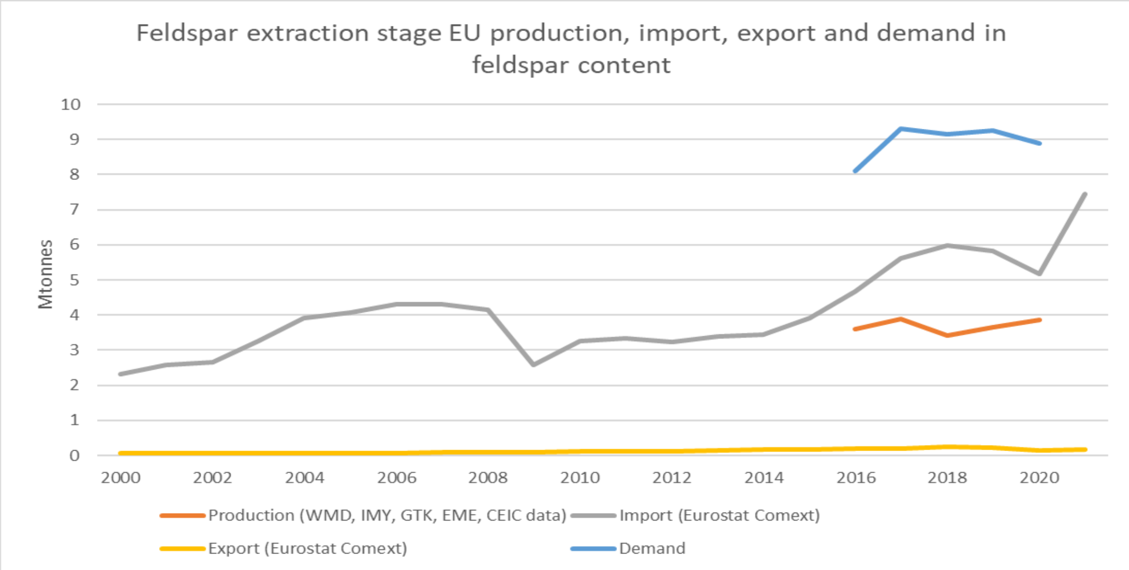

Figure 10. Feldspar (CN 25291000 and CN 25293000) extraction stage apparent EU consumption. Production data is available for years 2016-2020. Consumption is calculated in feldspar content (EU production+import-export).

Average import reliance of feldspar at extraction stage is 54% for 2016-2020.

USES AND END-USES

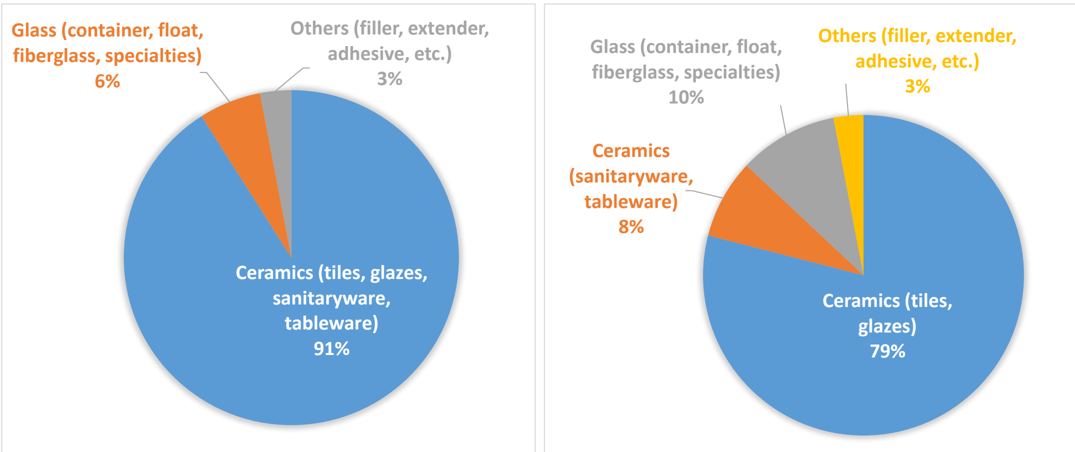

Figure 11: Left: EU end uses of feldspar, average figures for 2012-2016. Right: EU end uses of feldpar (SCREEN experts, 2022 - personal estimation by M.Dondi)

Feldspars are used widely in the glass and ceramics industries. Alkali feldspars are more commonly used commercially than plagioclase feldspars. Albite, or soda spar as it is known commercially, is used in ceramics. The feldspar-rich rocks larvikite and a few anorthosites are employed as both interior and exterior facing slabs. In addition, several feldspars are used as gemstones.

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The calculation of economic importance is based on the use of the NACE 2-digit codes and the value added at factor cost for the identified sectors.

Table 4. Feldspar applications, 2-digit NACE sectors and examples of associated 4-digit NACE sector, and value-added per sector (Eurostat 2022).

Applications	2-digit NACE sector	Value-added of sector (millions €)	Examples of 4-digit NACE sector
Ceramics (tiles, sanitaryware, tableware, glazes)	C23 - Manufacture of other non-metallic mineral products	69,888.20	23.31, 23.42, 23.41, 23.4
Glass (container, float, fiberglass, specialties)	C23 - Manufacture of other non-metallic mineral products	69,888.20	23.11, 23.13, 23.14, 23.19
Constructions, brick, tiles	C23 - Manufacture of other non-metallic mineral products	69,888.20	

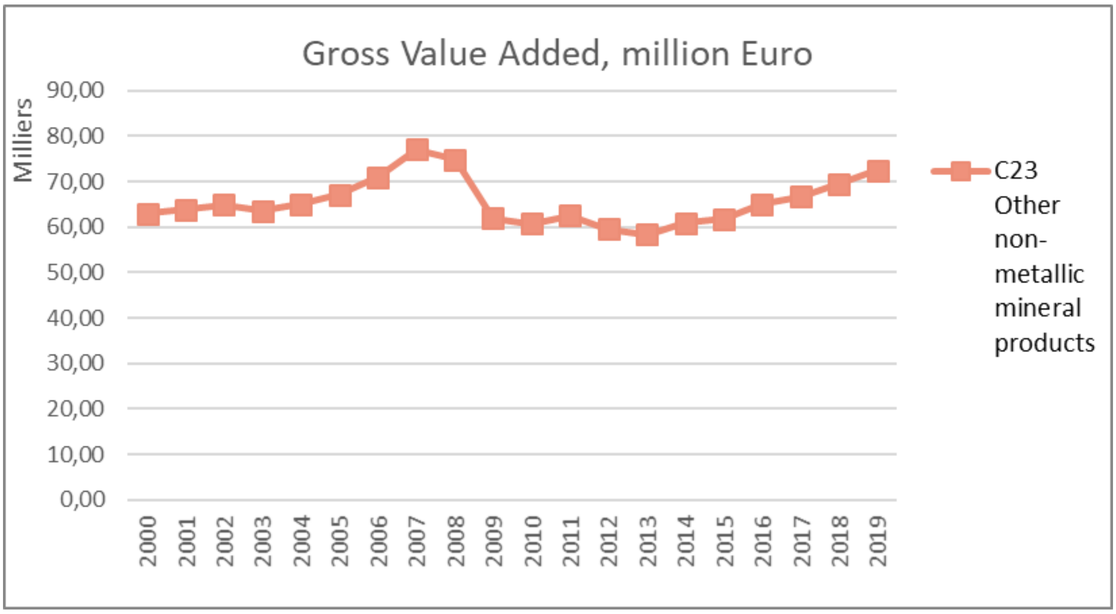

Figure 2. Value added per 2-digit NACE sector over time (Eurostat, 2022)

APPLICATIONS OF FELDSPAR IN THE EU:

CERAMICS

In the manufacture of ceramics, feldspar is the second most important ingredient after clay.

Feldspar improves the strength, toughness, and durability of the ceramic body and cements the crystalline phase of other ingredients, softening, melting and wetting other batch constituents.

GLASS

In glassmaking, alumina from feldspar improves product hardness, sturdiness, and resistance to chemical corrosion.

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In glass manufacture, feldspar is used as fluxing agent and as a source of alumina (Al2O3), alkali (Na2O and K2O), and silica.

Fluxing agents are substances, usually oxides, used in glasses, glazes and ceramic bodies to lower the high melting point of the main glass forming constituents, usually silica and alumina. These materials play a key role in the vitrification of clay bodies by reducing the overall melting point and the most common fluxes used in clay bodies are potassium oxide and sodium oxide, which are found in feldspars.

SUBSTITUTION

CERAMICS AND GLASS

There are several feldspar substitutes in the ceramics and glass industries, including the following that have found some industrial use (Dondi, 2018; Dondi, 2019):

- low-melting materials, like sericite or natural glass in volcanic rocks, which constitute pottery stone, eurite or some rhyolites;
- sintering promoters, like talc, diopside, dolomite, chlorite-bearing rocks and basic igneous rocks;
- waste from quarry dumps, instead of freshly mined rocks, with environmental benefit and slope stabilization;
- fired scraps and processing sludges from the manufacture of vitrified ceramics, such as porcelain stoneware tiles and vitreous china sanitaryware;
- glassy materials from municipal waste sorting, including soda-lime container glass, glass from PC-TV screen, borosilicate vial glass, glasses from various types of lamps.

As batch design is strictly constrained in the glass industry, well defined alternatives can be indicated, the most common being kaolin as an alumina source.

FILLERS AND EXTENDERS

There is a large range of substitutes in these applications, including calcium carbonate, talc, wollastonite, kaolin, mica, pyrophyllite, silica, diatomite, and bentonite (IMA-Europe, 2018; Kogel, 2006; SCRREEN workshops, 2019, 2022).

Table 5. Uses and possible substitutes

Use	Share*	Substitutes	Sub share	Cost	Performance
Ceramics (tiles, glazes)	79%	Talc	2%	Slightly higher costs (up to 2 times)	Reduced
Ceramics (tiles, glazes)	79%	Dolomite	1%	Similar or lower costs	Reduced
Ceramics (tiles, glazes)	79%	Wollastonite	1%	Very high costs (more than 2 times)	Similar
Ceramics (tiles, glazes)	79%	Pottery stone, Phyllite	1%	Similar or lower costs	Reduced
Ceramics (tiles, glazes)	79%	no substitute	95%		No substitute

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Ceramics (sanitaryware, tableware)	8%	Lithium silicates	5%	Very high costs (more than 2 times)	Similar
Ceramics (sanitaryware, tableware)	8%	no substitute	95%		No substitute
Glass (container, float, fiberglass, specialties)	10%	Kaolin	5%	Slightly higher costs (up to 2 times)	Reduced
Glass (container, float, fiberglass, specialties)	10%	no substitute	95%		No substitute
Others (filler, extender, adhesive, etc.)	3%	Lime (calcium carbonate)	5%	Similar or lower costs	Similar
Others (filler, extender, adhesive, etc.)	3%	Talc	5%	Slightly higher costs (up to 2 times)	Similar
Others (filler, extender, adhesive, etc.)	3%	Wollastonite	5%	Very high costs (more than 2 times)	Similar
Others (filler, extender, adhesive, etc.)	3%	Kaolin	2%	Slightly higher costs (up to 2 times)	Similar
Others (filler, extender, adhesive, etc.)	3%	Mica	2%	Slightly higher costs (up to 2 times)	Similar
Others (filler, extender, adhesive, etc.)	3%	Pyrophyllite	2%	Similar or lower costs	Similar
Others (filler, extender, adhesive, etc.)	3%	Silica	2%	Similar or lower costs	Similar
Others (filler, extender, adhesive, etc.)	3%	Diatomite	1%	Similar or lower costs	Similar
Others (filler, extender, adhesive, etc.)	3%	Bentonite	1%	Slightly higher costs (up to 2 times)	Similar
Others (filler, extender, adhesive, etc.)	3%	no substitute	75%		No substitute

*based on EU end use share of feldspar, 2020 (SCRREEN Experts, 2022)

SUPPLY

EU SUPPLY CHAIN

About 3.7 mt of feldspar were annually extracted in EU during the period 2016-2020. Italy (3.7 Mtonnes) and Spain (2.4 Mtonnes) are the most significant producers. Smaller amounts are produced also in Germany and Portugal and Finland. About 5.5 Mtonnes of feldspar were annually imported at the same period mainly form Turkey (about 5 Mtonnes). The exported amounts are low limited at 0.2 Mtonnes annually. The end-of-life recycling rate in EU is estimated at 6% (Eurostat, 2021).

SUPPLY FROM PRIMARY MATERIALS

GEOLOGICAL OCCURRENCE/EXPLORATION

Feldspars and feldspathoids are essential components of many igneous, sedimentary and metamorphic rocks, to such an extent that the classification of a number of rocks is based upon the feldspar and feldspathoid

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content (Potter, 2006; McLemore, 2006; Dondi, 2019). The feldspar group includes orthoclase ($KAlSi_3O_8$), albite ($NaAlSi_3O_8$) and anorthite ($CaAl_2Si_2O_8$). Compositions comprised between albite and anorthite are known as "plagioclase", while those comprised between albite and orthoclase are called "alkali feldspar" due to the presence of sodium and potassium. The alkali feldspars are of particular interest in terms of industrial use of feldspars. Among feldspathoids, only nepheline, $(Na,K)AlSi_2O_6$, meets a wide industrial interest.

Feldspathic raw materials are mined from a wide range of deposits in different geological contexts (Dondi, 2019). The main sources are granitic suites, including acid differentiates (pegmatite and aplite) and the corresponding extrusive and hypabyssal terms (rhyolite, porphyry). Leucogranite is the most important resource among granitoids. Alkaline complexes with silica-undersaturated rocks are the source of nepheline syenite and its extrusive equivalent (nepheline phonolite). Among the deposits of sedimentary origin, feldspathic arenites are widely exploited, principally arkoses. Metamorphic and metasomatic rocks are extensively utilized, especially albitites and phyllites.

RESOURCES AND RESERVES

The resources of feldspathic raw materials are thought to be huge, because of the feldspar abundance in the Earth's crust, even though not always conveniently accessible to the principal centers of consumption. According to the USGS, identified and undiscovered resources of feldspar are more than adequate to meet anticipated global demand, although their quantification is missing in most cases. Quantitative data of different feldspar sources (e.g., feldspathic sand, granite, pegmatite, albitite) have not been compiled (USGS, since 2000).

Reserves data are accessible just for a few countries, but they are approximate and not directly comparable to each other, due to different approaches followed in the various countries to define the reserves (Table 6). Estimations span from optimistic (with sufficient reserves for centuries at the present rate of consumption, e.g. Brazil, Egypt, Iran) to conservative (with an amount of feldspar certainly available for two or three decades with current mining production, e.g. India, Poland, Turkey).

Reserve data for some countries in Europe are available from Minerals4EU (2019) but cannot be summed as they are partial and they do not use the same reporting code. Considering that the market will progressively move towards feldspar types with high fusibility and a low amount of iron oxide, it is necessary to get data (resources and reserves) specific for every source, with special emphasis on sodic feldspar and nepheline syenite (Table 7).

Table 6. Feldspar reserves by country (USGS, since 2000).

Country	Amount in thousand tonnes
United States	NA
Brazil (beneficiated marketable)	150 000
China	NA
Czechia	22 000
Egypt	NA
Germany	NA
India	320 000
Iran	630 000

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Country	Amount in thousand tonnes
Italy	NA
Korea, Republic of	180 000
Malaysia	NA
Mexico	NA
Poland (processed; includes imports)	NA
Russia	NA
Saudi Arabia	NA
Spain (includes pegmatites)	NA
Thailand	220 000
Turkey	240 000
Venezuela	NA
Other countries	NA
World total (rounded)	Large

Table 7: Reserve data for the EU compiled in the European Minerals Yearbook of the Minerals4EU website (Minerals4EU , 2019)

Country	Reporting code	Quantity	Unit	Grade	Code Reserve Type
Spain	None	174.1	Mt	-	Proven
Ukraine	Russian Classification	0.36	Mt	-	(RUS)A
Poland	Nat. rep. code	5.2	Mt	-	Total
Romania	UNFC	2	Mt	-	111
Slovakia	None	3.1	Mt	-	Probable (Z2)
Czechia	Nat. rep. code	25.9	Mt	-	Economic explored

WORLD MINE PRODUCTION

Figure 12 presents the global production of feldspar according to WMD data. As it can be seen, Turkey and India are the major producers, with 10 and 6.2 Mt respectively, in 2020 (WMD, since 1984). A notable feldspar production is taking place also in China, Italy and Iran, with 2.4, 2.2 and 1.9 Mt, respectively. Similarly, Figure 13 presents the global production of feldspar according to USGS data. Both India and Turkey consists the major producers, with 6.0 and 5.0 Mt respectively, in 2020 (USGS, since 2000). A notable feldspar production is taking place also in China, Iran and Italy with 2.5, 2.4 and 2.2 Mt, respectively.

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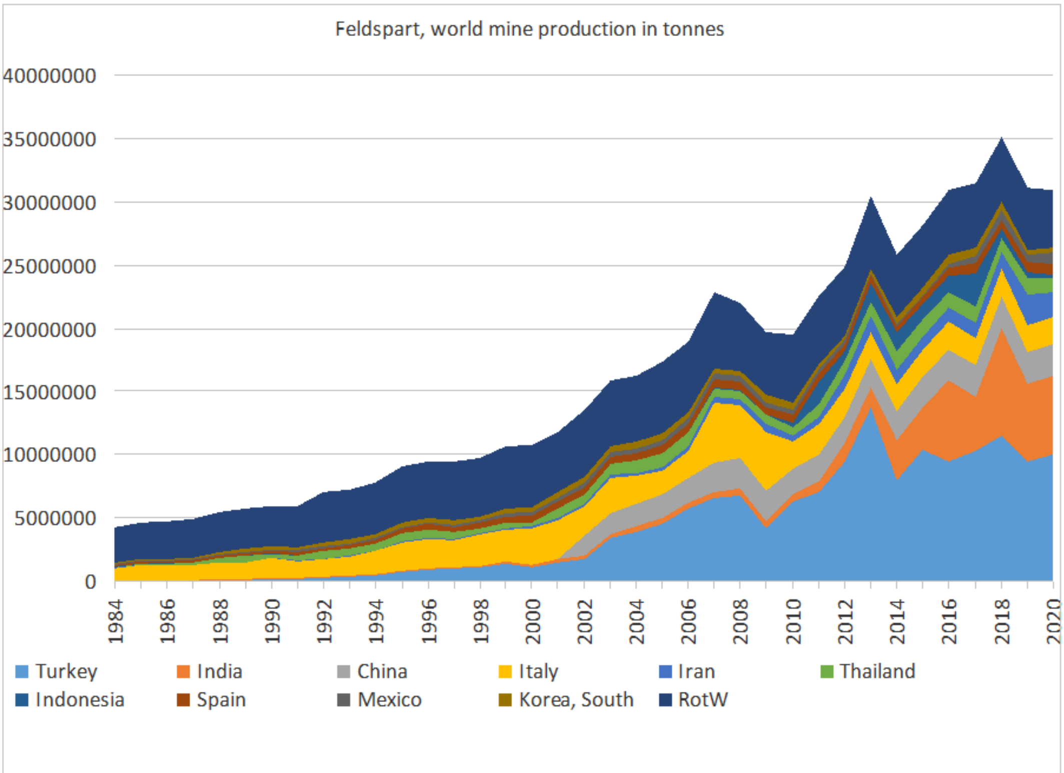

Figure 12: Global feldspar production since 1984 according to WMD (WMD, since, 1984)

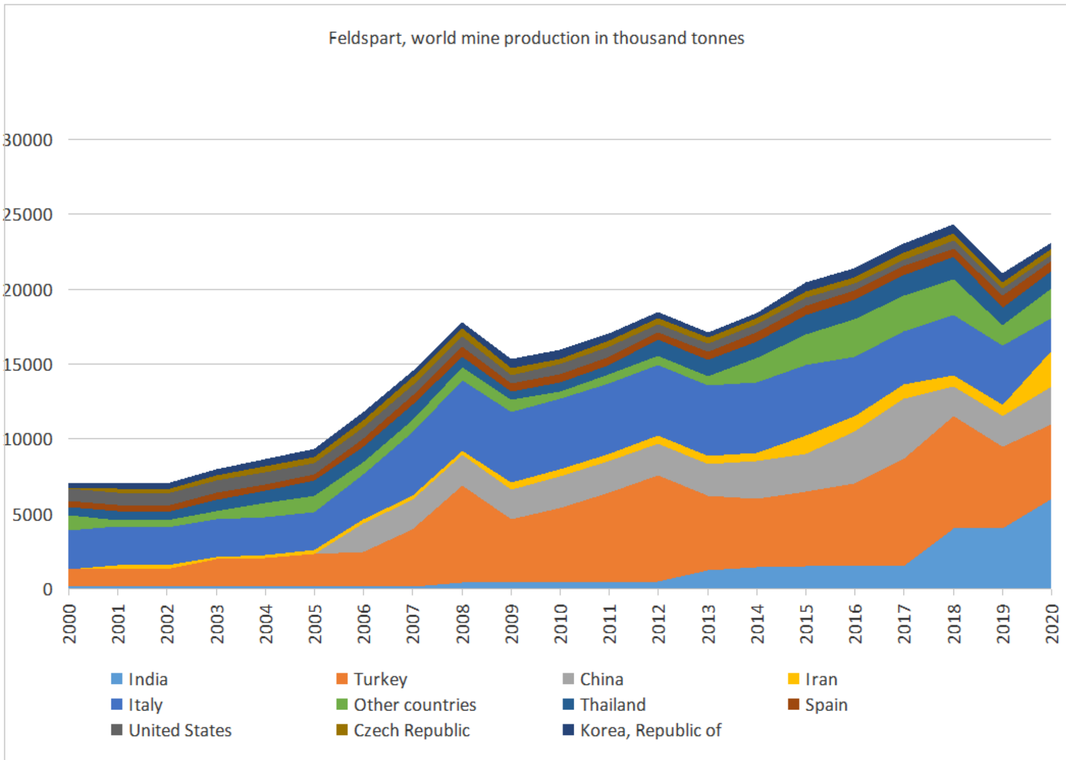

Figure 13: Global feldspar production since 2000 according to USGS (USGS, since, 2000)

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OUTLOOK FOR SUPPLY

52% of the market's growth will originate from APAC. China and India are the key markets for feldspar market in APAC. Market growth in this region will be faster than the growth of the market in other regions.

The significant increase in the demand from the glass and ceramic industry from countries such as China and India will facilitate the feldspar market growth in APAC. This market research report entails detailed information on the competitive intelligence, marketing gaps, and regional opportunities in store for vendors, which will assist in creating efficient business plans.

The feldspar market share growth by the glass segment will be significant. The growth is attributed to the significant increase in the demand for glass fibers in construction, transportation, and consumer products (Technavio, 2022).

SUPPLY FROM SECONDARY MATERIALS/RECYCLING

Feldspars (and feldspathoids) are mainly used as fluxes in ceramic and glass production (98.5%). In these applications, they are melted and no feldspars exist in the finished products (Dondi, 2018; IMA-Europe, 2018). Thus, recycling entails end-of-life glass and ceramics (containing the original feldspars transformed in a vitreous phase) that can act as flux. Feldspars and feldspathoids used as fillers and extenders are englobed into paints, glues, plastic and rubber products, so no recycling is possible.

One of the key challenges to the global feldspar market growth is the recycling of the glass industry. Currently, in the glass manufacturing process, 20%- 25% of the cullet is used for new glass production along with virgin raw materials. Moreover, the recycling of one metric ton of broken/waste glass saves the emission of 0.315 tons of CO2 into the environment. In Europe, glass industry associations and manufacturers are encouraging the public to collect and recycle broken and waste glass to minimize the glass content disposed of in landfills and reduce their production costs. However, glass recycling is a major challenge for feldspar vendors, as it reduces the consumption of virgin feldspar products. For instance, recycled glass can replace 95% of virgin raw materials (such as feldspar) used in the production of glass. More glass manufacturers such as Nippon Electric Glass Co., Ltd. and Sibelco are adopting recycled glass, which may restrict the growth of the market in focus (Technavio, 2022).

Glass can be recycled without any loss in purity and quality, but the average glass recycling rate in the EU is around 73% in the EU Member States (IMA-Europe, 2018). This because of loss during waste collection and sorting, and the occurrence of various contaminants (ceramics, metals, plastics, glues). In other terms, recycled glass (after primary and secondary beneficiation processing) is reducing feldspar consumption up to 70% in glass manufacturing.

Overall, when combining fledspar end-uses and recycling at end-of-life of products, the recycling rate (EoL-RIR) for feldspar is estimated to be around 7-8%.

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PROCESSING OF FELDSPAR

Conventional open-pit mining methods including removal of overburden, drilling and blasting, loading, and transport by trucks are used to mine ores containing feldspar. Processing of feldspathic raw materials encompasses washing, comminution, and beneficiation-concentration steps (Potter, 2006; McLemore, 2006). Various mineralurgical treatments are set up according to the desired characteristics of the final product. Comminution consists in primary and secondary crushing, often in circuit with high-field magnetic separation (and/or electrostatic separation) to remove micas, amphiboles and other undesired minerals (containing iron or titanium). Further wet or dry grinding (rod or ball mills) may be necessary to get the standard particle size (with a desliming step). Sometimes air classification is performed to get micronized powders in the dry route. High-quality feldspar products require further beneficiation or concentration, typically done by flotation and acid leaching. Flotation can be performed in multiple stages: cationic (to separate mica), anionic (to remove garnet, 150 ilmenite and other iron-bearing minerals) and cationic by amine with hydrofluoric acid (to enrich feldspars by separating quartz). From the completed flotation process, the feldspar float concentrate is dewatered to 5 to 9 percent moisture. A rotary dryer is then used to reduce the moisture content to 1 percent or less. Rotary dryers are the most common dryer type used, although fluid bed dryers are also used. Following the drying process, dry grinding is sometimes performed to reduce the feldspar to less than 74 µm (200 mesh) for use in ceramics, paints, and tiles. Drying and grinding are often performed simultaneously by passing the dewatered cake through a rotating gas-fired cylinder lined with ceramic blocks and charged with ceramic grinding balls. Material processed in this manner must then be screened for size or air classified to ensure proper particle size (epa.gov. 1996).

OTHER CONSIDERATIONS

HEALTH AND SAFETY ISSUES

According to the International Agency for Research on Cancer (IARC, 2012) the crystalline silica in the form of quartz or cristobalite dust, which is one of the components of feldspars, is carcinogenic to humans and it is thus included in Group 1 carcinogens. The (EU Directive on protection of workers from carcinogens, mutagens or reprotoxic substances, 2004) set the exposure limit to respirable crystalline silica at 0.1 mg/m^3 at an 8-hour average. Lately, (EU Directive 431, 2022) amending the (EU Directive on protection of workers from carcinogens, mutagens or reprotoxic substances, 2004), stipulated that in 2022 the European Commission shall initiate a process for evaluating the need to modify the exposure limit to respirable crystalline silica. This evaluation has still be pending as of March 2023.

(Gualtieri, A. et al., 2018) applied a protocol including morphometric, chemical, and crystallographic characterization on feldspar samples to study the presence of asbestos tremolite in the mineral. Asbestos is a known carcinogen and thus mining, processing and commercialisation of this mineral are forbidden by Italian legislation (Law 257 on the termination of the use of asbestos, 1992). The samples of the feldspar were extracted in the Orani mine, in Italy, and were analysed and compared with the United Kingdom Health and Safety Executive standard tremolite asbestos. The results demonstrated that the sample contained respirable tremolite asbestos, causing a potential health hazard. This substance is highly biodurable and biopersistent,

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which increases the likelihood of adverse effects and pathogenicity. In 2015 the Orani mining activity was suspended following the (Law 257 on the termination of the use of asbestos, 1992)

ENVIRONMENTAL ISSUES

No information was found.

NORMATIVE REQUIREMENTS RELATED TO MINING/FELDSPAR PRODUCTION, USE AND PROCESSING OF THE MATERIAL

No relevant normative requirements are available on Feldspar.

SOCIO-ECONOMIC AND ETHICAL ISSUES

ECONOMIC IMPORTANCE OF FELDSPAR FOR EXPORTING COUNTRIES

Table 8 shows that Turkey is the only country for which the economic value of feldspar product exports represents 0.1 % of the total value of their export.

Table 8: Countries with the highest economic shares of feldspar exports in their total exports

Country	Export value (USD)	Share in total exports (%)
Turkey	290,893,537	0.1

Source: COMTRADE (2022), based on data for 2021.

For all other countries, the value of these exports remains below 0.1 %.

SOCIAL AND ETHICAL ASPECTS

During 2016 and 2017 different companies presented four project proposals to mine feldspar in Sierra de Yemas, Sierra de Ávila and Valle del Corneja, in Castilla y León region, Spain. The exploitation proposals implied the use of roughly 4,000 ha and the involvement of 17,000 direct and indirect employees. In response, the local population created associations, panels, and informal groups to fight the foundation of the quarries, aiming at defending water streams, and avoiding air pollution and landscape damage (Environmental Justice Atlas, 2022, de Dios, J., 2022).

RESEARCH AND DEVELOPMENT TRENDS

RESEARCH AND DEVELOPMENT TRENDS FOR LOW-CARBON AND GREEN TECHNOLOGIES

- Feldspar as a substitute for sand in white concrete to increase thermal insulation (Torres-Carrasco, M. et al., 2020)

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The increase in thermal properties of white concrete substituting sand filler with glass-ceramic feldspar was investigated. The elimination of sand reduced the concentration of chromophore cations, augmented the reflectance, and thus enhanced the thermal insulation of the mortar. Complete replacement of sand with crystalline feldspar increased solar reflectance by 12 % (from 59 % to 71 %) and halved thermal conductivity (from 0.86 W/mK to 0.35 W/mK). As a downside effect, the investigations showed that the substitution of sand with feldspar reduced mortar compression resistance. However, it satisfies standard building requirements. In conclusion, feldspar-filled white concretes are construction materials that lower energy consumption and contribute to the reduction of the heat-island effect in cities.

- Porous feldspar for improved concrete heat storage (Han, J-G., et al., 2020)

The thermal and mechanical properties of concrete when mixed with porous feldspar were investigated. The researchers ran various experiments and adjusted the composition for achieving optimum performance. To increase compressive resistance, a solidifying agent (0.1 % of the weight of the cement) was added to a mixture containing 70 % of Portland concrete and 30 % of porous feldspar with a particle size of 80 µm. The results show that the porous feldspar mixture performed with a compressive strength of 18 MPa and enhanced its thermal diffusion by 12 % in comparison to standard concrete. In summary, the study proved that porous feldspar may be used as an energy-efficient aggregate without affecting the mechanical properties of the mortar.

- Scalable recycling of feldspar slime into high-quality concentrates by removal of colored minerals using the combined beneficiation processes (Zhan et al. 2023)

Feldspars are the main raw materials for glass and ceramics. The feldspar slime generated during beneficiation processes contains a high content of colored iron-bearing minerals, which is an obstacle to its utilization. In this study, dishwashing liquid is used as the flotation collector and frother, and combined beneficiation processes, including wet ball milling, froth flotation and magnetic and gravity separation, are employed to remove the iron-bearing minerals from feldspar slime in order to achieve high-quality concentrates.

OTHER RESEARCH AND DEVELOPMENT TRENDS

- Removal of feldspar from phosphate ore using Gemini quaternary ammonium salt as a novel collector (Liu et al 2022)

This work aims to provide a reference for using Gemini as collector combined with reverse flotation approach to achieve the effective removal of sesquioxide from phosphate ore and further enhance the quality of phosphate fertilizers. Feldspar is a typical sesquioxide which is associated with phosphate ore. It can greatly prevent the formation of calcium sulfate crystals during the wet process of phosphoric acid production, resulting in the loss of P2O5, and therefore lowering the phosphoric acid recovery. To achieve the selective separation of feldspar from phosphate ore, we first tried using a new Gemini quaternary ammonium salt as the collector in conjunction with a reverse flotation approach. The flotation tests of single minerals and artificially mixed minerals were employed to investigate the collecting ability and selectivity of the collector, the adsorption mechanism was also evaluated by means of zeta potential measurements and molecular dynamic calculations. The flotation results demonstrate that the collector showed a strong

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harvesting effect and selectivity on feldspar rather than fluorapatite. When the Gemini concentration was set at 7.5 × 10^{-6} mol/L, the P2O5 grade could reach 31.69 % with a corresponding recovery of 77.57 %, indicating that Gemini collector could suitably be used as a potential chemical to achieve the effective removal of feldspar from phosphate ore. The results obtained from zeta potential measurements and molecular dynamics simulations indicate that the adsorption of Gemini collector on feldspar was more pronounced compared to that on fluorapatite surface and the interaction between Gemini and both minerals was mainly ascribed to electrostatic interaction.

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