SCRREEN2

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

MAGNESITE

AUTHOR(S):

TABLE OF CONTENT

MAGNESITE 3
Overview 3
Market analysis, trade and prices 6
Global market 6
EU TRADE 6
Price and price volatility 7
DEMAND 8
Global and EU demand and consumption 8
EU uses and end-uses 9
Substitution 12
SUPPLY 13
EU supply chain 13
Supply from primary materials 14
EU resources and reserves 16
World and EU mine production 16
Supply from secondary materials/recycling 19
Other considerations 22
Health and safety issues related to magnesite or specific/relevant compounds at any stage of the life cycle 22
Environmental issues 22
Normative requirements related to the use and processing of magnesite 23
Socio-economic and ethical issues 23
Research and development trends 26
References 26

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MAGNESITE

OVERVIEW

Natural magnesite is the common name for the mineral magnesium carbonate ($MgCO_3$). Magnesite is mainly used in magnesia processing and refined in three commercial grades: caustic calcined magnesite (CCM), dead burned magnesite (DBM) and fused magnesia (FM). DBM and FM are predominantly used in the refractory industry for cement, glass, iron and steel making but it is also an important raw material in some advanced electrical application, leather tanning and other similar applications; CCM is mostly used in chemical-based applications such as fertilisers and livestock feed, pulp and paper, iron and steel making, hydrometallurgy and waste or water treatment.

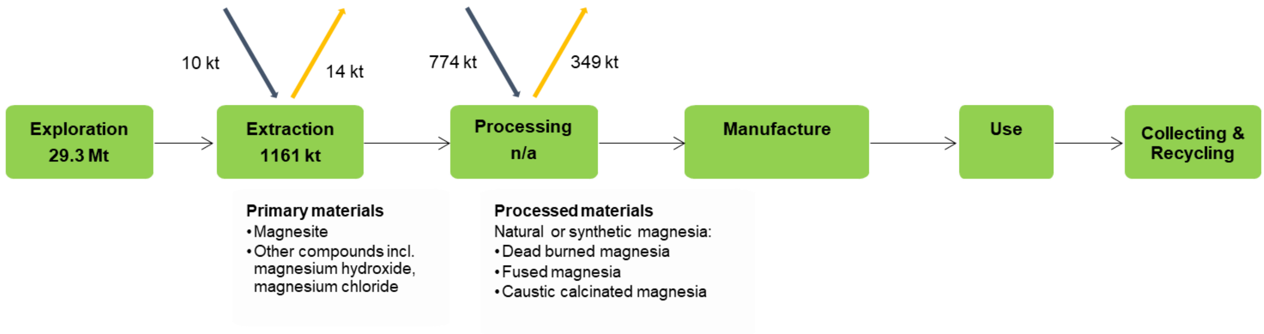

Figure 1. Simplified value chain for magnesite in the EU[1]

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

Global production	Global Producers	EU consumption	EU Share	EU Suppliers	Import reliance
28.0 million tonnes	China 66% Turkey 7% Brazil 6% Russia 5% Slovakia 3% Austria 3% Spain 2%	2.9 million tonnes	10.3%	Slovakia 31% Austria 25% Spain 23% Greece 14% Finland 2% Poland 3% Turkey 1%	0%

Prices: The prices of magnesite are defined for each grade, based on material purity. Policy changes in China affected the prices and availability of all grades of magnesia in the world market (USGS, 2020). Decreased demand in China resulted in lower prices as producers in China increased exports (USGS, 2020).

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

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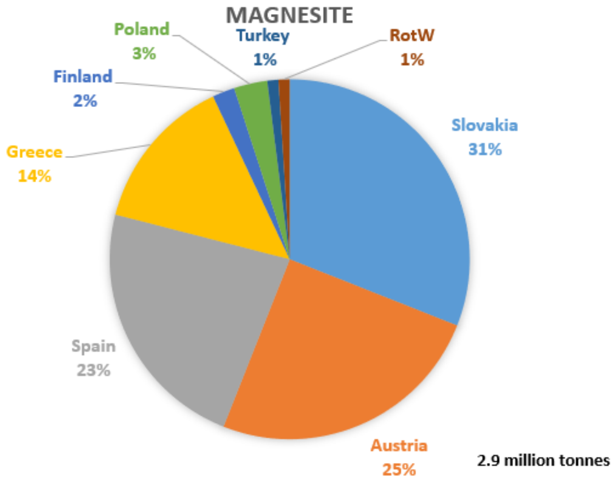

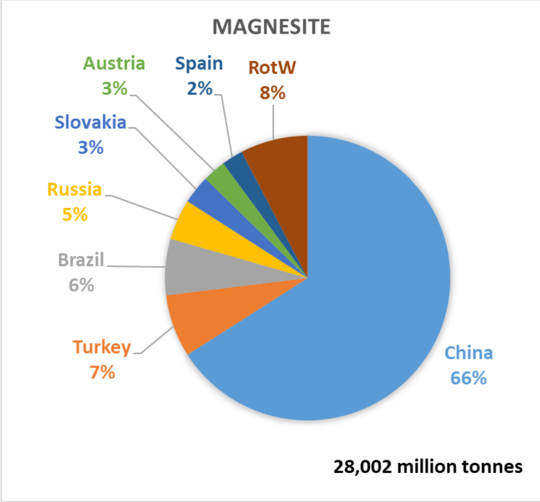

Figure 2. EU sourcing of magnesite and Global mine production (in MgCO3 content)

Primary supply: China remains the world's largest producer (66% of global production), followed by Turkey and Brazil (about 7 and 6% of global production respectively). Austria, Slovakia and Spain present notable productions in EU.

Secondary supply: Magnesia is poorly recovered from post-consumer waste. Agricultural applications using caustic calcined magnesia are dispersive, thus not allowing for any recovery. Recycling of refractory materials is possible in the steel industry and in the construction industry. Most refractories last from few weeks to several years, depending on service conditions and material performance. However due to the low value of spent refractory materials, and the abundance of primary magnesia, there is little incentive to recycle spent refractory.

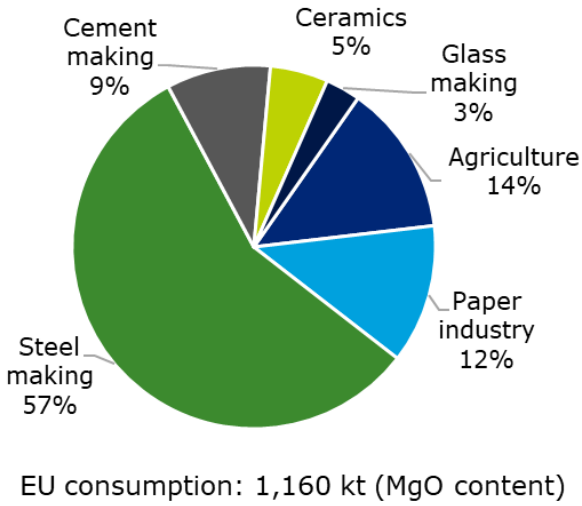

Figure 3: EU uses of magnesite

Uses: more than half of the magnesite production is used in the steel making industry (57%). In Europe, magnesite is used in magnesia processing only (SCRREEN workshops, 2019 / 2021). Therefore, there is no need

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to distinguish between end-uses of magnesite and magnesia. The magnesia end-uses cover end products manufacturing from both synthetic and natural magnesia.

Substitution: There are no materials that can replace any of the main uses of magnesite and magnesia without serious loss of end performance or increase of cost[2] There is no material for replacement of CCM in agriculture and industrial applications, which are the major uses of CCM (SCRREEN workshops, 2019).

Table 2. Uses and possible substitutes

Use	Share*	Substitutes	Sub share	Cost	Performance
Agriculture	14%	no substitute			
Paper industry	12%	no substitute			
Steel making	57%	MgCl2	5%	Similar or lower costs	Reduced
Steel making	57%	Brines	5%	Similar or lower costs	Reduced
Steel making	57%	Graphite	5%	Similar or lower costs	Reduced
Steel making	57%	no substitute	85%		
Cement making	9%	no substitute			
Ceramic industry	5%	no substitute			
Glass making	3%	no substitute			

* EU end uses share of magnesite average (2012-2016)

Other issues: Magnesite is classically not extracted from artisanal mining nor associated with Acid Mine Drainage. It is extracted from deposits with a limited association of other heavy metals and radioactive substances (German Environment Agency, 2020), despite air emissions from magnesite mining may still be responsible for larger concentrations of heavy metals in soils. Soil contamination by magnesium, and subsequent consequences in terms of soil functions, have been reported in areas of magnesite mining, in particular in China (Wang et al., 2015). Magnesium oxide (MgO) is a major component of dust in these mining areas, consequently implying an increase of soil pH. The observed contamination eventually affects ecologically important soil functions, with a reduction in water penetration rate and an increase in rainfall-runoff (Wang et al., 2015). Moreover, air emissions from former operations of magnesite mining in Slovakia have also been observed to affect soil microorganisms (Kautz et al., 2001).

According to OEC (2022) in 2020, the top exporters of magnesium carbonate (magnesite) are China ($18.7M), Spain ($13.2M) and Turkey ($5.58M). With regards to the total exports of the respective countries, the export market of China represented about 0,0007% of the total export; 0,004% of Spain's export and 0,003% for Turkey.

[2] No new technical developments or substitution opportunities were highlighted during SCRREEN2 Expert & Validation Workshop (2022).

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MARKET ANALYSIS, TRADE AND PRICES

GLOBAL MARKET

Table 3. Magnesite supply and demand (extraction) in metric tonnes, 2016-2020 average

Global production	Global Producers	EU consumption	EU Share	EU Suppliers	Import reliance
28.0 million tonnes	China 66% Turkey 7% Brazil 6% Russia 5% Slovakia 3% Austria 3% Spain 2%	2.9 million tonnes	10.3%	Slovakia 31% Austria 25% Spain 23% Greece 14% Finland 2% Poland 3% Turkey 1%	0%

The main driver for demand for the magnesia sector globally and in Europe is the growth in refractory demand, especially from the steel industry, and the glass and cement sectors. Dead burned magnesia (DBM) currently makes up the largest portion of produced magnesia intermediate products. Due to fused magnesia's (FM) superior stability and strength, demand and market share for FM is expected to grow in the future. The magnesite market is projected to register a compound annual growth rate (CAGR) of over 5% from 2021 to 2026 (MordorIntelligence, 2022). One of the main factors is the increasing demand for magnesite, especially in the chemical and construction industries and the production of different grades worldwide (IndustryARC, 2022).

EU TRADE

For the purpose of this assessment, magnesite is evaluated at both extraction and processing stage.

Table 4. Relevant Eurostat CN trade codes for magnesite

Mining	
CN trade code	**title**
2519 10 00	Natural magnesium carbonate (magnesite)

Figure 4 shows the EU trade of natural magnesium carbonate "magnesite" (CN 2519 10 00) between 2000 and 2021. In this period, the EU was a net importer of magnesite. Between 2014-2020, there were trade changes where the EU became a net exporter. However, the EU magnesite exports varied from 167,325 tonnes in 2020 to 63,803 tonnes in 2021, while the EU imports increased from 52,815 tonnes in 2020 to 81,279 tonnes in 2021.

Figure 5 provides the average EU imports of magnesite by country for the period 2000-2021. The major EU supplier of magnesite was Turkey, which corresponds to 72% of the EU magnesite imports in the period. China,

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Brazil, Pakistan, and the UK followed with 16%, 3%, 2%, and 1% respectively. In 2021, the EU magnesite imports from Turkey represented more than 90% of the total imports.

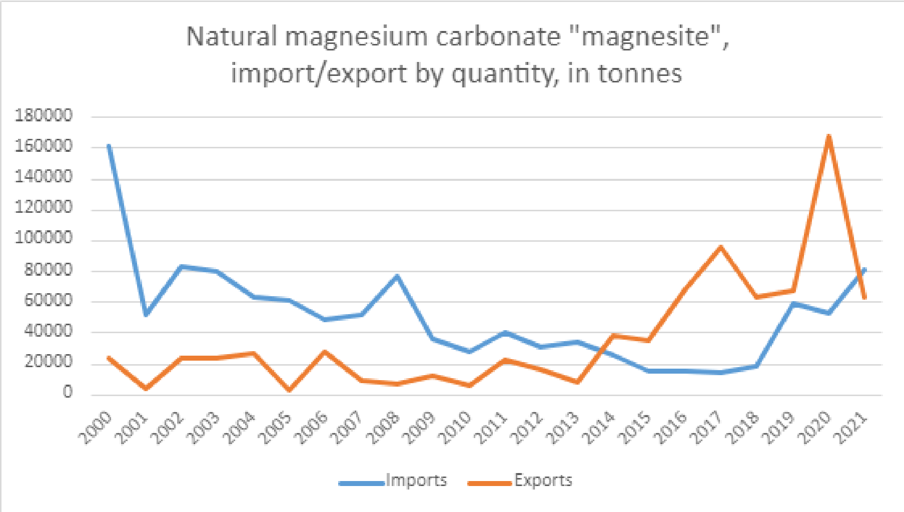

Figure 4. EU trade flows of natural magnesium carbonate "magnesite" from 2000 to 2021 (Eurostat, 2022)

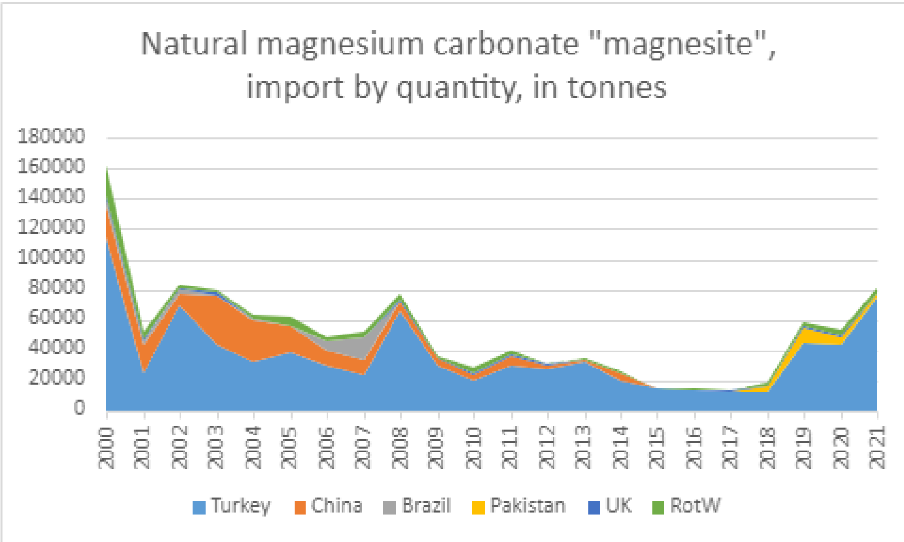

Figure 5. EU imports of natural magnesium carbonate "magnesite" by country from 2000 to 2021 (Eurostat, 2022)

PRICE AND PRICE VOLATILITY

The prices of magnesite are defined for each grade, based on material purity. Policy changes in China affected the prices and availability of all grades of magnesia in the world market (USGS, 2020). Decreased demand in China resulted in lower prices as producers in China increased exports (USGS, 2020). Lower prices for fused magnesia caused prices for dead-burned magnesia to also decrease; the export price range for dead-burned magnesia from China decreased by about 33% from the start of 2020 to June (USGS, 2020). By December 2021,

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the estimated magnesite prices were: €127 /tonnes for 47.2% MgO; €84/tonnes for 47.0% MgO, and €56/tonnes for 46.8% MgO (IMFORMED, 2022).

DEMAND

GLOBAL AND EU DEMAND AND CONSUMPTION

The EU annual apparent consumption of magnesite totalled 1,203 ktonnes MgO contained, averaged over 2009 to 2020.

A reasonable estimate of magnesia apparent consumption in the EU was 1,700 ktonnes MgO contained annually, on average between 2009 and 2020. It was estimated based on magnesite apparent consumption, as well as imports and exports of magnesia (both natural and synthetic forms). However synthetic magnesia production is missing (no robust information available).

Magnesite extraction stage EU consumption is presented by HS code CN 25191000 Natural magnesium carbonate "magnesite". Import and export data is extracted from Eurostat Comext (2022). Production data is extracted from WMD (2022).

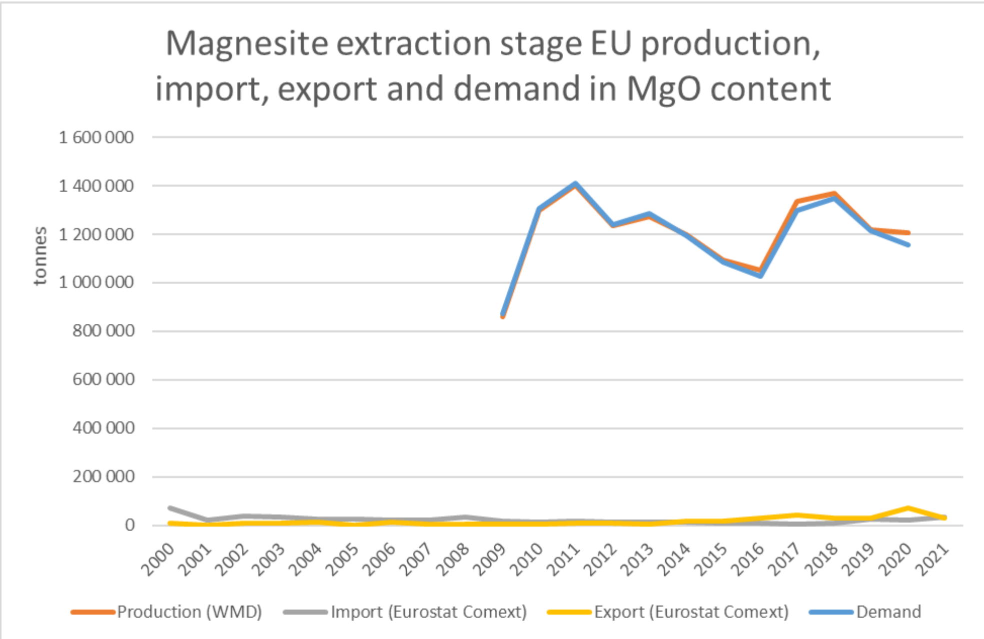

Figure 6. Magnesite (CN 25191000 Natural magnesium carbonate "magnesite") extraction stage apparent EU consumption. Production data is available from WMD (2022) for 2009-2020. Consumption is calculated in MgO content (EU production+import-export).

Based on Eurostat Comext (2022) and WMD (2022) average import reliance of magnesite at extraction stage for 2016-2020 is 0%.

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Magnesite processing stage EU consumption is presented by HS codes CN 25199030 Dead-burned "sintered" magnesia, whether or not containing small quantities of other oxides added before sintering;, CN 25199090 Fused magnesia; CN 25199010 Magnesium oxide, whether or not pure (excl. calcined natural magnesium carbonate). Import and export data is extracted from Eurostat Comext (2022). Magnesite processing stage production data is not available from Eurostat Prodcom (2022).

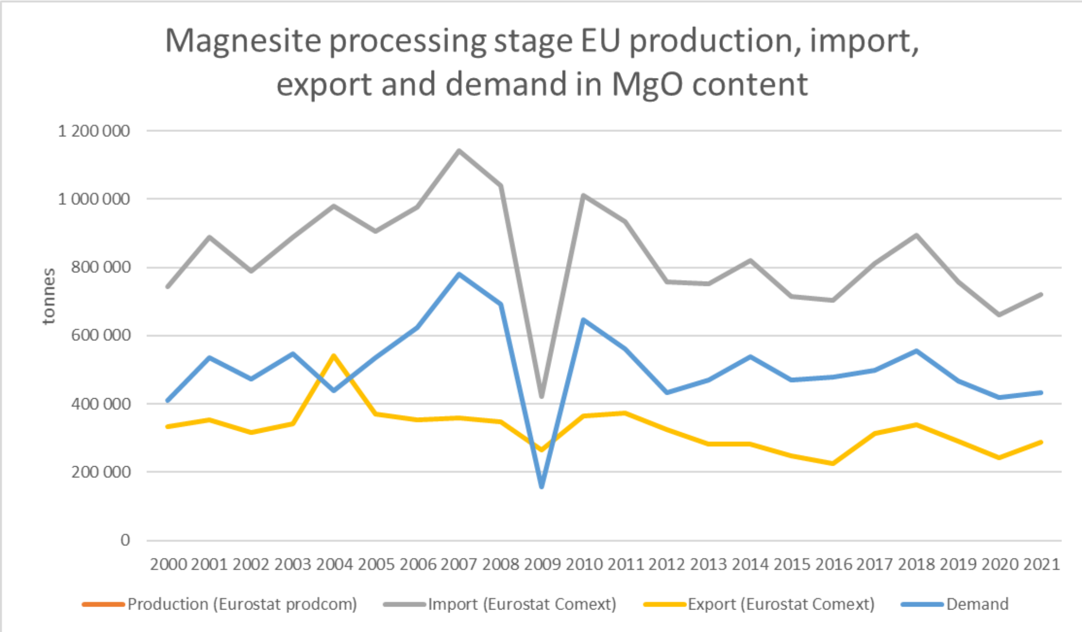

Figure 7. Magnesite (CN 25199030, CN 25199090, CN 25199010 processing stage apparent EU consumption. Production data is not available from Eurostat Prodcom (2022). Consumption is calculated in MgO content (EU production+import-export). Spike in 2009 was due to global economic crisis and its impact in lowered demand of magnesite in steel industry and other applications (USGS, 2010).

EU USES AND END-USES

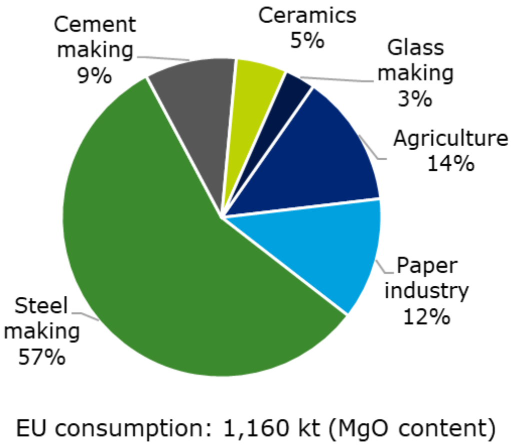

Figure 8: EU end uses of magnesite average 2012-2016 – no update available following SCRREEN workshop 2022.

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The main uses of magnesite in the EU are shown in Figure 8: EU end uses of magnesite average 2012-2016 – no update available following SCRREEN workshop 2022.. Relevant industry sectors are described using the NACE sector codes (Eurostat, 2022).

Table 5. Magnesite applications (Euromines, 2020); SCRREEN workshops, 2021/22, 2-digit associated NACE sectors, and value added per sector (Eurostat, 2022)

Applications	2-digit NACE sector	Value added of NACE 2 sector (millions €) - 2019
Agriculture	C20 - Manufacture of chemicals and chemical products	117,150*
Agriculture	C10-12 Manufacture of food products; beverages and tobacco products	251,015
Paper industry	C17 - Manufacture of paper and paper products	47,452
Steel making	C24 - Manufacture of basic metals	63,700
Cement making	C23 - Manufacture of other non-metallic mineral products	72,396
Ceramics	C23 - Manufacture of other non-metallic mineral products	72,396
Glass making	C23 - Manufacture of other non-metallic mineral products	72,396

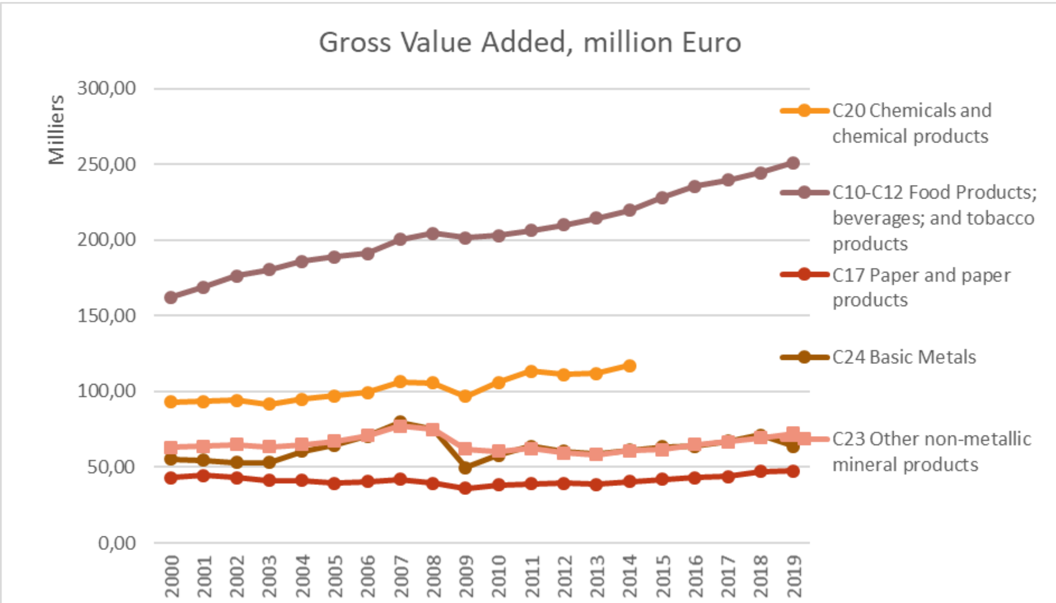

Figure 9. Value added per 2-digit NACE sector over time (Eurostat, 2022))

APPLICATIONS OF MAGNESITE IN THE EU:

In Europe, magnesite is used in magnesia processing only (SCRREEN workshops, 2019 / 2021). Therefore, there is no need to distinguish between end-uses of magnesite and magnesia. The magnesia end-uses cover end products manufacturing from both synthetic and natural magnesia.

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98%+ of magnesite is used for magnesium processing and refined in three types of products: caustic calcined magnesia (CCM); dead burned magnesia (DBM) and fused magnesia (FM) (Euromines 2020).

DBM accounts for the largest volumes compared with FM CCM.

DBM is used in high-duty refractory products, welding electrodes and fluxes, as well as in low duty electrical insulation components for industrial and domestic devices and appliances (electrical grade DBM).

The major use of FM is in refractories. It is also used for electrical insulation in medium and high-duty heating elements (Euromines, 2016 and 2020).

CCM is mainly used in agricultural applications as fertiliser and soil improvers. It is also used as animal feed supplements. There is an increasing consumption of CCM in industrial applications such as pharmaceuticals and food, pulp and paper industry, and in specific environmental applications, such as in wastewater treatment (Euromines, 2016).

The end-uses of magnesite and magnesia are as follow:

STEEL INDUSTRY

DBM and FM are used as the main raw material for basic refractories.

The magnesia refractories can be classified as 'shaped' and 'non-shaped'. 'Shaped' magnesia refractory bricks are often impregnated with carbon (tar, pitch, graphite) to give optimum properties for corrosion resistance in environments of basic slags, particularly in BOF (basic oxygen furnaces) or slag lines of treatment ladles.

Magnesia bricks, often in combination with spinel or chrome, are also used in ferroalloy and non-ferrous industries (AZoM, 2001).

Magnesia is used in hot metal transport and machinery (JRC, 2013).

The 'unshaped' magnesia products are also used in special repair mixes.

AGRICULTURE

The Magnesium element contained in magnesium oxide is required for plant photosynthesis and is a nutrient contributing to animal health.

CCM is the most commonly used source of magnesium for ruminant nutrition and is also used for sheep and poultry.

CCM is used in various fertiliser applications, especially for crops such as citrus, potatoes, vegetables, fruit and grass pastures (Baymag, 2016).

PAPER MANUFACTURING

CCM is used in the chemical process of wood pulping as raw material for magnesium sulphite production, subsequently used for pulping as a cellulose protector and peroxide stabiliser (after pulp bleaching). The sulphite processes represent 10% of global wood pulp production (Grecian Magnesite, 2013).

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Magnesia may be used in wastewater treatment that paper and pulping mill operate for the disposal of their water (Van Mannekus & Co, 2016).

CONSTRUCTION

Sorel cement is a strong binder based on magnesia and a magnesium oxychloride formulation. It is fast-hardening and has several specific (e.g., industrial floors) and general repair applications. Magnesia is also used as a room temperature curing agent for phosphate cements (AZoM, 2001).

CERAMICS

Magnesia ceramics have high thermal stability, good corrosion resistance, good insulating properties and thermal conductivity. They are used mainly for manufacturing high temperature crucibles, thermocouple tubes, heating elements, and foam ceramic filters for molten metal or in kiln furniture (SubsTech, 2015).

GLASS MAKING

Magnesia is used by the glass industry for its thermal and pyrochemical resistance in melting furnaces and regenerator chambers (JRC, 2013). As constituent in the glass formulation leads to increased mechanical properties that are required in glass used in modern constructions and other technological applications.

OTHERS

Other applications of magnesite and magnesia include electrical insulation components (DBM), pharmaceuticals and cosmetics (CCM), sugar refining (CCM), fillers in plastics, rubber, paints and adhesives (CCM). (SCRREEN workshops, 2019), Euromines, 2020).

SUBSTITUTION

Table 6. Potential substitution options for magnesite in main uses

Use	Share*	Substitutes	Sub share	Cost	Performance
Agriculture	14%	no substitute			
Paper industry	12%	no substitute			
Steel making	57%	MgCl2	5%	Similar or lower costs	Reduced
Steel making	57%	Brines	5%	Similar or lower costs	Reduced
Steel making	57%	Graphite	5%	Similar or lower costs	Reduced
Steel making	57%	no substitute	85%		
Cement making	9%	no substitute			
Ceramic industry	5%	no substitute			
Glass making	3%	no substitute			

* EU end uses share of magnesite average (2012-2016)

There are no materials that can replace any of the main uses of magnesite and magnesia without serious loss of end performance or increase of cost[3]

[3] No new technical developments or substitution opportunities were highlighted during SCRREEN2 Expert & Validation Workshop (2022).

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There is no material for replacement of CCM in agriculture and industrial applications, which are the major uses of CCM (SCRREEN workshops, 2019).

In agriculture, magnesia is used for its magnesium element and can therefore not be substituted.

DBM has a very high melting point and an excellent resistance to slag attack, thus imparts exceptional properties when used in refractories. Although potential substitutes such as refractory materials made of alumina, silica etc. exist, the substitution of DBM would not be without loss of performance or increase of cost. The only product that has even higher refractory properties is electrofused magnesia (SCRREEN workshops, 2019).

SUPPLY

EU SUPPLY CHAIN

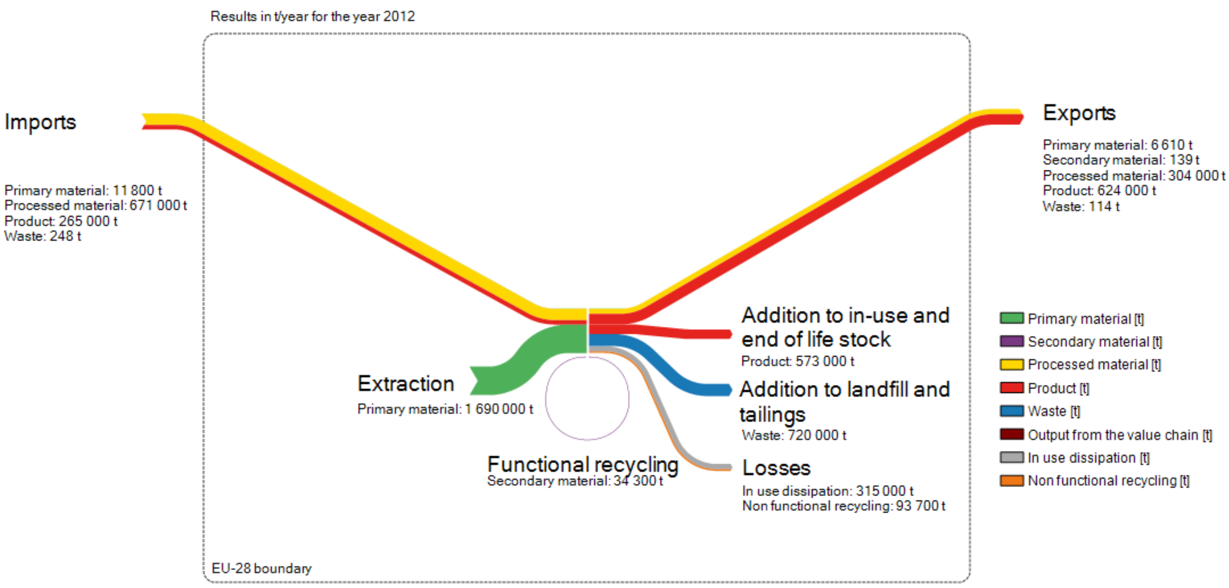

Figure 10. Simplified MSA of magnesite flows in the EU (BIO Intelligence Service, 2015).

The EU supply chain of magnesite and magnesia can be described by the following (averaged over the period 2012 to 2016):

- The 5-year average European production of magnesite was 1,160 ktonnes (MgO content) per year, which accounts for 10% of the global production. Producing countries include Slovakia, Austria and Spain, Greece and Poland.
- Average primary magnesite (natural magnesium carbonate with impurities) production in EU in the period 2016-2020 was 1,234 mt. The produced amount slightly exceeds the EU demand. In the same period, low imported and exported amounts are reported (14.000 tonnes and 40.000 tonnes, respectively) (Eurostat, 2020). According to WMD, EU production in 2020 corresponds to about 7% of the global production (WMD, since 1984).

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- Magnesite is processed into natural magnesia in Europe. In addition, synthetic magnesia is produced in European countries such as Netherlands and Ireland. However, no robust information is available on synthetic magnesia production.
- There were few magnesium oxide producers in the EU, and thus a correspondingly low number of plants producing magnesia (JRC, 2013).
- The traded quantities of magnesite between the EU and the rest of the world are not significant compared to magnesite extraction in Europe. The EU trade balance can be considered in equilibrium.
- Most of MgO material traded between the EU and the rest of the world occurs under magnesia form. The EU was a net importer of magnesia since the domestic production of magnesite and magnesia did not satisfy the European demand. Net imports of magnesia were of 774 ktonnes MgO contained. China is the main country supplying magnesia, and accounts for 35% (Eurostat, 2019).
- The import reliance for magnesite in Europe was very close to zero; however the import reliance for magnesia in Europe may be estimated around 25% based on data available on magnesite extraction and trade of magnesite and magnesia.
- India imposed an export tax for magnesia, which was at 3.25% in 2014 and was still in place in 2017 (OECD, 2019).
- In 2005 and 2006, the European Commission imposed definitive anti-dumping duty on imports respectively of magnesium oxide and dead burned magnesia from China, which expired in 2010 and 2011 respectively (European Commission, 2016).
- A Customs Union Agreement exists with one of EU major suppliers of magnesite and magnesia, namely Turkey (European Commission, 2016).
- There is no significant recycling of magnesia from end of life products (Bio Intelligence Service, 2015; Euroalliages, 2016; SCRREEN workshops, 2019).

SUPPLY FROM PRIMARY MATERIALS

GEOLOGY, RESOURCES AND RESERVES OF MAGNESITE

GEOLOGICAL OCCURRENCE

Magnesia has a concentration of 1.94% in the Earth crust (Fluck und Heumann, 2002). Magnesite is the common name for the mineral magnesium carbonate ($MgCO_3$). Pure, uncontaminated magnesite contains the equivalent of 47.8% magnesium oxide (MgO), and 52.2% of carbon dioxide. Impurities in magnesite are mainly carbonates, oxides and silicates of iron, calcium, manganese and aluminium.

Magnesite occurs mainly in four types of deposits. **Crystalline magnesite** deposits found in replacement of dolomite vary in size and in the level of impurities – from 2-20%. In determining the value of this type of deposit, grade is as critical as size, particularly for the magnesite that will be used to manufacture high purity refractories. Magnesite also occurs as **impure crystalline** masses replacing ultramafic rocks or as cryptocrystalline masses in ultramafic rocks. Deposits of **cryptocrystalline magnesite** are generally smaller than crystalline magnesite deposits. They occur as nodules, veins, and stockworks in serpentinised zones of ultramafic rocks, or can be found as small deposits in tuffs. Deposits of this type are as variable in size as those

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that occur in dolomite. Finally, **sedimentary magnesite** is a carbonate rock that probably formed by evaporation. This type of magnesite is interbedded with dolomite, clastic rocks, or strata of volcanic origin. Even though some sedimentary deposits contain high grades of magnesite, usually, the thin beds cannot be mined economically (Kramer, 2006).

According to the development and characteristics of deposits, two types of magnesite crystals can be found. Crystalline magnesite forms crystal visible to the eye; cryptocrystalline or microcrystalline magnesite ranges from 1-10 µm. In addition to varying in crystal size, the two types also vary in the sizes of the deposits and in modes of formation. Crystalline magnesite deposits occur in relatively few, but generally large deposits, on the order of several million tonnes. Calcite and dolomite are the main impurities. Cryptocrystalline magnesite is often found in small deposits. Siliceous minerals such as serpentine or quartz are generally present (Kramer, 2006).

On the overall, replacement deposits containing sparry magnesite in carbonate rocks have the highest economic importance, accounting for 80% of the worldwide magnesite extraction. They occur in mainly in Austria, Spain, Slovakia, USA, Korea and China. Cryptocrystalline magnesite, on the other hand, from the decomposition of serpentine rocks, occurring for example in Greece, Serbia and Turkey. Brucite has been exploited in the past for the production of magnesia but is no longer an important source as minable concentrations of brucite are rarely found (Kramer, 2006).

GLOBAL RESOURCES AND RESERVES

Table 7 presents the magnesite reserves worldwide in 2021 according to the USGS data. As it can be seen, in Russia (32%) and China (14%) occur the most extended reserves. According to earlier USGS data (USGS, 2019) major reserves occur also in North Korea.

Table 7. Global reserves of magnesite, in MgO content, in thousand tonnes in 2021 (USGS, since 2000)

Country	Tonnes
Australia	290,000
Austria	49,000
Brazil	200,000
China	1,000,000
Greece	280,000
Russia	2,300,000
Slovakia	370,000
Spain	35,000
Turkey	110,000
USA	25,000
Other countries	2,600,000
World total (rounded)	7,200,000

Identified world magnesite resources are estimated at over 12 billion tonnes with the majority located in China, Russia, North Korea, Australia, Slovakia, Brazil, Turkey, India and Canada. Over 90% of magnesite

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resources are sedimentary-hosted, while the rest of them (≈ 10%) occur as veins or talc-magnesite bodies within ultramafic rocks (Simandl, 2007).

EU RESOURCES AND RESERVES

Reserves for some EU countries are available (Minerals4EU, 2019), but cannot be summed as they do not use the same reporting code, or do not specify the grade ($MgCO_3$ contained).

Table 8. EU Resources from the European Minerals Yearbook (Minerals4EU, 2019)

Country	Reporting code	Quantity	Unit	Grade	Code Resource Type
Slovakia	None	21.88	Mtonnes	42.37% $MgCO_3$?	Verified - Economic
Greece	USGS	12.5	Mtonnes	NA	Measured
Poland	Nat. rep. code	4.46	Mtonnes	NA	Measured + Indicated
Ireland	None	2	Mtonnes	33% $MgCO_3$?	Estimate

Table 9. 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
Slovakia	None	21.88	Mtonnes	42.37% $MgCO_3$	Verified
Poland	Nat. rep. code	4.18	Mtonnes	NA	Total
Spain	None	3.25	Mtonnes	NA	Proven

WORLD AND EU MINE PRODUCTION

Magnesite mining technique is dependent of the type of deposit. Large, massive, near surface deposits are usually exploited through open pit methods. Narrow and deep deposits are mined underground. The mined ore is rarely shipped or used in crude form. It is processed near the mine site to yield magnesia products. Invariably some degree of sorting or beneficiation is applied to the ore prior to heat treatment (Kramer, 2006).

There are interesting deposits of magnesite in EU. Since 2017, there is a new mining site producing magnesite, located in Castilla y Leon region (Spain) (SCRREEN workshops, 2019).

The global produced amount of primary magnesite ($MgCO_3$ by country according to WMD since 1984 is presented in Figure 11 (WMD, since 1984). China remains the world's largest producer (≈65 of global production in 2020 according to WMD data), followed by Turkey and Brazil (about 5.5% of global production each in the same year). Austria, Spain and Greece present notable productions in EU (2.8, 2.2 and 1.3% of the global production respectively). USGS provides data under the general term "magnesium compounds" which is referred to the MgO content in a wide number of materials including: caustic-calcined magnesia, magnesium chloride, magnesium hydroxide, and magnesium sulphates, dead-burned magnesia, fused magnesia, and olivine which consist of raw materials for metallurgical, chemical and refractory industries and agriculture.

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Global MgO amounts according to WMD (Figure 11) and USGS (Figure 12) are not directly comparable since in the second case are included the MgO-contained brines.

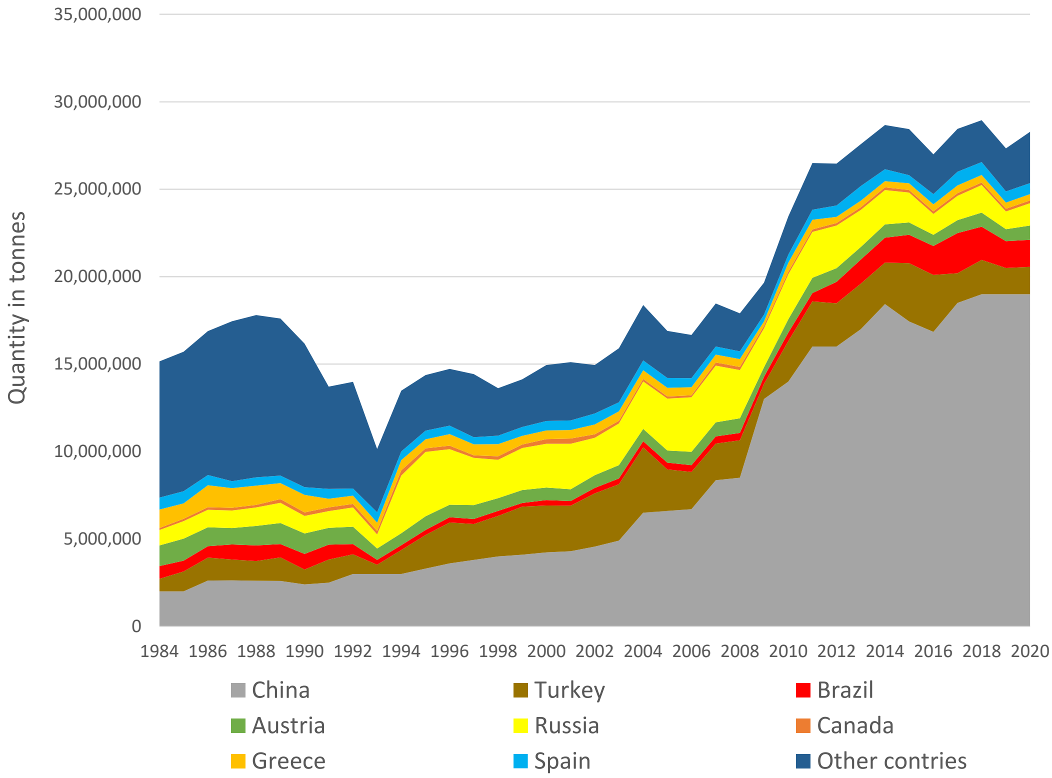

Figure 11. Global primary production of magnesite since 1984 (WMD data).

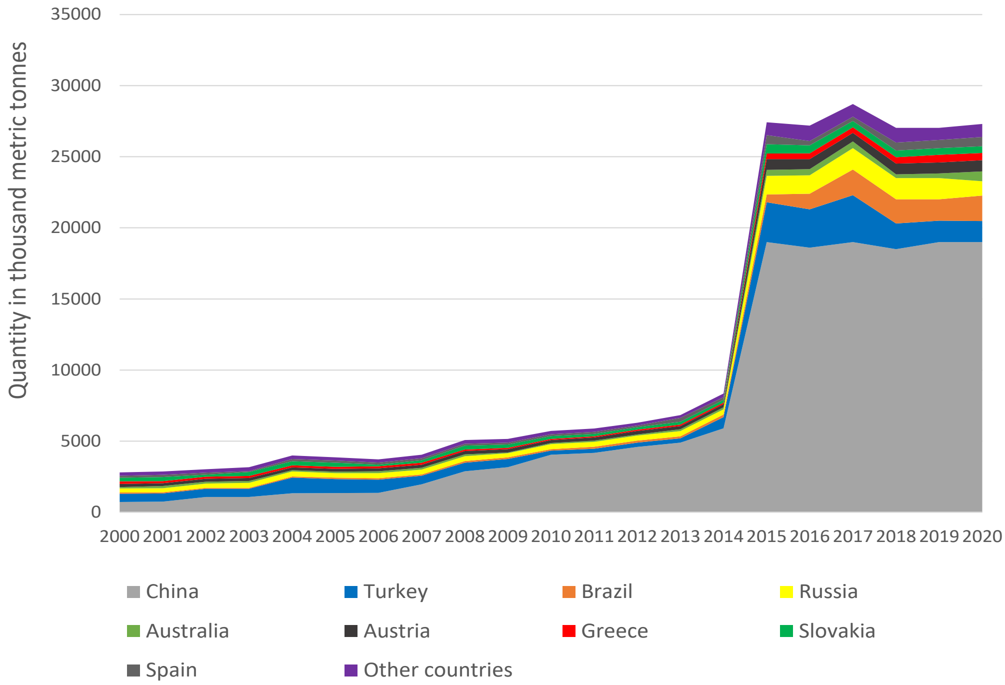

Figure 12. Primary extracted MgO contained in "magnesite compounds" since 2000 (USGS data).

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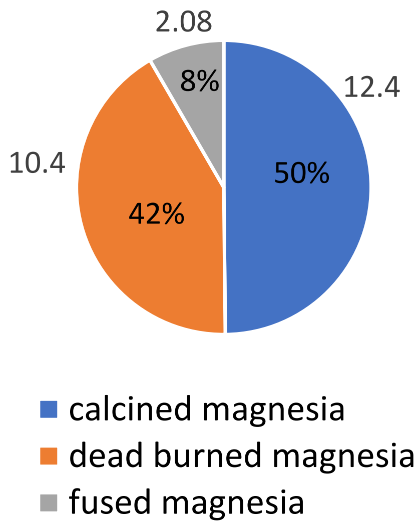

Figure 13. Global Amounts (in Mt) of produced calcined, dead burned and fused magnesia according to INFORMED data for 2018 (O'Driscoll, 2020).

Figure 13 shows the global percentage of the magnesia products (calcined, dead burned and fused magnesia) in 2018.

OUTLOOK FOR PRODUCTION

The magnesia supply trend is unpredictable as:

- Since 2017 there are new mining restrictions (for dynamite bans etc.) that have led to the closure of mines and plants.
- There is an inconsistent and unpredictable availability in magnesia in terms of supply volumes, quality, and prices.
- There is a growth in domestic demand for magnesia in China. Recently China started importing magnesia.

The supply gap is expected to be overlapped through:

- The new lease of life for existing ex-China sources of magnesite
- The beginning of new mining projects in the following countries with magnesite deposits: Saudi Arabia, Serbia, Greece, Morocco, Turkey, Jordan, Australia, Brazil, Pakistan
- An Increasing use of dolomite and synthetic minerals

It should be noted that new mining/processing plants are expected to start operation in: Norway by RHIM for the processing of dolomite, Russia in Magnezit to produce dead burned and fused magnesia, South Korea by Wonjin Worldwide to produce fused magnesia, Spain by Magna (new magnesite line), and in Greece and Jordan by Ternamag and Manaseer respectively to produce dead burned magnesia (O'Driscoll, 2020).

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SUPPLY FROM SECONDARY MATERIALS/RECYCLING

POST-CONSUMER RECYCLING (OLD SCRAP)

Magnesia is poorly recovered from post-consumer waste. Agricultural applications using caustic calcined magnesia are dispersive, thus not allowing any recovery.

Recycling of refractory materials is possible in the steel industry and in the construction industry. Most refractories last from few weeks to several years, depending on service conditions and material performance. However due to the low value of spent refractory materials, and the abundance of primary magnesia, there is little incentive to recycle spent refractory. Potential reuses in the refractory sector include use of recycled magnesia as repair material for cracks and crevices in the highly erosive zones of the steel furnace; or as foamy slag additive, thus reducing electrical energy consumption and overall refractory consumption (Kwong and Bennett, 2002; Angara Raghavendra, 2008).

On the overall, recycling in the steel and the construction sectors remains quite low, or the magnesia contained in post-consumer products is recycled in other applications (non-functional recycling). Up to 10% of refractory bricks are recycled (BIO Intelligence Service, 2015). In the refractory use, there are a huge area for R&D, in order to recover and process, shaped and unshaped refractories. It is important to avoid cross-contamination to achieve a secondary raw material for refractory application (it is not feasible for agriculture uses due to heavy metals content). An example of R&D project is LIFE 5REFRACT[4]. A reasonable recovery ratio for waste refractories seems to be: >50% for shape refractories and >15% for unshaped refractories. However, a substantial improvement of the recovery system is needed to also achieve economic viability.

Table 10. Material flows relevant to the EOL-RIR of Magnesite

MSA Flow	Value (ktonnes)
B.1.1 Production of primary material as main product in EU sent to processing in EU	1088.6
B.1.2 Production of primary material as by product in EU sent to processing in EU	0.0
C.1.3 Imports to EU of primary material	11.8
C.1.4 Imports to EU of secondary material	0.0
D.1.3 Imports to EU of processed material	671.1
E.1.6 Products at end of life in EU collected for treatment	253.2
F.1.1 Exports from EU of manufactured products at end-of-life	0.1
F.1.2 Imports to EU of manufactured products at end-of-life	0.2
G.1.1 Production of secondary material from post consumer functional recycling in EU sent to processing in EU	0.0
G.1.2 Production of secondary material from post consumer functional recycling in EU sent to manufacture in EU	34.3

[4] https://www.life5refract.eu/en/project/

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All the above considered, the end-of-life recycling input rate (EoL-RIR) is calculated at 2% for magnesite and magnesia (Bio Intelligence Service, 2015).

PROCESSING OF MAGNESITE INTO MAGNESIA

Magnesite and magnesium hydroxide (brucite) are converted into magnesium oxide by burning (calcining). Magnesite is burnt in horizontal rotary or vertical shaft kilns, normally by direct firing with oil, gas and petcoke. Decomposition of magnesium carbonate to form magnesium oxide and carbon dioxide begins at a temperature above 500°C (Lehvoss 2016). The temperature and duration of the calcination process determines the grade of magnesia. Grades produced at relatively low temperatures (up to approx. 1,300°C) are called caustic calcined magnesia and have a moderate to high chemical reactivity. Burning at temperatures above 1,600 °C produces dead burnt magnesia and fused magnesia, two magnesium oxide grades with extremely low reactive properties, strength and resistance to abrasion (used as refractory material) (Kramer, 2006; Lehvoss 2016; Euromines, 2016).

Commercial grade of caustic calcined magnesia contains 80% up to 97% MgO. Dead burned magnesia and fused magnesia have an 85% up to 98% MgO purity.

The production capacity of magnesite and magnesia is much higher than the actual production. According to experts (SCRREEN workshops, 2019), the Chinese dead-burned magnesia (DBM) capacity is 11 Mtonnes/y, i.e. 2.2 times the actual production in China, while the electro-fused magnesia (EFM) capacity is 3.6 Mtonnes/y, 2.1 times the actual production in China. The capacity of EU producers burned magnesia exceeds 1 Mtonnes/y of DBM per year in the period 2016-2020. EU capacity could increase, if macroeconomic, political and environmental conditions would allow it. Taking into account the political decision of zero-CO_2 emissions in EU until 2050, magnesite processing should adopt environmentally friendly methodologies.

The very high temperatures (>1600 °C) required to produce burned magnesia generate high CO_2 emissions, since, according to the existing technologies, these high temperatures can be generated only by fossil fuels combustion. The future perspectives to replace the fossil fuels are the followings (**Euromines, 2020**):

- The use of biofuels and biogas that will be produced by the CO_2 captured from the magnesia production and H_2 produced using renewable energy sources. Most of the CO_2 generated in the MgO production will be used back to the process as fuel – close CO_2 loop.
- High temperature kilns powered by renewable energy sources, either as traditional kilns and burners technology using H_2 fuel or new generation of kilns.

Figure 14 presents a simplified flowsheet of calcination and electrothermal processes using H_2 and biofuels for the production calcined magnesia and dead burned magnesia.

About 6% (data for year 2018) of globally produced magnesia is obtained from seawater brines (O'Driscoll, 2020). The production of magnesia from seawater is in general a simple and well known process. The method is based on the reaction of $MgSO_4$, Mg^{2+} and $MgCl_2$ phases in seawater with calcium hydroxide, previously produces by limestone or dolomite rock, to $Mg(OH)_2$. Due to its poor solubility at the surrounding pH conditions, $Mg(OH)_2$ precipitates and forms a suspension of fine crystals, while calcium ions remain in solution.

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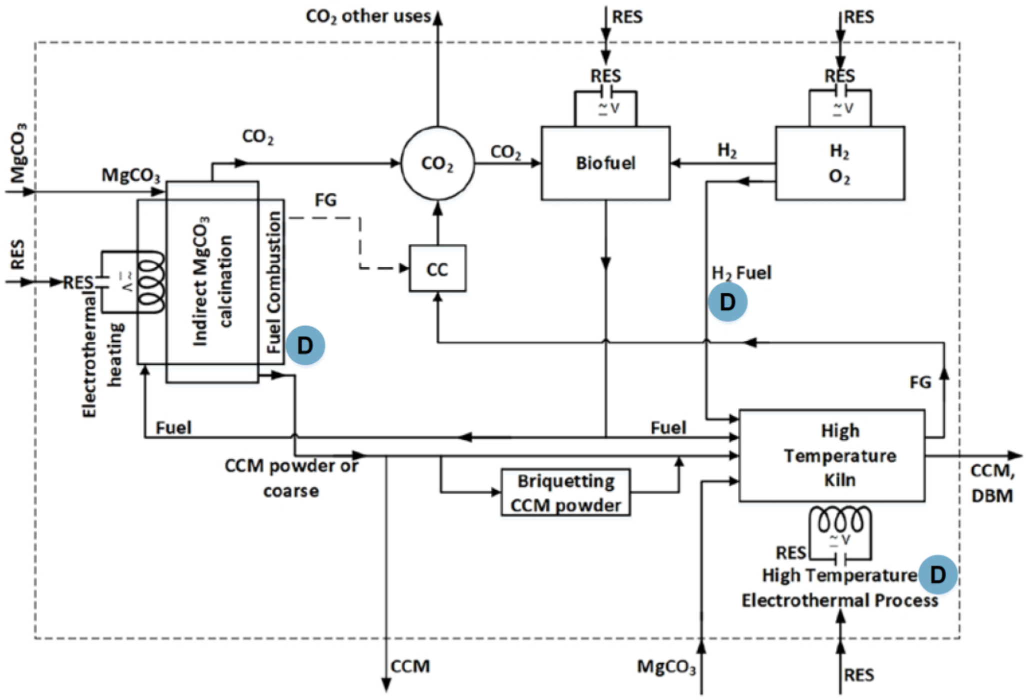

Figure 14. Flowsheet of zero-CO_2 emissions technology for the production of calcined magnesia (CCM) and dead burned magnesia (DBM) (Euromines, 2020).

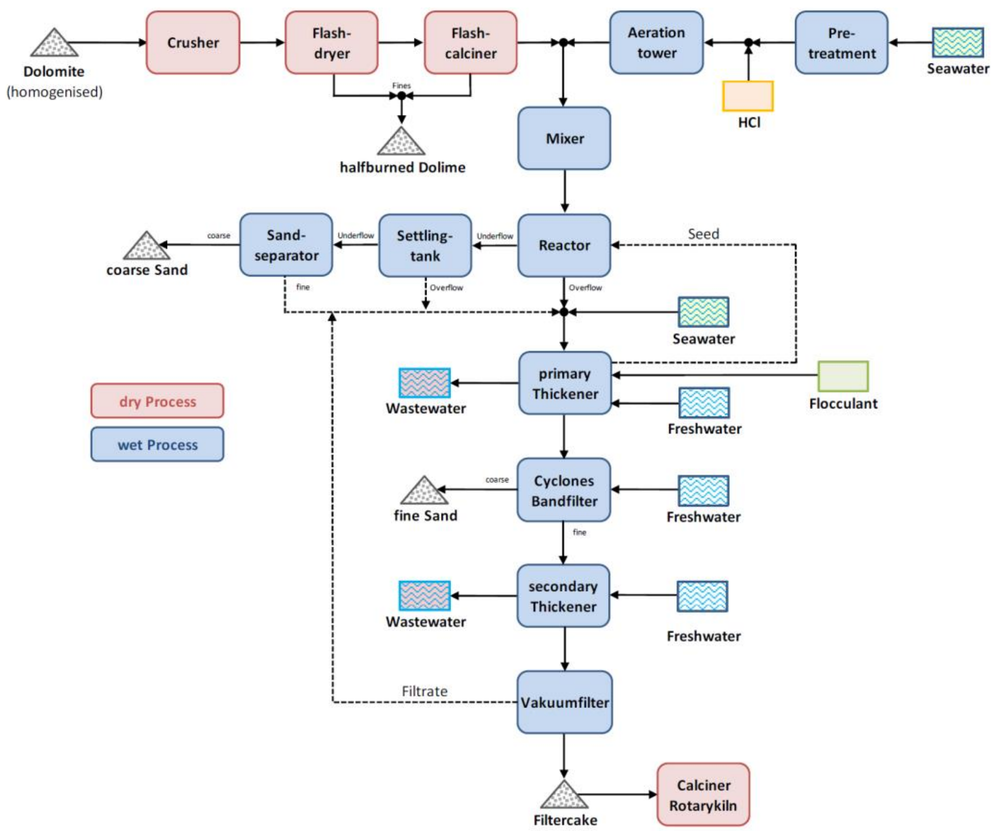

Figure 15. Flowsheet of the production of $Mg(OH)_2$ from seawater (Messner, 2016).

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Since the process is done in an excess of calcium, there is still calcium hydroxide available to precipitate magnesium ions. Therefore the overflow of the hydro separator is mixed with additional seawater in a chute on the way to the primary thickener (Figure 15) (Messner, 2016).

PROCESSING OF SYNTHETIC MAGNESIA FROM OTHER SOURCES OF MGO

Magnesium oxide may also be processed differently than by calcination of magnesite, e.g. by producing magnesium hydroxide or magnesium hydroxide carbonate chemically, then calcined to give synthetic magnesia. Magnesium hydroxide may be obtained from various sources, such as magnesium-rich solutions as precipitate (using dolime, limestone, seawater or magnesium chloride), from $MgCl_2$ pyro-hydrolysis or as a residue remaining after the lime fraction of calcinated dolomite is removed. Magnesium chloride may be recovered after solar concentration of solutions of natural brines for production of salt or potash, or from brines and seawater.

No robust data is available on natural and synthetic magnesia production worldwide or at the EU level. Synthetic magnesia is estimated to represent about 5% of global magnesia production (Bio Intelligence Service, 2015). Historically, the main global producers of high grade dead burnt magnesia were based on synthetic technology, converting magnesium rich seawater or brine into magnesia. However there are several natural dead burnt magnesia producers in Turkey and Australia (Ispat Guru, 2015).

The main countries producing synthetic magnesia are the Netherlands, Ireland, Norway, Israel, Japan, South Korea, Mexico, the US, Russia and reportedly China. In the past, synthetic magnesia was also produced by more producers in Japan, the US, Italy, UK and one other plant in Ireland, among others (Kramer, 2006; Euromines, 2016).

OTHER CONSIDERATIONS

HEALTH AND SAFETY ISSUES

Magnesite is classically not extracted from artisanal mining nor associated with Acid Mine Drainage. It is extracted from deposits with a limited association of other heavy metals and radioactive substances (German Environment Agency, 2020), despite air emissions from magnesite mining may still be responsible for larger concentrations of heavy metals in soils, as e.g. observed in the surroundings of a former mining site in Slovakia (Fazekaš et al., 2018).

The use of magnesite is not restricted under REACH Regulation (EC) No 1907/2006 Annex XVII (Deutsche Forschungsgemeinschaft and Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area, 2002).

ENVIRONMENTAL ISSUES

Soil contamination by magnesium, and subsequent consequences in terms of soil functions, have been reported in areas of magnesite mining, in particular in China (Wang et al., 2015). Magnesium oxide (MgO) is a

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major component of dust in these mining areas, consequently implying an increase of soil pH. The observed contamination eventually affects ecologically important soil functions, with a reduction in water penetration rate and an increase in rainfall-runoff (Wang et al., 2015). Moreover, air emissions from former operations of magnesite mining in Slovakia have also been observed to affect soil microorganisms (Kautz et al., 2001).

Yet the step of magnesite mining has also been observed to have limited contribution to the cradle-to-gate environmental impacts of magnesia production (Li et al., 2015), including regarding carbon footprint as specifically focused on by An and Xue (2017). Electricity consumption has a large contribution to the environmental impacts of magnesia production, in particular regarding fused magnesia production (Li et al., 2015; An and Xue, 2017). An and Xue (2017) further estimated that the direct carbon footprint resulting from the production of all kinds of magnesia in 2014 in the Liaoning province (China) was over 1.66×10^7 tonnes CO_2–eq, while the indirect carbon footprint was over 1.79×10^7 tonnes CO_2–eq.

In this context, CO_2 capture in the magnesia production process may be a potentially effective measure to be considered for a significant decrease in the carbon footprint of magnesia products (An et al., 2018; Zhao et al., 2016).

Finally, as opposed to CO_2 emissions generated along magnesite extraction and further processing for magnesia production, the potential use of magnesite to repeatedly capture CO_2 from the atmosphere has been recently investigated (McQueen et al., 2020), and observed to have the potential to make a meaningful contribution to mitigating climate change according to the authors.

NORMATIVE REQUIREMENTS RELATED TO THE USE AND PROCESSING OF MAGNESITE

No data is available.

SOCIO-ECONOMIC AND ETHICAL ISSUES

ECONOMIC IMPORTANCE OF MAGNESITE FOR EXPORTING COUNTRIES

According to WMD (Federal Ministry Republic of Austria, 2022), in 2019 magnesite is produced mainly in China (19.000.000 tonnes), Brazil (1.700.000 tonnes), Turkey (1.496.081 tonnes), Russia (1.013.800) and Spain (750.000 tonnes).

According to WITS (2022) in 2019, top exporters of magnesium carbonate (magnesite) are Spain ($12.606.04K), China ($9.900 K) and Ireland ($8.543K). With regards to the total magnesium exports of the respective countries, the magnesium export market of Spain represented about 0,004% of the total export; 0,0006% of China's export and 0,005% for Ireland.

According to OEC (2022) in 2020, the top exporters of magnesium carbonate (magnesite) are China ($18.7M), Spain ($13.2M) and Turkey ($5.58M). With regards to the total exports of the respective countries, the export market of China represented about 0,0007% of the total export; 0,004% of Spain's export and 0,003% for Turkey.

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Table 11 and Table 12 list the top exporters in 2019 and 2020.

Table 11: Part of the magnesium market in main producers' economy in 2019 - top exporters of magnesium (source: UN [COMTRADE], 2020; WITS, 2022 [COMTRADE])

Country	total exports in US$	magnesium exports in US$	share
Spain	337.2 bln	12.606.000	0,00370%
China	2494 bln	9.900.000	0,000602%
Ireland	170.7 bln	8.543.000	0,00500%

Table 12: Part of the magnesium market in main producers' economy in 2020 - - top exporters of magnesium (source: UN [COMTRADE], 2021; OEC, 2022)

Country	total exports in US$	magnesium exports in US$	share
China	2590.6 bln/	18.700.000	0,000722%
Spain	312.1 bln	13.200.000	0,00422%
Turkey	169.7 bln	5.580.000	0,00328%

China continues to hold a monopolistic position in the magnesium market, occupying nearly 87% of the global market share, in terms of production. Shaanxi and Shanxi provinces in China remain the world's largest production hubs for magnesium. Fugu county in Yulin, Shaanxi Province contributes to nearly 65% of the country's total magnesium output (Chakarapani, 2021). Magnesium in China is produced using the pyrometallurgical Pidgeon process, which is highly energy and labor-intensive (Chakarapani, 2021). China produced 860.000 tonnes of magnesium in 2018, magnesium consumption in China was estimated to be 450.000 tonnes, total magnesium product exports from China were 410.000 tonnes, 11% less than those in 2017 (USGS, 2021). In 2021, China produced 961.000 MT of magnesium metal in 2020, declining by 1% as compared to 970.000 MT in 2019, as production levels in the country recovered in April 2020, post the control of COVID-19 pandemic spread (Chakarapani, 2021). One of the main magnesium manufacturer and exporter is (for example) Shanxi United Magnesium Industry, having appr. 1000 employees (Linkedin, 2022).

Spain belonging to the global top exporters, produces 3% of world magnesium production. The magnesite that Spain extracts and processes thus has a high strategic value for the national economy. In Spain, between mines and transformer plants, of the production of magnesium oxide depends on 320 direct jobs. In Spain, Magnesitas Navarras (Magna) operates two of the three magnesite mines in Spain, the one located in the Navarrese council of Eugui and the one in Borobia (Soria). The third is in Lugo and belongs to Rubián Magnesites. To these three deposits are added the processing plants, which produce magnesium oxide from magnesite. Another processor is located in Calanda (Teruel), belonging to the Intrasa company. Of those 13 million tons of magnesium oxide that are produced annually in the world, 350.000 are provided by Spain: about 250,000 tons Magna and the rest Magnesitas de Rubián. Of those 350.000 total tons, 200.000 tons are used for refractory products and about 100.000 for animal and plant nutrition. Once the national magnesium supply is secured, most of the Spanish production ends up abroad. Magna attests to this: 20% of the magnesium oxide

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it produces stays in Spain, another 45% is sold to European countries, and 35% to the rest of the world (Pérez, 2021).

SOCIAL AND ETHICAL ASPECTS

Since several years China is restricting its export with a double intention: to better control the price at the world level, and to protect its sources for future generations (Pérez, 2021). However, with China's 'Dual Control Policy' China even went a step further and immensely disrupted the magnesium export in September 2021 (Chakarapani, 2021; Gestion, 2021). Even the disruption was a short one, it has caused enormous problems for the downstream sectors outside of China, particularly Europe. In general, this behaviour seems not to be fair and European manufacturers remain concerned.

The European trade bodies (European Aluminium, European Automobile Manufacturers Association, European steel association Eurofer, European metals association Eurometaux, Association of European ferro-alloy producers) are concerned about such acute shortfall of magnesium, with car manufacturers and some steel mills facing potential threats to shut-down their operations. The European automotive industry was the worst affected, as 95% of its imports are dependent on China and thus, a drastic downfall in the supply of magnesium from China, disrupted the European magnesium supply chain (due to power rationing in China, see below). Germany and Italy, the leading car manufacturing hubs in Europe, were highly concerned about the lingering magnesium shortage. With Europe's magnesium stocks anticipated to get exhausted by November-end, massive losses to the auto business and employment were expected. In Europe, nearly 45% of magnesium goes into the aluminium industry, followed by the automotive (die casting) and iron/steel industries, and thus, the current supply squeeze has left the European auto sector in a red zone (Chakarapani, 2021; Gestion, 2021). The secure supply of magnesium therefore is of utmost importance. Fortunately, in November 2021, magnesium production restarted in China, however, the question of concern remains.

China's 'Dual Control Policy' and determining Global Magnesium Supply Chain

The National Development and Reform Commission (NDRC) of China on September 16, 2021 proposed a "Dual Control "policy scheme, with an aim to improve the "Dual Control Policy", a policy that is directed toward limiting energy consumption and reducing the energy intensity, thereby curbing the country's emissions. The Chinese government's control of energy intensity was first proposed way back in 2006, during the country's 11th Five Year Plan (FYP). The Chinese government thus introduced various plans to reduce energy intensity, to curb emissions. The policy on energy consumption was first introduced during the 13th FYP in 2016. China's stringent enforcement of energy control policies has forced all the magnesium producers in Fugu and Shenmu counties of Yulin city, Shaanxi province to suspend/reduce their production to achieve energy targets for 2021. Orders issued by the Chinese National Development and Reform Commission to Yulin's magnesium industry,

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impacted approximately 40 producers, owing to which, Yulin's magnesium output for September 2021 decreased by 6 per cent, as compared to August 2021 and averaged at 34,900 tonnes. Several provinces were at higher risk of power rationing, and the power restrictions significantly impacted the industrial activities and the economic growth of the country. The major reasons behind the power rationing are likely higher coal prices and energy/emission goals. China's environmental inspections on coal mining highly disrupted the regional production of coal, thereby weighing on the domestic coal prices. On the other hand, imports also took a major hit, due to Beijing's ban on coal imports from Australia, heavy floods in Indonesia, and the sudden increase in the pandemic outbreak in Mongolia (Chakarapani, 2021).

The growing shortage of magnesium raises fears of a shortage that could cripple essential European industries. In this context, amongst others, Spanish Association of Magnesia Manufacturers (Mages) insists that the Spanish government must recognize the importance of magnesium production (in Spain) and act accordingly. Publicly highlighting the economic and environmental advantages of this resource and, thus, highlighting these mining projects, which are often contested by social movements that oppose these exploitations. The current moment (which is also influenced by global magnesium shortcut perspectives of China) is especially important for Spanish magnesium, due to the need to explore new exploitable reserves. Of the only three mines in Spain, the Eugui's deposit will be depleted in eight years. And the only viable alternative to giving continuity to these Navarrese deposits, which have been exploited for 75 years, is to open a new mine in the vicinity (Pérez, 2021). Magna has tried to find other viable points of exploitation, but the only feasible one is the one that has been identified near the Zubiri plant. The enclave that has been located is within an area protected by the EU's Natura 2000 Network, which does not impede economic activity, but requires that it be compatible with the environment. It is possible to respect the values of the Natura 2000 Network, as shown in a study that Magna has conducted (twenty specialists have participated over two years). To summarize, the future of Spanish magnesium depends to a great extent on this Navarrese project (Pérez, 2021).

RESEARCH AND DEVELOPMENT TRENDS

No data is available.

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