15 MAGNESIUM

15.1 Overview

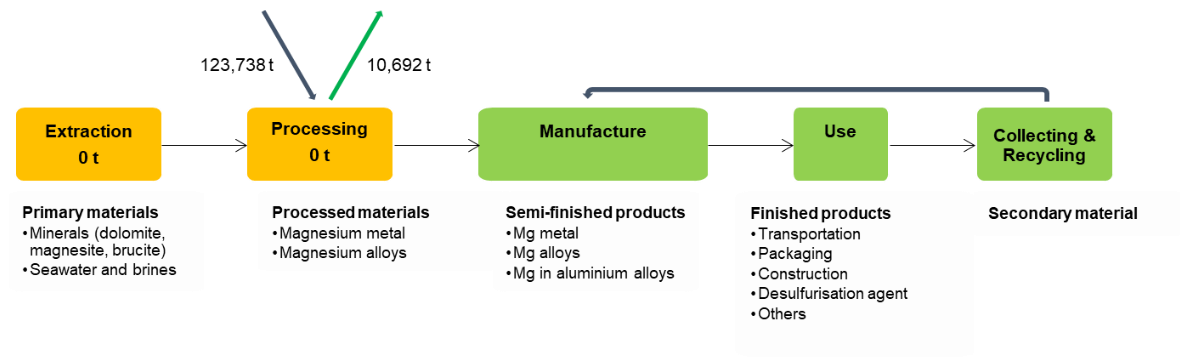

Figure 186: Simplified value chain for magnesium[142] for the EU, averaged over 2012-2016

Magnesium (chemical symbol Mg) is the eighth most abundant element in the Earth's crust (2.1% in weight) and the third most abundant element in solution in seawater. Magnesium is a metal which does not occur in its elemental form in nature, but is found in different forms in minerals (dolomite, magnesite, carnallite) as well as in seawater and brines. Although seawater was a major source of magnesium during the second half of the twentieth century, closure of seawater magnesium plants and increase in output from China led to a magnesium supply now dominated by mineral sources. Magnesium is the lightest of all commonly used structural materials.

Magnesium is commercialised under the form of pure metal or as casting alloys. The former may be used as such, for instance in the steel industry (as a desulfurization agent), or in aluminium alloys.

The trade codes used in this assessment are CN 81041100 (99.8% Mg contained) and CN 81041900 (90% Mg contained) (Eurostat Comext, 2019).

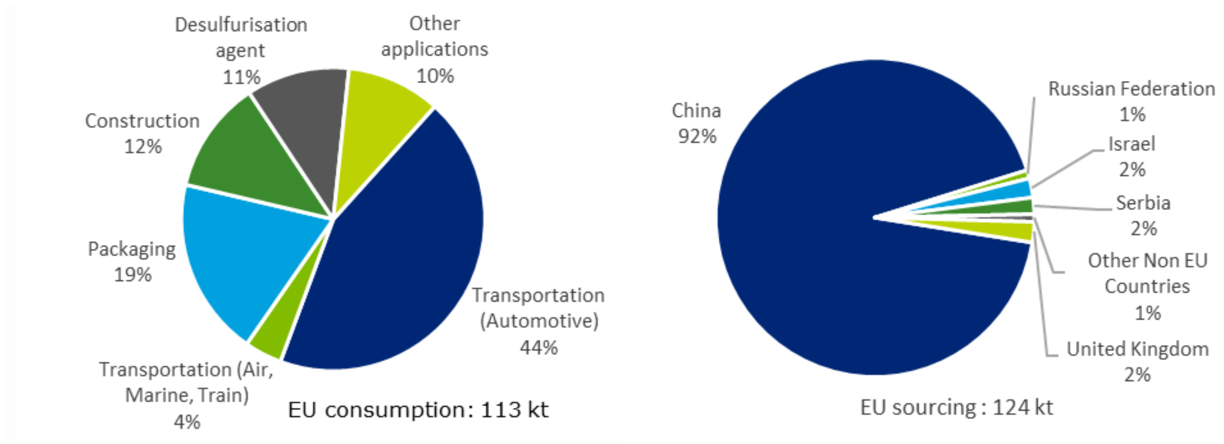

Figure 187: End uses (IMA-Europe, 2019) and EU sourcing (BGS, 2019; Eurostat, 2019) of magnesium (metal), 2012-16.

.JRC elaboration on multiple sources (see next sections)

There is no production of pure magnesium in the EU: the supply for the manufacturing industry entirely relies on imports from China and a few other non-EU countries (Israel, Russia, and Turkey). The EU apparent consumption of magnesium represents around 15% of the consumption worldwide[143].

After a price hike in 2008, magnesium prices remained more stable, and gradually decreased down to US$ 2.5/kg in 2018 (CM Group, 2019).

The EU consumption of magnesium was 113 kt (annual average in 2012-2016) and was 184 kt in 2018, which are entirely sourced through imports, mainly from China (92%). United Kingdom, Serbia and Israel contribute with the 2% of the EU sourcing, while Russian Federation and USA each supply to the EU is below 2% of the total. Import reliance is 100%.

Magnesium metal is used in aluminium alloys (39% in the EU) and magnesium alloys (40% in the EU) for its lightness, in a variety of industry sectors including transports, packaging and construction. Other applications include steel industry, as well as pharmaceutical and agricultural chemical production.

According to USGS (2019), as magnesium metal is derived from natural brines, dolomite, serpentine, and other minerals, magnesium reserves are sufficient to supply current and future requirements. Resources are also considered as virtually unlimited and globally widespread.

For Europe, there is no complete and harmonised dataset that presents total EU resource and reserve estimates for magnesium. Minerals4EU (2019) is the only EU-level repository of some mineral resource and reserve data for magnesium, but this information does not provide a complete picture for Europe. It includes estimates based on a variety of reporting codes used by different countries, and different types of non-comparable datasets (e.g. historic estimates, inferred reserves figures only, etc.).

The world production of magnesium metal is about 928,000 tonnes annually[144], with 89% produced in China and 4% in the US (average 2012-2016). There is no production of magnesium metal in the EU.

Secondary magnesium is an important component in global magnesium supply, with production estimated[145] at 265 kt, of which 45% is located in the US (DERA Mg workshop 2019). In the EU, the EoL-RIR (End-of-Life Recycling Input Rate) for magnesium is assessed at around 13%.

EU has an import quota for both magnesium metal (80,000 tonnes starting January 1st 2017 suspended mid-2019 and expanded to 120,000 tonnes as of 2020[146]) and magnesium powder (2,000 tonnes[147]).

[143] 20% considering the 4 digit code 8104; 15% considering the sum of 6 digit codes 810411 and 810419

[144] 943kt according to CM Group IMA Budapest 2019

[145] Estimated capacity

[146] https://ec.europa.eu/taxation_customs/dds2/taric/quota_consultation.jsp?Lang=en&Origin=&Code=092722&Year=2019&Year=2018&Critical=&Status=&Expand=true

[147] https://ec.europa.eu/taxation_customs/dds2/taric/quota_consultation.jsp?Lang=de&Origin=&Code=092840&Year=2019&Year=2018&Year=2017&Critical=&Status=&Expand=true

15.2 Market analysis, trade and prices

15.2.1 Global market analysis and outlook

Global growth in the magnesium demand in the short term is expected to average 4,9% per year reaching almost 1,100 kt per year by 2020[148]. Aluminium alloys (10y CAGR[149] 4,1%) and magnesium die casting (10y CAGR 6,8%) are predicted to be the fastest growing markets. Transportation will probably be the main applications affecting magnesium demand because of greater unit consumption and increased vehicle production.

Worldwide demand is expected to increase at a CAGR of 6.8% in the next decade (CM Group 2019). In particular, the development of R&D technologies could significantly impact the long-term demand for magnesium, such as: incorporation of nanoparticles in magnesium alloys to improve its properties (e.g. strength, stiffness, plasticity and high temperature stability) and magnesium-ion rechargeable batteries (with twice the capacity and energy density of lithium-ion batteries) (International Mining, 2016). The commercial introduction of new manufacturing processes (3D printing, Mg wrought products profiles and sheets) will also impact future growth of magnesium (IMA 2019).

On the supply side, leading players in the magnesium metal market are expected to continue expanding in the coming years, for instance in China, US[150] and Turkey[151]. In China, the consolidation of the mining sector is continuing, the number of plants will be reduced, but producing plants will become bigger (BGR, 2019). New projects are under progress, for instance Qinghai Salt Lake in China – initially due on stream in 2017 (100 kt/y as first stage), is only ramping-up its production slowly. Other planned projects aiming at production before 2020[152] include Alliance Magnesium in Canada (50 kt/y); Latrobe in Australia (40 kt/y) (IMA 2019).

Overall, it is expected that global primary capacity will expand in line with over 42% of underutilised capacity in China and other Western smelters expanding capacity or creating new plants (IMA, 2017). Dead Sea Magnesium in Israel is a high cost producer with capacity for 35 kt/y.

Regarding magnesium prices after 2017, no major change is expected assuming continuation of stable supply from China. Therefore, magnesium prices will probably remain in the US$ 2 to US$ 3/kg range (IMA, 2019).

Estimations for the outlook for supply and demand of magnesium are shown in Table 82. Environmental and legislative influences are expected to promote the use of magnesium compared to steel and aluminium. As lightweight and fuel-efficient vehicles gain centre stage in the automotive landscape, magnesium is gaining traction as a preferred manufacturing material (Future Market Insights, 2016; SCRREEN workshops, 2019).

[148] CM Group Base 2018 975 Mt, CAGR 4,9%
[149] CAGR: Compound Annual Growth Rate
[150] Expansion in US and Turkey might be on hold. Little information about China.
[151] According to BGR (2019), in 2019 Turkey is back by producing some thousand tonnes. KAR Mineral Madencilik is now the producer at Cifteler. https://www.karmadencilik.com.tr/en.
[152] Both projects are at least delayed for 2022.
Alliance: " This first phase will be followed by a 50,000 ton commercialization plant, whose construction is planned for 2022"
http://alliancemagnesium.com/news/
Latrobe: "Start construction in Feb 2020 ⍰ Commence production at 3,000tpa in July 2021 ⍰ Start construction of 40,000tpa ~12 months later"
https://latrobemagnesium.com/wp-content/uploads/19-12-05-Community-Briefing.pdf

Table 82: Qualitative forecast of supply and demand of magnesium

Materials	Criticality of the material in 2020		Demand forecast			Supply forecast		
	Yes	No	5 years	10 years	20 years	5 years	10 years	20 years
Magnesium	x		+	+	+	+	+	+

15.2.2EU trade

With no primary extraction of magnesium, the EU supply entirely relies on imports of primary magnesium. As well as on processing new scrap (pre-consumer or processing scrap) and production of secondary magnesium (from post-consumer recycling) although less significantly.

The average annual net import figure in the period 2012-2016 was of 124 kt (Figure 188). The main supplier of the EU is China, with 92% of the imports to the EU – which is consistent with China being the largest worldwide producer. The Chinese prevalence in EU imports started in the past decade: in 2000, only 27% of EU magnesium imports originated from China, behind Norway the main supplier to the EU (36% of imports in the same year). Norway production of primary magnesium stopped since then.

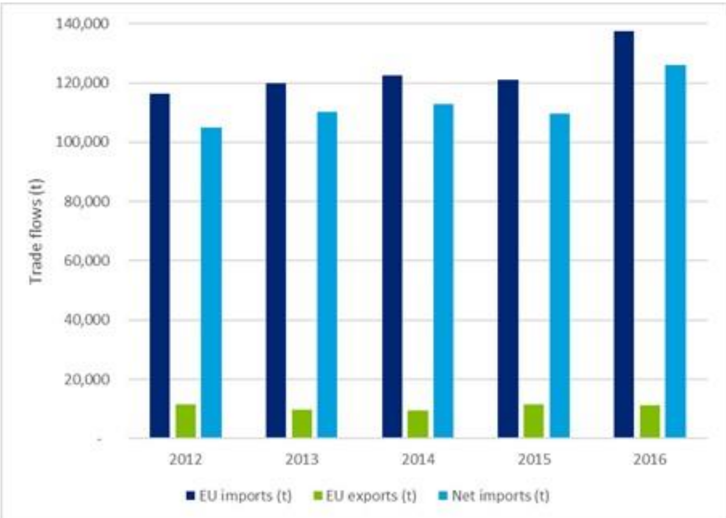

Figure 188: EU trade flows for magnesium (Eurostat, 2019b)

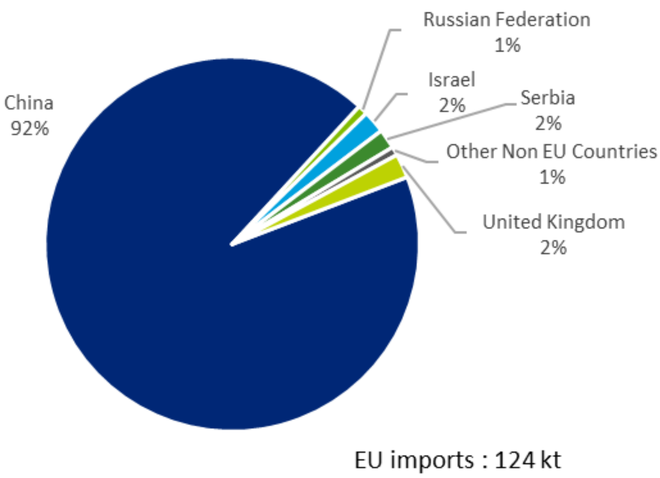

Figure 189: EU imports of magnesium. Average 2012-2016 (Eurostat 2019c)

Imports of magnesium to the EU increased regularly until 2007, with a 7% annual rise between 2000 and 2007. In 2009, EU trade of magnesium with extra-EU countries collapsed mainly due to reduced primary magnesium production. From 2010 to 2014, EU trade remained stable. EU imports increased by 13% from 2015 to 2016. Around 57% of magnesium imports in 2015 are under the form of pure metal ('Unwrought magnesium, containing ≥99.8% by weight of magnesium'); the rest is under the form of magnesium alloys ('Unwrought magnesium, containing <99.8% by weight of magnesium'). The breakdown remained similar in the past years. The Eurostat statistics partly include magnesium processed from secondary material (e.g. imports from Serbia, since there is no primary magnesium production in the country); once processed, there is no distinction between primary and secondary magnesium.

Exports of magnesium from the EU are not significant compared to imported volumes, with an average of 10.7 kt/y over the 2012-2016 period. Most of exported volumes are under the form of magnesium scrap. Major destinations for exported magnesium scrap are the United States (40% in 2018) and Brazil (21% in 2018).

Since 2013, there is no restriction on commercial trade of magnesium metal and magnesium alloys (i.e. no export tax, export quota or export prohibition of magnesium from extra-EU countries) with the EU Member States. With the exception of an import quota for both magnesium metal (80 kt starting January 1st 2017 suspended mid-2019 and expanded to 120 kt as of 2020[153]) and magnesium powder (2 kt[154]). Until end of 2012, China had established a 10% tax on magnesium exports from the country. In July 2011, the WTO ruled that China violated global rules by restricting exports of nine materials including magnesium, thus leading to the removal of the tax.

The EU trade of magnesium scrap is not included in the factsheet due to data availability and data quality issues, however large volumes are traded to US companies as source of low-cost metal. The US anti-dumping duties on Chinese magnesium causes price differential between the two markets (IMA, 2017). Export restrictions apply to magnesium waste and scrap imports to the EU. There are export taxes in Argentina (5%), Jordan (5%), Morocco (7.5%), Russia (20%), Vietnam (22%) and Zambia (25%) . There is an export prohibition in Burundi, Kenya and Rwanda. Licensing requirements apply in many countries, for magnesium waste and scrap as well as unwrought magnesium (OECD, 2019).

15.2.3Prices and price volatility

Prices for magnesium metal are primarily cost driven, reflecting supply overcapacity (particularly in China). In 2008, magnesium plants were shut down for environmental concerns during Beijing Olympics game, which led to a price hike on the global market up to US$ 6 per kilogram of metal since China is the major supplier of magnesium worldwide (IMA, 2017).

[153] https://ec.europa.eu/taxation_customs/dds2/taric/quota_consultation.jsp?Lang=en&Origin=&Code=092722&Year=2019&Year=2018&Critical=&Status=&Expand=true

[154] https://ec.europa.eu/taxation_customs/dds2/taric/quota_consultation.jsp?Lang=de&Origin=&Code=092840&Year=2019&Year=2018&Year=2017&Critical=&Status=&Expand=true

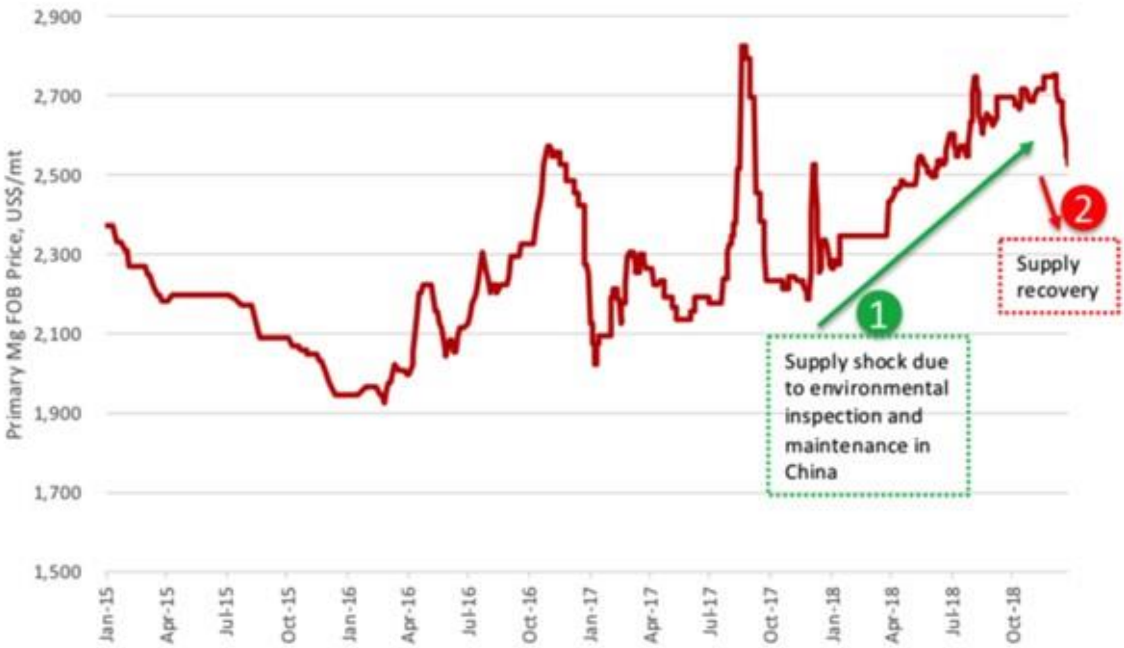

Figure 190: Magnesium metal prices in US$/t, 2015-2018. (CM Group, 2019)

Since 2008, magnesium prices remained more stable, and gradually decreased down to US$ 2 per kilogram until the first quarter of 2016. As prices moved below this level at the end of 2015, resistance from producers coupled with firming coal prices and better than expected performance in the Chinese economy pushed the price of magnesium up by 11% in April 2016 (International Mining, 2016).

There is an antidumping-duty in the US for magnesium from China, therefore the price of magnesium metal is higher in the US compared to the EU[155].

15.3 EU demand

15.3.1 EU consumption

The EU apparent consumption of magnesium is calculated at about 113 kt per year of processed material. Almost all of magnesium is imported in the EU as pure magnesium or magnesium alloys; swarf, granules and powders represent gross volumes of about 14 kt (IMA, 2017).

Magnesium casting alloys and aluminium alloys represent respectively 43% and 39% of magnesium use in the EU over the 2010-2014 period. It can be considered that the majority of magnesium alloys are used in transportation applications[156]; some castings are alloyed with rare earth elements to improve creep and corrosion resistance (International Mining, 2016).

Aluminium alloys are used in packaging, transportation and construction sector. Magnesium is present in aluminium alloys in distinct proportions: transportation aluminium alloys contain around 1% of magnesium, while there is around 2% of magnesium in packaging and 0.5% in construction aluminium alloys. Magnesium as alloying element is essential for the aluminium industry (IMA, 2019).

[155] antidumpingpublishing.com, 2017

[156] Also other applications like Power tools could be mentioned.

15.3.2 Uses and end-uses of magnesium in the EU

The major end-uses of magnesium in the EU are in the transportation sector. In addition, magnesium in aluminium alloys is used in packaging and construction. Magnesium is also used in non-structural applications such as desulfurization agent (European Commission, 2014b; IMA, 2019; SCRREEN workshops, 2019):

- Automotive industry: Magnesium casting alloys is mainly used in vehicles to lower the overall weight, e.g. in replacement of steel or aluminium. Magnesium is used in many vehicle parts from gearbox, steering column and driver's airbag housings to steering wheels, seat frames and fuel tank covers. The use of magnesium as one single cast piece in vehicles may also increase the strength of the material compared to various steel components.
  In addition to being used in terrestrial vehicles such as cars, vans and trucks, magnesium is also used in trains and aerospace applications both civil and military: for instance, in thrust reversers, as well as in engines and transmission casings of aircrafts and helicopters. Spacecraft and missiles also contain magnesium as it is capable of withstanding exposure to ozone and impact of high energy particles and matter (IMA, 2016).
- Desulphurisation of steel: Due to its high affinity for sulphur, magnesium is injected in molten iron or steel to reduce the sulphur content. The process prevents sulphur from damaging steel as it causes brittleness in steel; low sulphur facilitates modern production processes (IMA, 2019; International Mining, 2016).
- Packaging applications represent 35% of magnesium use in aluminium alloys (IMA, 2019). Magnesium improves aluminium strength without removing the material workability. In addition to aluminium beverage can, magnesium is also used in aluminium alloys in food cans and trays. Further detail may be found in the aluminium factsheet.
- Construction equipment: Magnesium in aluminium alloys is used for doors, windows, cladding, roofing, staircases, air conditioning units, among other components. Further detail may be found in the aluminium factsheet.
- Other uses: Medical applications, sport applications, among others. Magnesium can be used in electrochemical applications: magnesium anodes prevent from galvanic corrosion of steel. It is also used in industrial synthesis such as the Grignard reaction in organic chemistry applications (IMA, 2019).

Magnesium alloys are used in small and portable electronic applications such as camera, cell phone and laptop for its lightness combined to strength and durability, e.g. in replacement of plastics. Many electronics require parts or casings with complex shapes which are possible with magnesium. The use of magnesium in electronic applications manufacturing is not significant in the EU (IMA, 2017). Finally, magnesium is used as a reducing agent in the production of beryllium, titanium, etc. – although not in the EU since there is no titanium or beryllium production.

The end-use shares provided in Figure 191 were calculated based on existing studies and stakeholders' feedback (IMA, 2017; IMA, 2019) and relevant industry sectors are described using the NACE sector codes in Table 83.

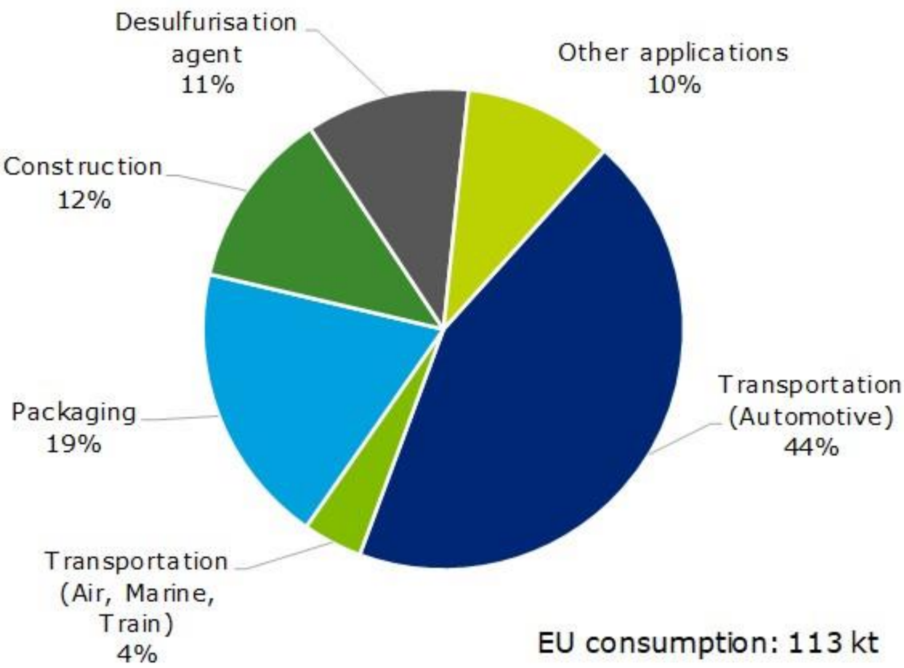

Figure 191: Global end uses of magnesium, 2012-2016 (IMA, 2019)

Table 83: Magnesium applications, 2-digit and associated 4-digit NACE sectors, and value added per sector. (IMA, 2019; Eurostat, 2019a)

Applications	**2-digit NACE sector**	**Value added of NACE 2 sector (M€)**	**4-digit NACE sectors**
Transportation	C29 - Manufacture of motor vehicles, trailers and semi-trailers C30 - Manufacture of other transport equipment	160,603 / 44,304	C2910 - Manufacture of motor vehicles; C2920 - Manufacture of bodies for motor vehicles; C2932 - Other parts for motor vehicles; C3030 - Manufacture of air and spacecraft; C3011 - Building of ships and floating structures; C3020 - Manufacture of railway locomotives and rolling stock; C3092 - Manufacture of bicycles
Packaging	C25 - Manufacture of fabricated metal products, except machinery and equipment	148,351	C2592 - Manufacture of light metal packaging
Construction	C25 - Manufacture of fabricated metal products, except machinery and equipment	148,351	C2511 - Manufacture of metal structures and parts of structures; C2512 - Manufacture of doors and windows of metal; C2599 - Manufacture of other fabricated metal products n.e.c.
Desulphurisation agent	C24 - Manufacture of basic metals	55,426	2410 - Manufacture of basic iron and steel and of ferro-alloys

15.3.3 Substitution

All the identified applications have been considered in the assessment (IMA, 2017; IMA, 2019; SCRREEN workshops, 2019). Consideration has been given to the cost and performance of each potential substitute in each application, relative to that of the material in question, together with the level of production, whether or not the substitute was previously considered to be 'critical' and whether the potential substitute is produced as a by-, co- or main product.

Specific data relating to all of these criteria are often difficult to find and a number of assumptions have had to be made to complete the calculations. Consequently, a significant degree of uncertainty is associated with the results. The level of precision shown for the Substitution Indices does not fully reflect this uncertainty.

Magnesium in casting alloys as well as in aluminium alloys may be partially substituted, e.g. to lower the need for magnesium. Possible substitutes are composites such as carbon-fibre reinforced plastic with recycling issues, as well as steel and titanium alloys. The information provided below for transportation, construction and packaging applications may also be found in the factsheet on aluminium substitution.

In transportation applications, reinforced plastics provide similar performance in vehicles and the latest aircraft but at much higher cost than aluminium alloys containing magnesium. Steel and titanium are possible substitutes in this sector; with steel being the only one of these were costs are similar to aluminium alloys. However, steel is heavier than aluminium and consequently lesser performing for certain applications.

In the construction sector, steel, plastics (such as PVC or vinyl) and wood were considered as possible substitutes. In all cases the cost and performance were considered to be similar to aluminium alloys containing magnesium. For packaging, steel, glass and plastics were identified as potential substitutes for aluminium alloys and again for all of these the costs and performance were considered to be similar.

The steel desulfurization process allows the use of several reagents such as lime (carbon oxide, CaO), calcium carbide (CaC_2) and magnesium (Mg), which remove the sulphur in the hot metal by chemical reaction and convert it to the slag. The performance of lime and calcium carbide is lower than with magnesium: the latter is soluble in hot metal and reacts with sulphur in solution; unlike the formers, magnesium is not subject to layer formation on steel, which would impede the desulfurizing reaction. Although more expensive, magnesium has approximately 20 times the capacity of removing sulphur as lime; calcium carbide, 8 times the capacity as lime (IspatGuru, 2013). Other substitutes such as zinc oxide (ZnO) are experimented but are not commercialized.

15.4 Supply

15.4.1 EU supply chain

The EU supply chain of magnesium can be described by the following key points:

- First stages of the value chain of magnesium (extraction, processing) take place outside of the EU, although there are reserves of magnesium in the EU. There are no imports of magnesium ores in Europe and all primary magnesium is processed outside the EU (except from very small volumes of magnesium alloys).
- The EU supply of magnesium entirely relies on imports of primary magnesium, as well on processing new scrap as on production of secondary magnesium (from post-consumer recycling) although less significantly. Averaged over 2012 to 2016 the EU net imports of magnesium was 112.7 kt per year (Eurostat, 2019b). The EU import reliance for magnesium is therefore 100%.Magnesium can be cast, rolled,

extruded, machined, and forged similar to any other metal. Magnesium is the lightest structural metal: one quarter the weight of steel, two thirds the weight of aluminium, and has same light weighting potential as carbon fibre.Europe imports primary magnesium in the forms of pure metal or alloys. In addition, the EU relies on imports of intermediate and final products, in particular in the electronics sector.

- At the EU level, the magnesium recycling capacity is about 75 kt/y (mostly for new scrap).
- The European Union is a net exporter of magnesium scrap, with net gross volumes of 10,370 tonnes in 2018. In 2018 40% of scrap exports are now directed to the US and 21% to Brazil, mainly due to price difference with primary magnesium (increased prices from anti-dumping measures, which were implemented in 2001). For comparison, 76% of scrap was exported to Norway in 2000 (Eurostat, 2019a)

15.4.2Supply from primary materials

15.4.2.1 Geology, resources and reserves of magnesium

Geological occurrence: Magnesium is a relatively common element with a concentration of about 2.1% (21,000 ppm) in the Earth's crust, and of about 46.7 ppm in the uppercrust (Rudnick, 2003). It is found in more than 60 distinct minerals. The most important minerals containing magnesium are rock-forming minerals: the chlorites, the pyroxene and amphibole group minerals, dolomite and magnesium calcite. Magnesium is also present in magnesite and hydrated carbonates (e.g. nesquehonite, lansfordite) as well as in brucite. In addition, a series of basic magnesium carbonates exist (e.g. hydromagnesite, artinite) (Shand, 2006).

Natural minerals supply the majority of commercialised magnesium (i.e. magnesium oxide): dolomite (85%), MG-brines (15% of commercialised output) (BGR 2019). Brucite is no longer used as a raw material for primary magnesium production (IMA, 2017).

Dolomite mineral ($CaMg(CO_3)_2$) is found in sedimentary rocks such as dolomite rock and limestones. It can occasionally be found in high-temperature metamorphic rocks and low-temperature hydrothermal veins. Dolomite is the raw material for the majority of the magnesium plants in China; it is also used in Turkey and Brazil (BGS, 2004).

Magnesite mineral ($MgCO_3$) exist as cryptocrystalline (amorphous) magnesite or macrocrystalline (bone) magnesite. Four types of magnesite deposits exist: as a sedimentary rock, an alteration of serpentine, as a vein filling or in replacement of limestone and dolomite (Shand, 2006). Magnesite deposits are fairly widespread but high-purity deposits of adequate size are uncommon (BGS, 2004). There are EU efforts to develop new opportunities to get magnesium from low grade sources of magnesite and dolomite based on biotechnology. An example, it is the project Biorecover[157].

Carnallite ($KCl.MgCl_2.6H_2O$) is the main source of magnesium in Russia and used to be significant in Chinese production, though not any longer. It is normally delivered as brine produced by the solution-mining of the solid carnallite deposits.

Global resources and reserves[158]: no information, but certainly large (USGS, 2019).

[157] https://cordis.europa.eu/project/rcn/223260/factsheet/en

[158] There is no single source of comprehensive evaluations for resources and reserves that apply the same criteria to deposits of magnesium in different geographic areas of the EU or globally. The USGS collects information about the quantity and quality of mineral resources but does not directly measure reserves, and companies or governments do not directly report reserves to the USGS. Individual companies may publish regular mineral resource and reserve reports, but reporting is done using a variety of systems of reporting

EU resources and reserves[159]: It is acknowledged that reserves of magnesium are large enough to meet the worldwide consumption needs for the next decades – either from dolomite and other magnesium-bearing evaporate minerals, or from magnesium-bearing brines.

15.4.2.2 Mining of magnesium ores and refining of magnesium

Magnesium-bearing ores are worked by open pit methods, although narrow and deep deposits may be worked by underground drifts and stopes. (United States International Trade Commission, 2012).

Magnesium can be produced through electrolytic methods or thermal-reduction methods such as the Pidgeon process.

The electrolytic method has dominated magnesium production from the 1970s to 1990s – the various processes consist of electrolysis of molten magnesium chloride (produced with different methods), the magnesium produced is liquid (molten). The source of magnesium can be seawater, brine or carnallite, among others (Wulandari et al., 2010). For instance, carnallite is used as raw material for the electrolysis process in Russia (BGR, 2017).

In the thermal-reduction method, calcined dolomite and calcined magnesite are broken down through the use of reducing agents. The mixture is heated in a vacuum chamber forming magnesium vapours which later condense into crystals. The crystals are melted, refined and poured into ingots for further processing (IMA, 2016).

The Pidgeon process is the most commonly used thermal-reduction method for production of magnesium due to the fact that its operation is relatively easy, versatile and has low capital cost; however, it is energy intensive and has low productivity. The largest producers of magnesium through the Pidgeon process are China, Brazil and Turkey (IMA, 2016). The process is based on silicothermic reduction of magnesium oxide from calcined dolomite. Dolomite calcination takes place at temperature ranges of 1,000 to 1,300°C. Calcined dolomite and ferrosilicon are mixed; at specific temperatures and pressure, the reduction of calcined dolomite by ferrosilicon produces magnesium vapor. High purity magnesium is obtained from condensation of the vapor; the potential impurities (Ca, Fe and Si) are low at these conditions (Wulandari et al., 2010).

New processes such as Carbothermic and the Mintek process are high productivity alternatives to the existing technologies that still require further development; they could achieve lower energy usage. There are EU efforts to develop new opportunities to get

depending on the location of their operation, their corporate identity and stock market requirements. Translations between national reporting codes are possible by application of the CRIRSCO template (www.crirsco.com), which is also consistent with the United Nations Framework Classification (UNFC) system. However, reserve and resource data are changing continuously as exploration and mining proceed and are thus influenced by market conditions and should be followed continuously.

[159] There is no complete and harmonised dataset that presents total EU resource and reserve estimates for magnesium. The Minerals4EU project is the only EU-level repository of some mineral resource and reserve data for magnesium, but this information does not provide a complete picture for Europe. It includes estimates based on a variety of reporting codes used by different countries, and different types of non-comparable datasets (e.g. historic estimates, inferred reserves figures only, etc.). In addition, translations of Minerals4EU data by application of the CRIRSCO template is not always possible, meaning that not all resource and reserve data for magnesium at the national/regional level is consistent with the United Nations Framework Classification (UNFC) system (Minerals4EU 2019). Many documented resources in Europe are based on historic estimates and are of little current economic interest. Data for these may not always be presentable in accordance with the UNFC system. However, a very solid estimation can be done by experts.

magnesium from low grade sources of magnesite and dolomite based on biotechnology. An example, it is the project Biorecover, that it has started few month ago[160].

15.4.2.3 World production of processed magnesium metals and alloys

World refined production of magnesium is summarised in Figure 192 and totals 927 kt/y (average 2012-2016). Primary magnesium is commercialised as pure magnesium (99.8% purity - which may later be used in aluminium alloys) and magnesium alloys (estimated 90% magnesium content in average). Global supply of magnesium is dominated by China with about 89%[161] of the total refined production, equivalent to 822 kt/y (average 2012-2016, BGS data). The United States and Israel are the second and third largest producing countries respectively accounting for 4% (40 kt/y; average over 2012-2016) and 3% (27 kt/y; average over 2012-2016) respectively of worldwide primary magnesium production. It is thought that production statistics for China may include production figures based on capacity rather than actual production and that some primary magnesium may be double counted when it is sold to local magnesium alloy producers (Roskill, 2013; IMA, 2019).

Production of primary magnesium jumped from 443 kt/y in 2000 to 957 kt/y in 2015, the first year with a slight decline (983 kt/y in 2014). The worldwide sourcing of primary magnesium significantly evolved since 2000: at that time, China represented 32% of worldwide refined production, whereas the US produced up to 21% of primary magnesium (Data from BGS World Mineral Statistics).

China's dominance of global magnesium production increased in the reported period, whereas there was little or no growth in other producing countries, despite some capacity expansion (e.g. Brazil) and new primary production units (e.g. in Malaysia, South Korea and Turkey). These capacity increases remained small compared to total global production (Roskill, 2013). According to IMA, Turkey plant produces 8 kt/y, with an installed capacity of 15 kt/y[162].

In 2015,there were about 50-80 magnesium smelting operations in China, most of them in the provinces of Shaanxi and Shanxi, which accounted for 61% and 28% of production. On a company basis, the largest productive capacity is held by Shanxi Yinguang Huasheng with 80 kt/y, averaged over 2012-2016, followed by Ningxia Hui-Ye Magnesium with 60 kt/y (International Mining, 2016).

There is no production of pure magnesium metal in the EU since 2001. However, magnesium alloys are processed in the EU based on primary magnesium (e.g. magnesium alloys) imported from extra-EU countries or from secondary magnesium production (IMA, 2017).

[160] https://cordis.europa.eu/project/rcn/223260/factsheet/en

[161] 85% according to IMA

[162] Closed in 2018 and reopened by KAR Mineral Madencilik in 2019 (BGR, 2019)

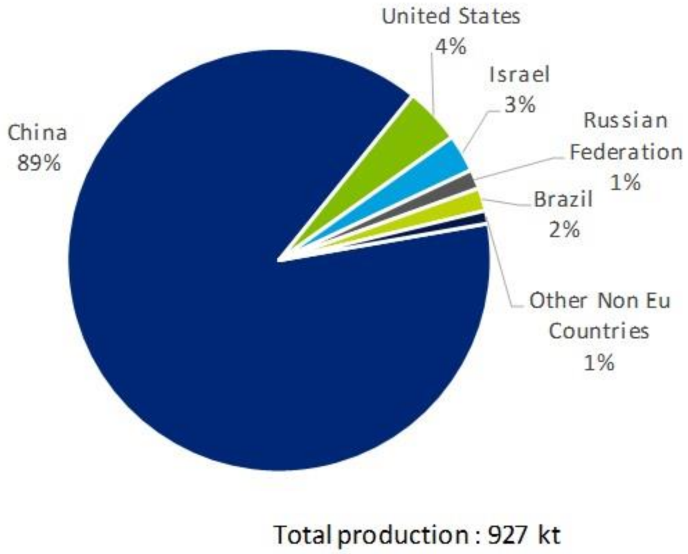

Figure 192: Global production of magnesium. Average 2012-2016. (BGS, 2017)

15.4.3Supply from secondary materials/recycling

15.4.3.1 Post-consumer recycling (old scrap)

Secondary magnesium is an important component in global magnesium supply, with production estimated to be in the range of 200-250 kt/y, 125 t/y of which is in the USA (International Mining, 2016). The amount of secondary material used in the magnesium industry depends on various factors, among others: amount of material lost in the melting cycle, quantity of different cast components, quality of process scrap, or recycling operation efficiency (IMA, 2016). At the EU level, the magnesium recycling capacity is about 75,000 t/y (mostly for new scrap). The main European players are in Austria (Non ferrum), Czech Republic (Magnesium Elektron [163]), Germany (Magontec, Real Alloy Germany GmbH), Hungary (Salgo-Metal), Serbia (Mg Serbien), Romania (Magontec), and in the UK (Magnesium Elektron) (Roskill, 2013, IMA 2019). In the EU, the EoL-RIR for magnesium is estimated at 12-13%, according to three sources: 13% in the MSA study (Bio Intelligence Service 2015), 12.4 % in the Oakdene Hollins report (Bell et al. 2017) and 13.4% in the current criticality assessment, which is in turn based on the MSA of aluminium (Passarini et al. 2018).

Various recycling methods exist and are currently used to re-melt magnesium scrap: a common process is the remelting and refining of heavy scrap. In order to ensure the same quality criteria (in terms of chemical composition, oxide content) for secondary and primary materials, other recycling methods may be required, in particular for old scrap. For instance, the addition of manganese reduces the levels of iron; distillation or dilution allow for nickel and copper control (IMA, 2016).

In the EU, a large share of magnesium is used as an alloying element in the production of aluminium alloys and derived applications. Therefore, most of end-of-life magnesium scrap is recycled as part of the aluminium value stream. In addition, magnesium alloys are entirely recyclable once they are collected from end-of-life products.

[163] Plant sold to: Crown Metals CZ s.r.o.

15.4.3.2 Industrial recycling (new scrap)

Recycling or reuse of new scrap is common in the magnesium industry; the scrap kept within a close loop system reduces the demand of primary magnesium by up to 50%. Die casting foundries recycle scrap internally or externally. Lower grade arising is used as reagents in steel desulfurization or other markets, as replacement to primary magnesium (IMA, 2016). There is no recycling of magnesium from steel desulfurization applications.

15.5 Other considerations

15.5.1 Environmental issues

Magnesium alloys have a great potential to reduce vehicle weight, fuel consumption, and greenhouse gas emissions in vehicles use life (Du et al., 2010). However, most magnesium is produced in China through the Pidgeon process that has an intensive energy usage and generates a large amount of greenhouse gas emissions, which may offset the potential advantage of using magnesium parts in automobiles (Cherubini et al., 2008).

New Mg primary projects are indicating a much more reduced Global Warming Potential (GWP) compared to China Pidgeon process. Magnesium out of the Qinghai Magnesium complex claims a GWP of 7.1 kg of CO_2 per kg of magnesium and also Latrobe Magnesium and Alliance Magnesium indicate much lower GWP (IMA 2019).

15.5.2 Socio-economic issues

No specific issues were identified during data collection and stakeholders consultation.

15.6 Comparison with previous EU assessments

The assessment has been conducted using the revised methodology introduced in the 2017 assessment. Therefore, the calculations of economic importance and supply risk are not directly comparable with results of the 2011 and 2014 assessments. Supply risk has been analysed at processing stage only. The results of this and earlier assessments are presented in Table 84.

Table 84: Economic importance and supply risk results for magnesium in the assessments of 2011, 2014, 2017, 2020 (European Commission, 2011a-2014b-2017c)

Assessment	2011			2014			2017			2020	
Indicator	EI	SR		EI	SR		EI	SR		EI	SR
Magnesium	6.45	2.62		5.48	2.53		7.14	3.98		6.63	3.91

Both the economic importance and supply risk of magnesium have increased since 2011 till 2017, and decreased in 2020.

15.7 Data sources

Market shares are based on existing studies (Bio Intelligence Service, 2015) and stakeholders' feedback (IMA, 2019; SCRREEN workshops, 2019). Production data for magnesium metal and alloys are from BGS World Mineral Statistics dataset. Additional feedback was received from stakeholders and included in the assessment to obtain data best representative of the global supply. Trade data were extracted from the Eurostat Easy Comext database (Eurostat, 2019a). Data on trade agreements are taken from the DG Trade webpages, which include information on trade agreements between the EU and other countries (European Commission, 2019). Information on export restrictions are derived from the OECD Export restrictions on the Industrial Raw Materials database (OECD, 2019.

For trade data the Combined Nomenclature (CN) codes 81041100 'Unwrought magnesium, containing >= 99.8% by weight of magnesium' and 81041900 'Unwrought magnesium, containing < 99.8% by weight of magnesium' have been used.

The EoL-RIR for magnesium was estimated considering that recycling of magnesium metal and alloys are similar to recycling of aluminium alloys.

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