

9. Magnesium

Magnesium is the lightest structural metal. During the last decade, magnesium production in China has increased enormously. China's production was 250 000 Metric tons in 2002 and 675 000 Metric tons annually in 2011.¹ This supply increase resulted in lower prices, leading to the closure of magnesium plants in the rest of the world. The last primary producer in Western Europe closed in 2002. There have been plans to start magnesium production in Europe over the past ten years, but continuing low prices have made it difficult to create a business case for it. Therefore, the production of magnesium is currently concentrated mainly in China.

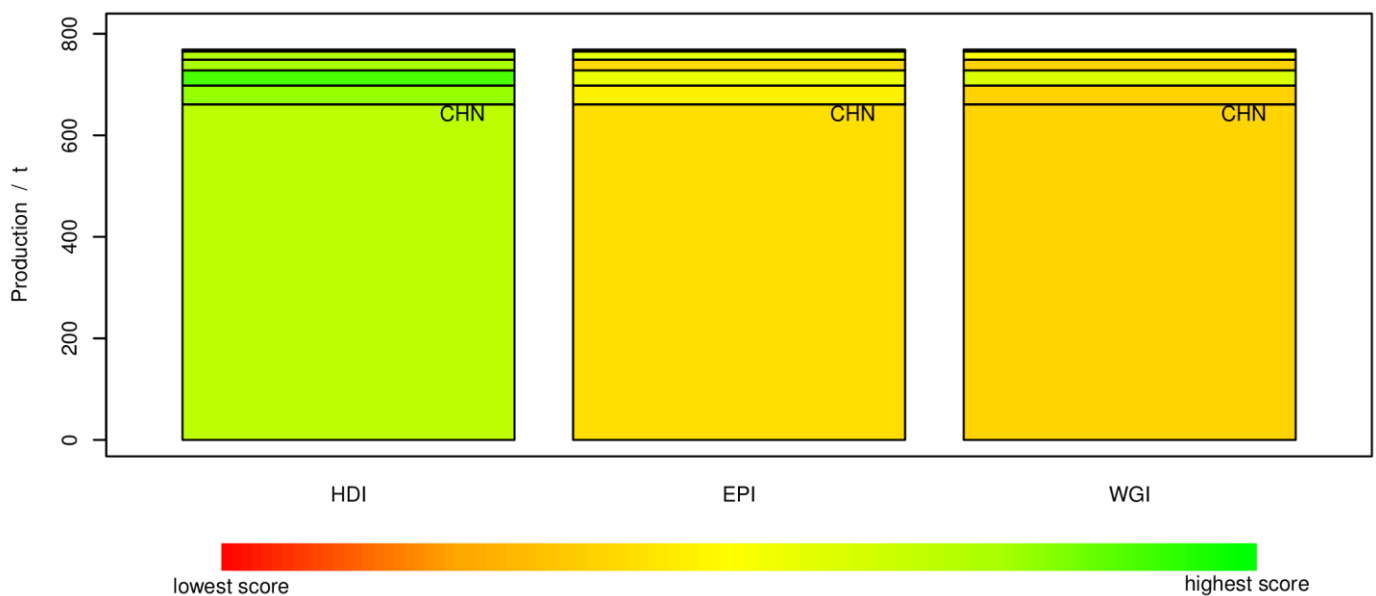


Figure 1: Distribution of magnesium production² and corresponding scores of the producing countries in the Human Development Index (HDI)³, Environmental Performance Index (EPI)⁴, and World Governance Indicators (WGI)⁵. Both the EPI and WGI are used to assess supply risks with the EU methodology for determining critical raw materials⁶. CHN = China.

After a price peak in 2009 the average price of magnesium metal has fallen down again. The average price of magnesium metal was 0.97 US\$/kg in 2011*, a decline of 33% since 2009.⁷ Looking at a longer time frame from 2005 to 2012 it appears that the price is rising overall. During the period from 2011 and 2012 the price was stable and then started to decrease at the beginning of 2013.⁸

* U.S. spot Western

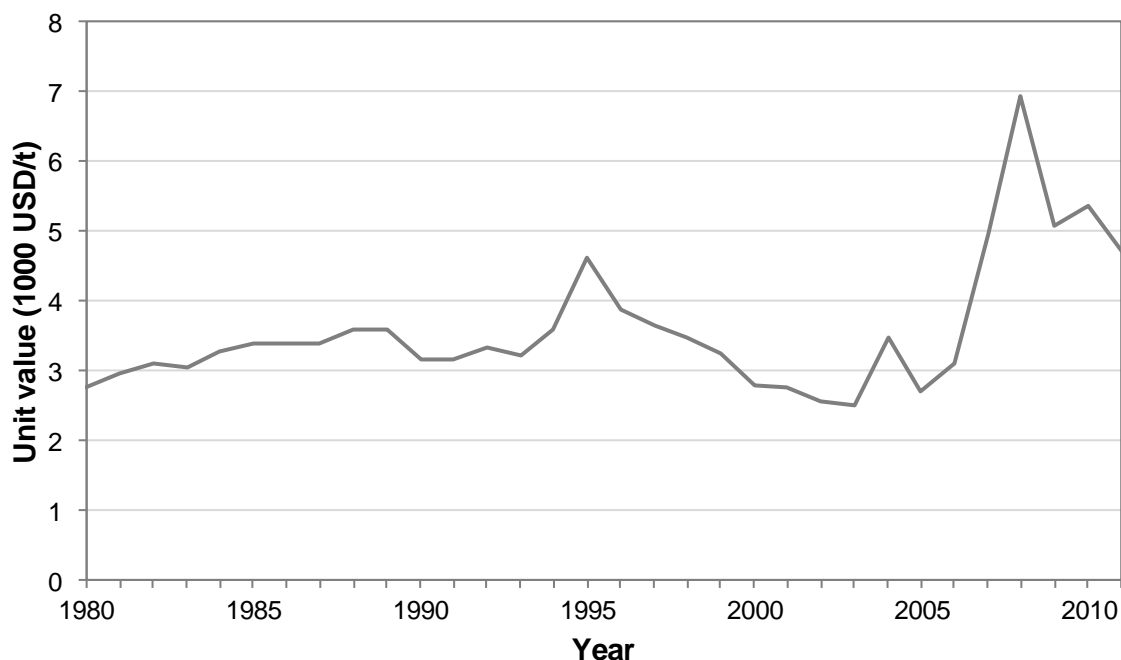


Figure 2: Magnesium metal price development during 1980 – 2011. The unit value is the value in dollars of 1 metric ton (t) of magnesium metal apparent consumption (estimated) ⁹.

Aluminium alloys

Magnesium as alloying element is most relevant for 5000 and 7000 series aluminium alloys since these contain typically more than 1% magnesium.¹⁰

The presence of magnesium as the main alloying element in the 5000 series (used up to 6 wt %) leads to solute hardening of the alloy, and efficient strain hardening, resulting in medium strength. The good formability, combined with the medium strength, excellent corrosion resistance, high quality anodising ability as well as weldability, result in many applications for outdoor exposure: in **construction** sheet (for example in anodised and electrocoloured facade panels), scaffolding, and in particular in marine applications (ship building, platforms, etc). In **automotive** applications, 5000 series alloys are also used for press formed body-parts and chassis components due to their good combination of strength and formability.

Three different strategies can be identified for substituting magnesium in aluminium alloys or the aluminium alloys themselves: use of other elements in the same alloy series, use of a different aluminium alloy series or the use of other materials altogether. Iron can substitute magnesium as the solution hardening element in aluminium alloys. However, adding iron to the alloy leads to a deterioration of the corrosion properties of aluminium. This is a particular drawback when aluminium is used in shipbuilding.

5000 series aluminium alloys can in some cases be substituted by 3000 series alloys. The 3000 series alloys have manganese (range 1–2 wt %) as the main alloying element. Manganese makes the alloys ductile, resulting in good formability while still allowing a wide range of mechanical properties through various strain hardened tempers. The 3000 series are medium strength alloys and are at present predominantly found in heat exchangers in automotives and power plants¹¹. Substitution of 5000 series with

3000 series in areas like **construction** and **transportation** will therefore be at the cost of the material strength.

Steel can be used as a substitute for aluminium in **packaging** (beverage cans), **construction** and **transportation** (automotive). The development of ultra high strength steels has resulted in steel alloys with a strength to weight ratio close to that of aluminium.

Advanced polymers can substitute aluminium alloys, like the use of carbon fibre-reinforced polymer in aircraft instead of 7000 series alloys.

Casting alloys

Magnesium alloys are typically used as cast alloys for many components of modern cars, and magnesium block engines have been used in some high-performance vehicles. Die-cast magnesium is also used for camera bodies and components in lenses. Magnesium alloys have a hexagonal lattice structure, which affects the fundamental properties of these alloys. Plastic deformation of the hexagonal lattice is more complicated than in cubic latticed metals like aluminium, copper and steel. It is therefore very difficult to forge the materials.

Polymer (e.g. acrylonitrile butadiene styrene ABS) injected moulded parts are a direct competitor to cast magnesium parts. Aluminium cast and forged parts can also compete with magnesium in several applications but at the cost of a higher weight of the part.

Wrought Alloys

Magnesium is seldom used as wrought alloy because of the poor formability. Extruded magnesium bars, sections and tubes are used in aerospace, nuclear and other engineering applications.

In these applications, age-hardened wrought aluminium alloys are a suitable substitute, although there is a weight increase.

Summary

Magnesium can be substituted in most applications at some extra cost or through a minor loss of performance with options already available today. The largest perceived performance loss is seen for casting alloys, though the use of magnesium results in cost and/or performance advantages in all applications.

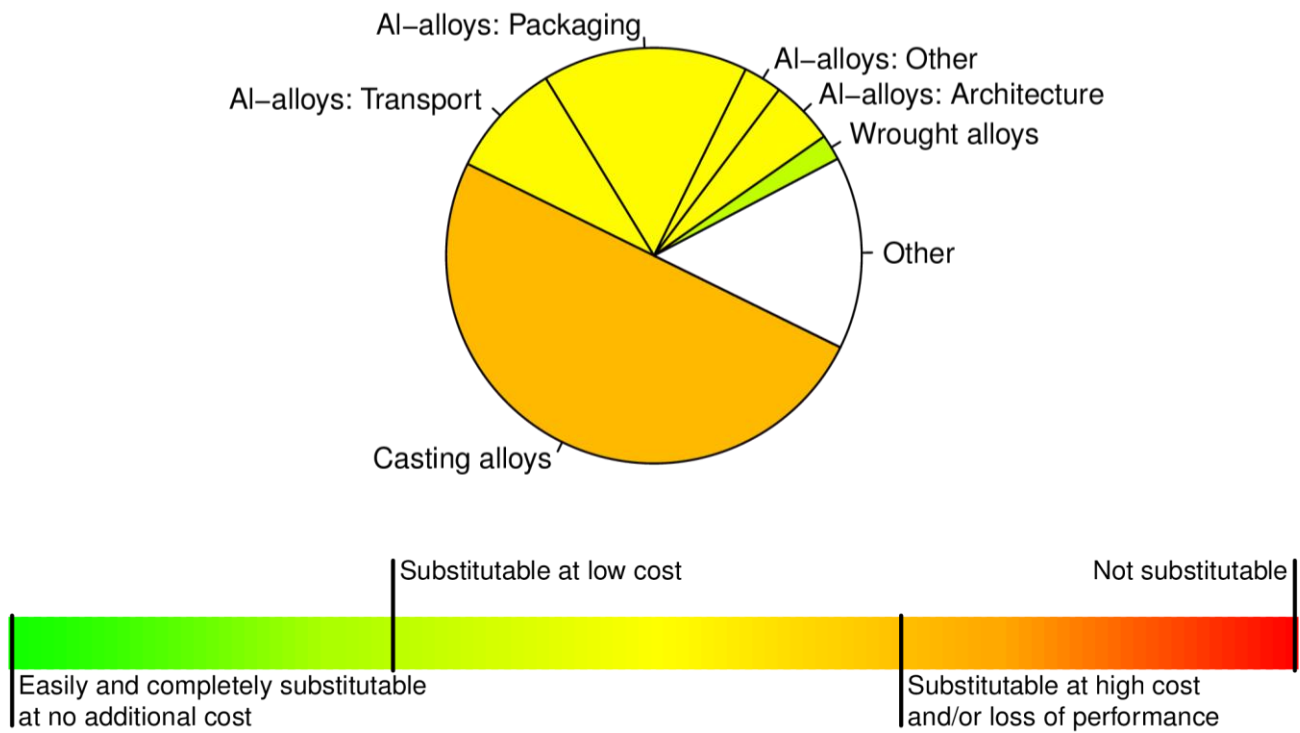


Figure 3: Distribution of end-uses and corresponding substitutability assessment for magnesium. The manner and scaling of the assessment is compatible with the work of the Ad-hoc Working Group on Defining Critical Raw Materials (2010).

References

- 1 U.S. Geological Survey (ed.) (2011) Minerals Yearbook
- 2 U.S. Geological Survey (2013) Mineral commodity summaries 2013
- 3 United Nations Development Programme (UNDP) (2013) The 2013 Human Development Report – "The Rise of the South: Human Progress in a Diverse World"
- 4 Yale Center for Environmental Law and Policy (YCELP) (2013) Downloads | Environmental Performance Index. <http://epi.yale.edu/downloads>. Accessed 26 July 2013
- 5 World Bank Group (2013) Worldwide Governance Indicators. http://info.worldbank.org/governance/wgi/sc_country.asp. Accessed 26 July 2013
- 6 Ad-hoc Working Group on defining critical raw materials (2010) Critical raw materials for the EU: European Commission
- 7 Kramer, D. A. (2013) Magnesium metal, in: U.S. Geological Survey (ed.) Mineral Commodity Summaries 2013, pp. 96–97
- 8 Metal Bulletin Magnesium MB free market min \$ per tonne: Latest Metal Prices Tracking and Comparison Tool. <http://www.metalbulletin.com/My-price-book.html>. Accessed 3 September 2013
- 9 DiFrancesco, C., Kramer, D. (2012) Magnesium Metals: Supply-Demand Statistics, in: U.S. Geological Survey Minerals Information
- 10 Hatch JE (1984) Aluminum: Properties and Physical Metallurgy
- 11 ESAP Welding & Cutting United States (2013) Understanding the Aluminum Alloy Designation System. <http://www.esabna.com/us/en/education/knowledge/qa/-Understanding-the-Aluminum-Alloy-Designation-System.cfm>. Accessed 7 August 2013