Latest developments and outlook for magnesium minerals and chemicals

Minerals production, market consumption drivers, new projects and forecast

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Magnesium Minerals and Chemicals

Overview of global magnesium minerals and chemicals market

• Main applications
• Resources, producers, consumption and outlook
• Magnesia
• Magnesium hydroxide
• Brucite
• Huntite /Hydromagnesite
• Outlook for 2018 and beyond
Steel – the number one market for magnesium minerals

Total MgO consumption just above 14 mt in 2017

- 85% Magnesium Oxide – MgO
  - 56% MgO for Refractory products
  - 40% MgO for Steel production

- 29% Magnesium Oxide-Refractory
- 29% Magnesium Oxide-Chemical
- 8% Magnesium Hydroxide
- 4% Magnesium Chloride
- 3% Magnesium Sulfate

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Magnesium carbonate based minerals are the most important
Magnesite is by far the most important Mg containing mineral

**Magnesium carbonates**

- **Magnesite** $\text{MgCO}_3$
- **Dolomite** $\text{CaMg(CO}_3\text{)}_2$
- **Huntite** $\text{Mg}_3\text{Ca(CO}_3\text{)}_4$
- **Hydromagnesite** $\text{Mg}_5\text{(CO}_3\text{)}_4\text{(OH)}_2\cdot4\text{H}_2\text{O}$

**Magnesium hydroxide**

- **Brucite** $(\text{Mg(OH)})_2$

**Magnesium sulfate**

- **Kieserite** $\text{MgSO}_4\cdot\text{H}_2\text{O}$
Magnesite

Is the number one magnesium resource
84% of magnesium chemicals derived from magnesite

Brine and seawater good sources for pure magnesium chemicals

- By-product / other: 2%
- Kieserite: 4%
- Brucite: 7%
- Seawater: 84%
- Brine: 0%
- Mineral / magnesite: 0%
Magnesium major minerals reserves / resources
As million tons MgO

China holds ca 13% of total magnesite reserves

USGS / IHS Markit estimates

Magnesite ca 3.4 bt
Brucite resources 0.5 mt
Kieserite ca 0.5 mt
China produced 66% the magnesite in 2017

Total magnesite production ca 12 mt in 2017 As MgO

China mined 66% of the worlds magnesite in 2017

USGS / IHS Markit estimates
World export magnesite
Natural magnesium carbonate

World exports by country

Major magnesite importers
Major importers in 2017

Importing countries

- Indonesia: 27%
- Russia: 13%
- India: 7%
- Ireland: 3%
- South Africa: 2%
- other: 48%
Magnesium Oxide - Types

DBM, CCM, Fused magnesia?

- Refractory Magnesia
- Non-Refractory Magnesia
- DBM
- Fused Magnesia
- CCM
Magnesia prices increase with process energy requirement

Average Chinese export prices for all grades have increased in Q1 2018

Fused Magnesia
- >2800°C
- >600µm

DBM – Dead Burned
- 1500-2300°C
- >75µm

CCM - Caustic Calcined
- Light burned 700 – 1000°C
- Hard burned 1000-1500°C
- <0.5µm

Increasing price

<table>
<thead>
<tr>
<th>Year</th>
<th>Fused Magnesia</th>
<th>DBM – Dead Burned</th>
<th>CCM - Caustic Calcined</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>0.50 $/kg</td>
<td>0.24 $/kg</td>
<td>0.20 $/kg</td>
</tr>
<tr>
<td>2017</td>
<td>0.57 $/kg</td>
<td>0.23 $/kg</td>
<td>0.15 $/kg</td>
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<tr>
<td>2018</td>
<td>0.90 $/kg</td>
<td>0.39 $/kg</td>
<td>0.18 $/kg</td>
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</table>
Magnesium oxide – only minor capacity additions 2013 to 2021

Source: IHS Markit

© 2017 IHS Markit
Capacity utilization of magnesium chemicals

Global MgO capacity running at 68% in 2017

Production capacity utilization, %

MgO capacity utilization expected ca 71% 2021
Half of global MgO exports originated in China in 2017

DBM 38%, CCM, 28% and FM 18% other low grade 16%

**World MgO exports 2017**

**World MgO imports 2017**
Chinese magnesia exports of MgO on the way up

Q1 export figures for CCM and FM show gains in volume and price

- MgO exports decreased through 2015 and 2016
- Prices reached a low point in 2016
- FM exports and prices up substantially 2018Q1
Trade and environmental controls causing turbulence in China

Uncertain supply of higher grade material

**Trade**

- Export quota system for MgO scrapped in Jan 2017
- Costly export license still required
- Export volumes increased in 2017

**Environment**

- Anti-pollution controls top priority
- 3 MgO producers have had licence revoked recently removing 195 kt MgO capacity
- Large scale inspections and temp closures throughout 2017 and early 2018
A high level of integration from mining through to refractories

Outside China there is little integration

- RHI Magnesitas – largest integrated miner, MgO and refractories producer
- Magnezit – also highly integrated

In China, many integrated producers
- Haicheng Xiyang Refractory Materials Co., Ltd.
- Haicheng Magnesite Refractory General Factory
## EMEA major MgO producers

<table>
<thead>
<tr>
<th>Company</th>
<th>Raw mat</th>
<th>CCM</th>
<th>DBM</th>
<th>FM</th>
<th>Refractories</th>
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<tr>
<td>RHI Magnesitas</td>
<td>Magnesite</td>
<td>143</td>
<td>550</td>
<td>85</td>
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<tr>
<td>Magnezit</td>
<td>Magnesite</td>
<td>200</td>
<td>130</td>
<td>70</td>
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<td>SMZ Slovakia</td>
<td>Magnesite</td>
<td>40</td>
<td>320</td>
<td>No</td>
<td>No</td>
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<tr>
<td>Nedmag</td>
<td>Brine</td>
<td>Yes</td>
<td>170</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Kumas</td>
<td>Magnesite</td>
<td>60</td>
<td>275</td>
<td>40</td>
<td>No</td>
</tr>
</tbody>
</table>
New Developments

**Magnohrom, Serbia**
- May 2018 bought by Finnish Afarak, 35kt DBM, Integrated miner

**Magnezit, Russia**
- Started a second 100kt CCM kiln for pulp & paper and hydrometallurgy in 2017 plus 130 kt DBM.
- Ca 100kt FM in 2019-20

**Magnezitas Navarra, Spain**
- 30 kt DBM added by upgrading kiln in 2017
Refractories – can resist ultra high temperatures >1,500°C

Basic Refractory bricks require DBM and Fused Magnesia

• DBM contains >85% MgO
  Fused Magnesia >97% MgO

• Approx. 80% of refractory production is consumed by the steel industry

• Basic burnt Magnesia good corrosion and chemicals resistance

• FM required in high performance Mag Carbon bricks used at BOF vessels and ladles plus EAF slag liners.
Fused magnesia produced >2800°C

Fused magnesia production ca 1.3 million metric tons in 2017

>80% FM production in China
China consumes ca 50% MgO globally for steel production

Ca 5.9 million tons MgO used for steel refractory product production in 2017

MgO consumption in the steel industry Total 5.9 mt in 2017
Just below 2 mt MgO consumed in cement industry

Consumption of MgO refractory products peaked in 2014
China is the largest producer of MgO, refractories and steel

Includes all bricks containing >50% Mg, Ca or Cr, total >1.7mt in 2017

- China: 47%
- Germany: 13%
- Austria: 7%
- France: 5%
- Poland: 3%
- United States:...
- Turkey: 2%
- Russia: 2%
- Poland: 3%
- Other: 18%
- Russia: 2%
- Poland: 3%
- United States:...
- Turkey: 2%
- Other: 18%

Mg refractory brick exports 2017

Major European Mg brick exporters
Any bright lights on the horizon?
Steel demand forecast to increase by 1.8% 2018

Refractory MgO demand 1.3% AAGR thru 2021

- Driven by favourable economic conditions
- Driven by investment in infrastructure in developed and undeveloped economies
- 0.9% increase forecast 2019
- Steel demand in China to remain flat, possible slight decline in 2019
- Overall growth after 2019 less than 1% per year
Magnesium Oxide (CCM) and Chemicals Flowchart

- **Kieserite or other minerals**
  - Magnesium sulfate
  - Magnesium carbonate
  - Thermal decomposition
  - CO₂

- **Magnesite or other minerals**
  - Magnesium Oxide Non-refractory
  - Calcination

- **Seawater**
  - Magnesium sulfate
  - Magnesium carbonate
  - Calcined dolomite or lime slurry

- **Brines**
  - Magnesium chloride
  - HCl
  - Calcined dolomite or lime slurry

- **H₂SO₄**
  - Magnesium Oxide (CCM)
Magnesium oxide - Non-Refractory Market >4 mt in 2017

The industrial construction growth drives the non-refractory MgO market

- Construction: 39%
- Agricultural: 26%
- Magnesium Chemicals: 15%
- Environmental: 11%
- Other: 9%

Ca 1.7 mt used in construction
Magnesium oxide non-refractory – global demand outlook - 2022

- **Chemicals**: +2-3%
- **Agriculture**: +1-2%
- **Environmental**: 1.5%
- **Manufacturing**: +3%

Increase 1.8% AAGR 2017 - 2022

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Other magnesium chemicals - smaller but important markets

- **Magnesium chloride**
  - Deicing and dust control
  - Sorel cement and food

- **Magnesium sulfate**
  - Most important in agriculture
  - Many industrial uses

- **Magnesium hydroxide**
  - Environmental applications
  - Flame retardants, chemicals, pulp and paper
Magnesium Hydroxide

*In Japan is produced mainly from seawater*
Japan is the largest producer of magnesium hydroxide

- Japan accounts for 36% global capacity
- Capacity in Japan reduced in 1980s to 90s
- Increases mainly for flue gas desulfurization
- Uses mainly slurry
- Under competition from cheap imported CCM
- Environmental uses, FGC and water treatment consume about 66% Mg(OH)2
- Flame retardants account for about 10%, just below 100 kt in 2016 as MgO

**World capacity magnesium hydroxide - 2017**

- Japan 36%
- EMEA 26%
- China 17%
- Americas 16%
- Other 7%

Source: IHS Markit © 2017 IHS Markit

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Magnesium Hydroxide

Flame retardants - a growing market?
ATH is the most important flame retardant by volume

World consumption of flame retardants by type - 2016

- Aluminum Trihydroxide: 38%
- Magnesium Hydroxide and Minerals: <5%
- Brominated: 17%
- Organophosphorus: 18%
- Chlorinated: 5%
- Antimony Oxides: 9%
- Other: 8%

Total ca 2.3 million metric tons

Source: IHS Markit

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Russia and China are the main brucite flame retardant producers

- Brucite has 69% MgO in the mineral
- The highest MgO of all the minerals
- Relatively low Si, Fe, Mn
- Much is milled and used directly
- Some is surface treated for FR
Greece is the major huntite and hydromagnesite producers

Another alternative to synthetic MDH for flame retardant applications,

- LKAB in Turkey produces Hydromagnesite / huntite (HMH)
- Reserves 10 mt
- Fillers and flame retardants for plastic, mainly wire and cable. Coated and uncoated.
- Sibelco produced a 60% Huntite / 40% Hydromagnesite in Greece.
- Reserves 500 kt
- Production is much lower over the last few years
Magnesium sulfate

Globally, about 78% is used in agriculture
German magnesium sulfate exports

- Germany is the largest producer of natural kieserite, MgSO$_4$.H$_2$O
- Produces total ca 1.1 million metric tons of MgSO$_4$ products in 2017
- Exported 171 thousand metric tons in 2017
- Purified magnesium sulfate mainly sold as Epsom salt, MgSO$_4$.7H$_2$O
- Exported mainly within Europe
- MgSO$_4$ salt export from Germany 17% of world in 2017. China, 67%
Strategic implications

- World construction spending is the major driver of MgO consumption. Steel growth estimated at 1.8% in 2018
- Construction, Agriculture and Environmental applications are major drivers of CCM consumption
- Overall AAGR 1.5% MgO to 2022
- FR ca 10% MDH market
- Opportunities as replacement for halogentated FR
- Synthetic MDH could be substituted in some cases by minerals.
- Opportunities for lower cost minerals when price and purity are good
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Thank you, any more questions?

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