

Analysis of the Magnesium Market



Executive Summary

- China's Magnesium Ingots are priced at USD 2,600 per metric ton as of May 2019
- China is one of the largest Magnesium suppliers in the world
- MagOne agrees with Tech Magnesium, and purchases full ownership on its technology

OUTLOOK & PROSPECTS

VRS RESEARCH TEAM

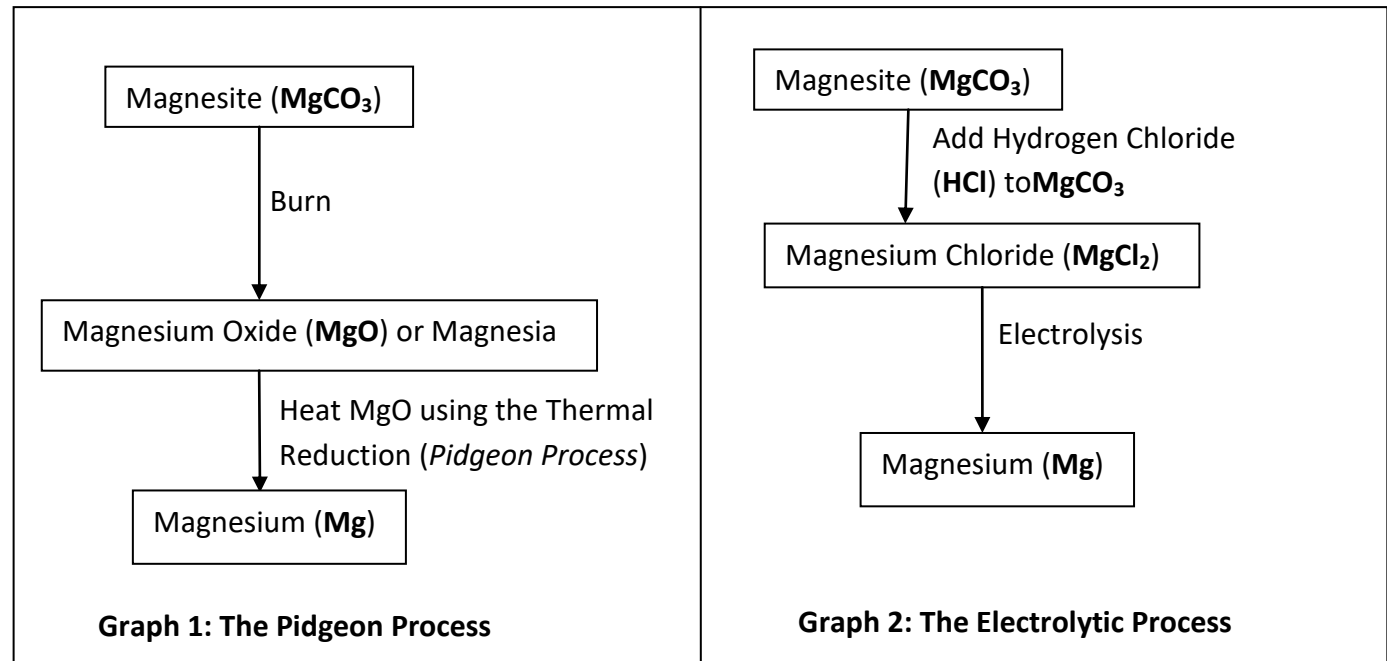
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Magnesite Breakdown



- Graph 1 displays the Pidgeon Process
MgCO₃ is the raw Magnesite, extracted from the mine. Burning **MgCO₃**, produces the **MgO**, known as Magnesia. Applying the Pidgeon Process, the Magnesium metal (**Mg**) is extracted.
- Graph 2 displays the Electrolytic Process
In the raw Magnesite **MgCO₃**, adding Hydrogen Chloride (**HCl**), leads to Magnesium Chloride (**MgCl₂**). Since **Mg** has +2 electrons and **Cl** has -1 electron, the process balances the surplus/deficit of electrons. **MgCl₂** is separated to **Mg** and **Cl₂**. **Mg** is the Magnesium metal.

Key Non-Chinese Players in the Magnesium Industry

Non-Chinese Magnesium Players	Country	Financial/Legal Information	Operations
Korab Resources	Australia	Listed on Australian Securities Exchange (ASX:KOR) and traded on ASX and Berlin Stock Exchange (BSE).	The company explores for gold, silver, phosphate rock, magnesium, tin, iron ore, copper, nickel, cobalt, lead, zinc, lithium, and rare earth metals. Based in Australia.
RHI Magnesita	Austria	Total assets of 3.53 B\$ and generated revenues of 3,08 B\$	Austrian-based company which produces approximately 1,7 million tonnes of refractory products per year
MagnesitaRefratarios	Brazil	Revenues of 911m\$ and Market Cap of 728m\$ (MAGG3:SAO)	Vertically integrated refractory manufacturer with over “13,000 products”. The third largest producer of refractory products in the world.
MGX Minerals	Canada	Market cap of 27.79m\$ (XMG:CSE)	MGX Minerals, Inc. engages in the acquisition, exploration and development of mineral resource properties, including magnesium
West High Yield Resources	Canada	Market Cap of 15,33m\$ (WHY:TSXV)	The Company focuses on development of gold, nickel, and magnesium properties. Based on Canada.
Mag One Products	Canada	Revenues of 7,61m\$ and Market Cap of 75,27m\$	Develops and commercializes technologies for the processing and production of magnesium (Mg) metals, and Mg related compounds, The manufacturing plant base is in southern Québec, Canada.
Dead Sea Magnesium	Israel	Subsidiary of ICL Israeli Chemicals Ltd (ICL:NYSE)	Supply of pure metal magnesium and magnesium alloys from the Dead Sea.
Ube Material Industries	Japan	A subsidiary of Ube Industries (4208:TYO). Net sales of 0.34m \$ (As of March 31, 2016)	Japan company that engages in the production, processing, and marketing of magnesia clinker and other refractory raw materials, calcia,ceramic materials, and magnesium.
Magnezit Group	Russia	Year over year revenues of 110m\$	Russian-based producer of refractory materials which is vertically integrated with its own raw material supply. Total number of proven magnesite reserves of the Group exceeds 278,5 million tons.
Solikamsk Magnesium Works	Russia	A Russian magnesium metal producer with Revenues of 93,8m\$ and Market Cap of 19,2m\$	Manufactures and sells magnesium, chemical, and rare metals products for use in high-tech industries in Russia and internationally.
US Magnesium	USA	Privately held company	Supply of magnesium through an electrolysis process from brines in the Great Salt Lake, Utah. Annual capacity 50.000 metric tons of Magnesium.
Premier Magnesia LLC	USA	Privately held company. Revenues of 60,2m\$ as of 2017	Nevada-based vertically integrated magnesia miner and processor. Provides Magnesia and Magnesium based products.
Nevada Clean Magnesium	USA	Market cap of 11,88m\$ (NVM:TSXV)	Produces and distributes magnesium extracted from its property in North Central Nevada.
Magpro LLC	USA	Estimated annual revenues of 11,8m\$	Is the second largest producer of Primary Magnesium in the United States. (Source: Company)

Key Chinese Players in the Magnesium Industry

Supply Side of Magnesium (Chinese Companies)	
1. China Magnesium Corporation	15. Fugu TianYu
3. Yinguang Magnesium Industry	17. Shaanxi XingmaoZhuluoji Magnesium Cell Group
4. Hui Ye Magnesium	18. Haotian Group
5. Taiyuan Yiwei Magnesium	19. Xinheyuan
6. Shanxi Bada Magnesium Co., Ltd.	20. Tianlong
7. SHANXI WENXI HONGFU MAGNESIUM	21. Huashun
8. Yulin Wanyuan Magnesium Industry	22. Fu Gu Yi De
9. Nanjing Yunhai	23. Shengxin Magnesium
10. Shanxi Meijin	24. Jinchuan Magnesium
11. Shanxi Jinxing	25. Shenmu Dongfeng Magnesium
12. Shanxi Credit	26. Fugu County Xintian Magnesium Alloy Co., Ltd.
13. Fugu Tongyuan	27. Ningxia Huayi Magnesium
14. Fuguxian Coal&Chemical	28. Liaoning Jinding

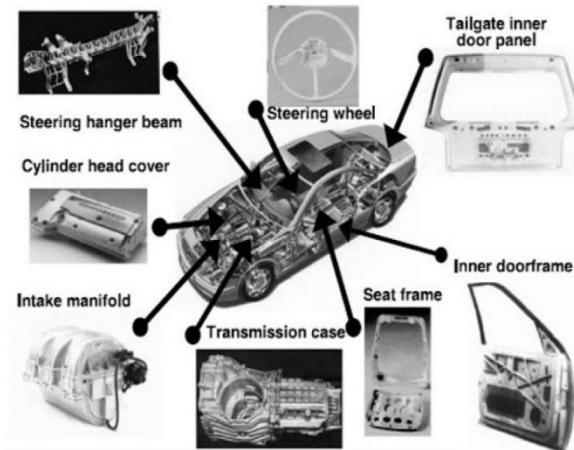
Even though China produces the 70% of the global magnesium supply, most of the companies are State-Owned or Private held companies being information-wise opaque.

Companies that are being Publicly traded in the Stock Exchange are:

- China Magnesium Corporation, listed on the Australian Securities Exchange
- Nanjing Yunhai, listed on the Shenzhen Stock Exchange (002182.SZ)
- Shanxi Meijin, listed on the Shenzhen Stock Exchange (000723.SZ)

Demand Side

Automotive Magnesium Alloy market	Magnesium Alloy Wheels Market	Magnesium Bike Frames
ION Wheels Nitto Tire American Racing STOLFIG TAKATA Autoliv GF Faw Foundry DY Group General Motors Ford Sumitomo Electric Industries, Ltd.	Marvic Wheels, BBI Autosport, Marchesini Vision Ability Dedication, OZ Motorbike APP Tech SMW Engineering, Tan-Ei-Sya	DT Swiss Zinn Cycles Paketa Cycles Segal Bikes Pinarello Allite Inc



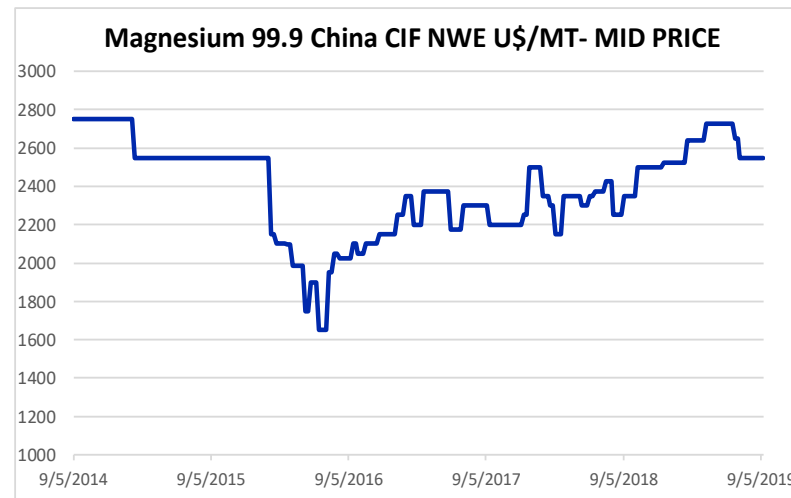
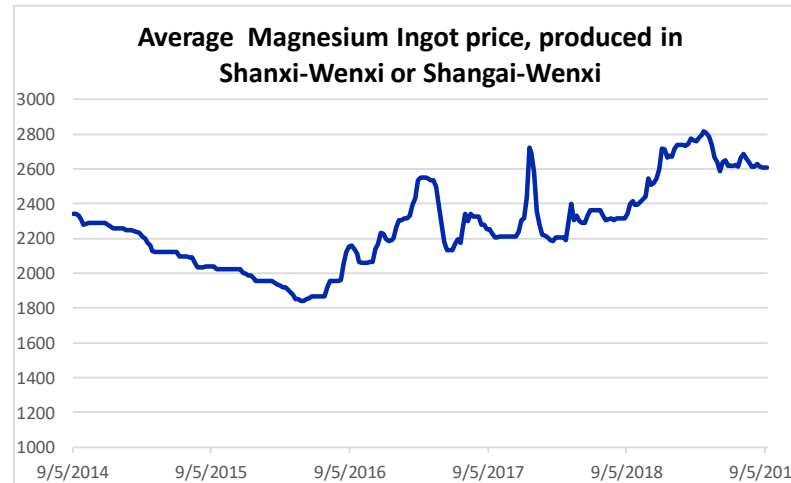
Source: Totalmateria.com

- Magnesium has multiple uses in automobiles, being included in gearboxes, steering wheels, fuel tank covers and seat frames. A typical automobile contains roughly 5 kilos of Magnesium.
- Aluminum wheels are x1.5 times heavier than magnesium wheels. All competitive racing rims are now made of magnesium alloy, as it offers lightness, a high damping capacity, and high specific strength.
- Allite Inc. in 2019, revealed the first Super Magnesium bike. Its frame is stiffer and stronger than aluminum, and less expensive than carbon, making it ideal for track racing.

Prices for Magnesium Produced in China

Figure 1 shows the Average Magnesium Ingot price (Ingot is a block of metal, typically oblong in shape).

Figure 2 displays the 99.9% Magnesium prices, including both insurance and freight costs.



Source: Thomson Reuters, Datastream

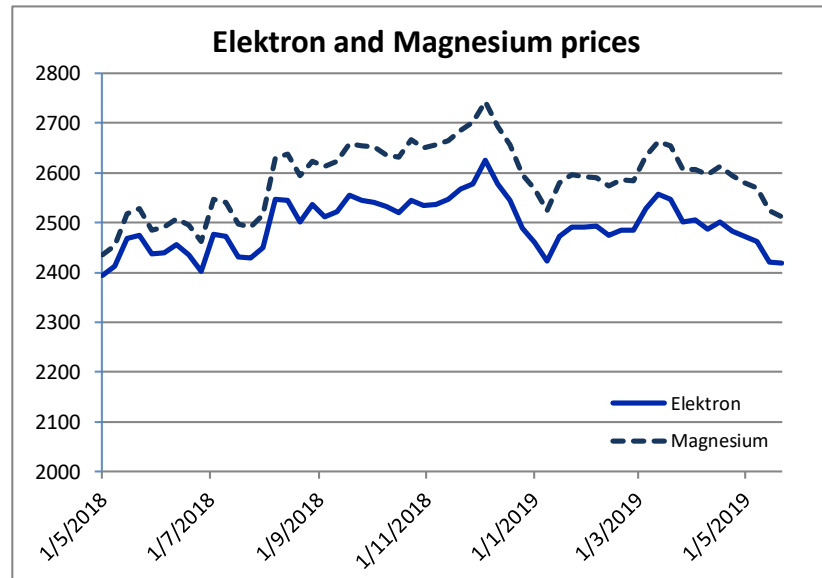
Elektron

Elektron is the registered trademark of a wide range of magnesium alloys manufactured by the British company Magnesium Elektron Limited.

There are about 100 alloys in the Elektron range, containing from 0% to 9.5% of some of the following elements in varying proportions: aluminum (< 9.5%), yttrium (5.25%), neodymium (2.7%), silver (2.5%), gadolinium (1.3%), zinc (0.9%), zirconium (0.6%), manganese (0.5%) and other rare-earth metals.

The composition of the initial Elektron alloy was approximately Mg 90%, Al 9%, other 1% (Usually Zn)

Elektron is a magnesium alloy, composed by **Mg (≈90%), Al (≈9%) and Zn (≈1%)**, with low density, suitable for auto racing and aerospace engineering applications. Elektron is not publicly traded and its price is approximated by the prices of its components.



Source: Thomson Reuters, Datastream

Elektron is found on turboprop jet engines (Rolls Royce), in Helicopter systems (McDonnell Douglas, Airbus). Moreover, Elektron 43 passed fire tests conducted by US FFA Working Group, removing restrictions of commercial usage in aviation.

Other applications are found in automotive and defense industry. The key player is **Luxfer MEL Technologies** (in 1996, Magnesium Elektron was sold to Luxfer Group).

China

Facts & Figures

China has a prominent role in Magnesium Market. Elaborating more on that, China is one of the largest Magnesium suppliers in the world. The rationale for this is that supply chain dominance ensures control of the price. **Low environmental standards of the previous years and abundant coal as the primary fuel for magnesium production have ensured that China is the lowest cost producer,** ensuring market share dominance. Nevertheless, over the last three years, Chinese authorities put in place strict reforms regarding Magnesium Production in the **13th Five-Year Plan**. This was a result of Magnesium's **vulnerability and the environmental effects of the Pidgeon Process**, the main Magnesium production process in Asia. More precisely:

- When news of a **gas explosion** in Haicheng (Liaoning province) emerged, local authorities immediately agreed on strong measures. The government had issued an order that **all magnesia plants using coal, gas and oil in their production must cease operations at once**. At the start of the year, the Haicheng government also issued **ban on illegal mining of magnesite** in the district, which includes the use of mechanical excavators as opposed to drill and blast techniques.
- In response to a **dynamite ban**, some large-scale miners adopted the use of excavators to extract magnesite ore, at apparently similar rates of recovery to blasting. **Smaller miners were unable to afford excavators.**
- **Government environmental inspectors started patrolling Liaoning** and stoppages started in magnesite mining and magnesia production.
- **Magnesite mining is understood to have completely stopped owing to no explosives**, while some fused magnesia production has been maintained only by those with remaining feedstock ore; overall, **the quality of Chinese fused magnesia production is deteriorating.**
- The majority of Magnesium companies became **state-owned**.
- The document of the **13th Five-Year Plan** stipulated that until the end of 2022, non-coal mines will be comprehensively governed by five mines, especially magnesite, and **the number of mines will be reduced by half**.

All in all, President Xi Jinping is focused on **pollution control** as well as **economic growth**, with implications for the global supply chain in magnesium compounds and many other industrial raw materials.

China

Pidgeon Process

- The Pidgeon Process, developed by Dr. Lloyd Pidgeon, is both an energy and labor-intensive form of thermal reduction.
- In this process, closed-end, nickel-chromium-steel alloy retorts are filled with a mixture of calcined dolomite ore and ferrosilicon, which are heated until magnesium crowns form. **Each cycle takes about 11 hours, requires manually filling and emptying of the vacuum tubes, and uses about 11 tons of raw materials for every one ton of magnesium produced.**
- The reason for the extensive use of the Pidgeon Process is due to the shift in **production to the coal-rich provinces in north-central China where labor and energy costs are significantly lower than in other magnesium producing regions.** However, **the environmental effects** of this process have fueled policy changes, proposed by the Chinese Ministry of environmental protection and the Chinese Ministry of Finance.

USA

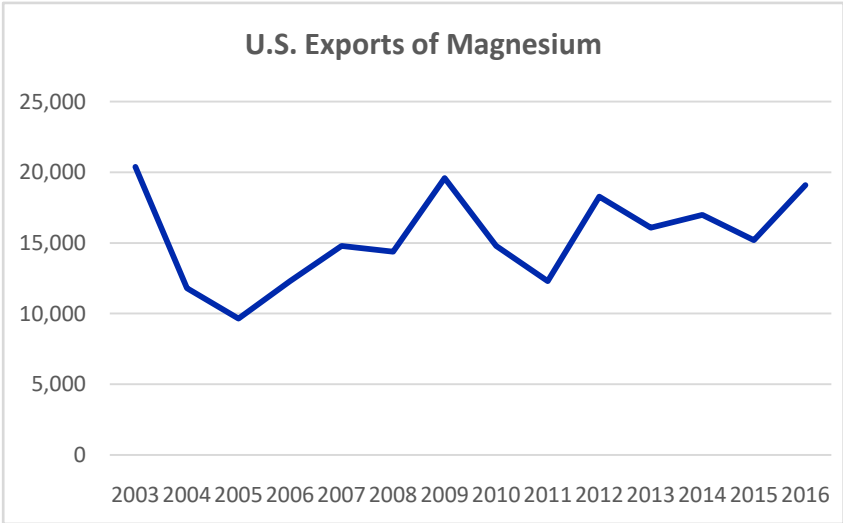
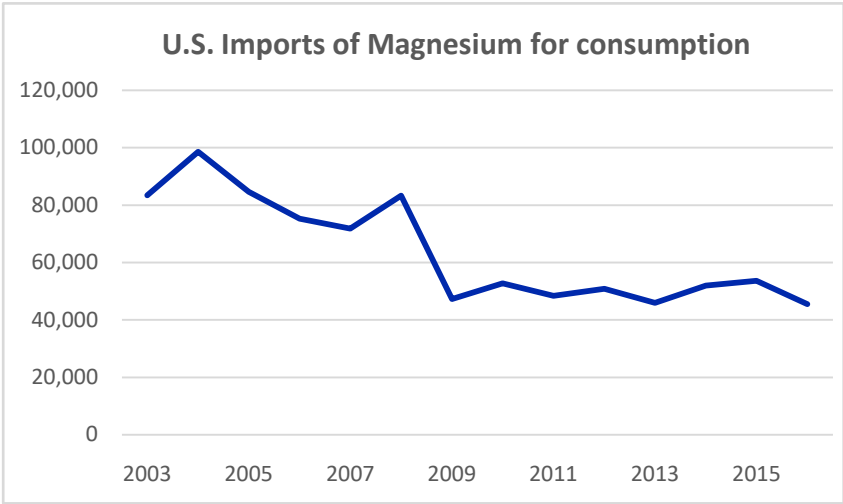
Facts & Figures

- In May, the US Department of the Interior named 35 minerals it **deems critical to national security**. While obvious resources like uranium, titanium and tin made the list, **magnesium was also added**.
- Currently, most of the US magnesium is imported from China; however, the **US does not want to rely solely on supply from the Asian nation**, especially as tariff and tax wars escalate.
- Issues of national security have also been raised regarding the **versatile element** — while magnesium is used in everything from batteries to fertilizers, some is earmarked for the aerospace sector.
- **Implementing green initiatives** globally will take some clever thinking and non-traditional resources. While most people think about green energy in terms of nuclear, wind or solar, there are also ways to look at the concept of building materials with more of a green focus. **Magnesium cement** is one of those materials. One tonne of magnesium cement has the ability to absorb as much as 100 kilograms more CO₂ than it produces and takes 30 percent less energy to produce than other types of cement.
- Between 2009 and 2016 **imports of Magnesium for consumption** ranged between 45,500 and 53,600 metric tons. On the other side, **exports of Magnesium** had a sharp decline from 20,400 (2003) to 9,650 metric tons (2005). After that quantities fluctuated among 12,300 (2011) and 19,600 (2009) metric tons, reaching 19,100 metric tons in 2016.

USA

Facts & Figures

(Continued)



Mag One Products Inc.

Mag one Products Inc. develops and commercializes technologies for the processing and production of magnesium (Mg) metals, and Mg related compounds, byproducts, and co-products from serpentinite tailings. The manufacturing plant base is in southern Quebec, Canada.

Main Operations:

- Production of high-purity MgO, Silica and other saleable co-products, byproducts and compounds.
- Production of 99.9% pure Mg ingots.
- Assembly and sale of magnesium oxide-based structural insulated sheathing panels.
- MagPower's Mg-Air Fuel Cell for emergency power on sea and land.

MagOne Enters in a Technology Agreement with Tech Magnesium

Mag One announced final agreement with **Tech Magnesium**, acquiring its **silicothermic and aluminothermic reduction processes** low cost, environmentally-friendly production of primary magnesium metal.

Mag One has an exclusive, worldwide license to the Tech Mag Technology as well as the **exclusive right** to acquire full ownership of the Tech Mag Technology and all associated intellectual property (IP). Tech Magnesium is an Ontario-based company, founded by Dr. Douglas Zuliani. Tech Mag possesses knowledge of casting, extrusion and other wrought processing methods for magnesium metal and alloys.

Mg provides weight savings of 20-30% over aluminum and 45-50% over other steels in structural applications, although with high operating costs. Producing clean Mg, using MgO from mine tailings as a feedstock for the Mg metal production process is a cost effective and highly innovative solution for the transportation industry.

Contracts with other companies

Mag One Products Inc. entered into a contract **with Dundee Sustainable Technologies Inc.** for the purchase of a 43-101 compliant technical report. In addition, the Company entered into an Option Agreement with **Asbestos Corporation Limited**.

Mag One Products Inc.

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Mg-Air Fuel Cell technology

Mag One Products Inc. has a wholly-owned subsidiary, **MagPower**, which is a global supplier of Magnesium-Air Fuel Cells. Acquired by Mag One in 2016, MagPower has worked over a decade developing its innovative Mg-Air Fuel Cell technology, producing the **MagPower battery**.

How it works: There's a magnesium anode and a gas-diffusion (air) cathode, with saltwater as the electrolyte. Technically, this is called an oxidation-reduction reaction, which occurs between the magnesium and the water. The air cathode "is the current collector" for the system. The air cathode is a membrane that breathes and allows oxygen from the air to enter the cell to facilitate the oxidation-reduction reaction.

Usage:

1. **Disaster-preparedness products**, because the Mg-Air Fuel Cells have a virtually unlimited shelf life (20+ years).
2. **Military applications**, because MagPower is light.
3. **Telecommunication systems**: Long-life redundant backups (continuous system operation at emergency). MagPower is good for low-amper functions, such as recharging systems and lighting systems, not suitable for cars.

Aqua Power Systems (OTCQB:APSI) in Japan, is already commercially producing its magnesium-air fuel cells.

Magnesium Batteries

In his book “The Magnesium Civilization: An Alternative New Source of Energy to Oil” Takashi Yabe proposed the production of Magnesium Batteries. However, even if he conducted thorough research and experiments in collaboration with companies and other academics, his initiative seems to be stagnant.

This was a result of:

- Cost of Magnesium;
- Practical issues. Current battery tech doesn't require to replace parts of the battery. A decent Li-Ion battery will last for years if it's treated well, and is rechargeable.
- The idea still uses a natural source. In their paper T. Yabe, Y. Suzuki and Y. Satoh claimed that current lasers can afford the production of batteries for 208 single person cars X 500km or 13,000 cellphones per year. Additionally, in their plan for Magnesium batteries they stated that extra supply of magnesium is needed.
- Nowadays, research focus on the use of raw solar energy.

Other initiatives:

It would be wrong not to mention the fact that in 2019, we have seen a European initiative regarding Magnesium batteries. The project is **named “E-Magic” the abbreviation for the European Magnesium Interactive Battery Community and is set to receive over €6.7 million from the EU Horizon project.** The aim is to develop new batteries that they are more powerful, cheaper and safer than lithium-ion ones and it could pave the way for the establishment of a competitive battery cell production landscape in Europe. **This could reduce the dominance of Asian battery cell manufacturers.**

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