Magnesium

The main uses of magnesium metal are in alloys with aluminum in order to obtain low density strong structures, used widely in cars and in planes

The main magnesium producing countries used to be:

USA

Canada

China

Russia

Israel

Norway

Australia

Mg

Atomic number	12
Atomic mass	24.31
Colour	Silvery grey metal
Density	1.738 $g.cm^{-3}$ at 20°C 1.58 $g.cm^{-3}$ at 650RC *(l)*
Melting point	650°C
Boiling point	1103°C
Crystal structure	close-packed hexagonal
Heat of combustion	25020 $kJ.kg^{-1}$
Flame temperature	~2800°C
Heat of fusion	368 $kJ.kg^{-1}$
Heat of vaporisation	5272 $kJ.kg^{-1}$
Specific heat	1025 $J.K^{-1}.kg$ at 20°C
Vapour pressure	20 Pa at 527°C *(s)* 360 Pa at 650°C *(l)* 1400 Pa at 727°C

Magnesium and magnesium alloys

Architects forum

- *Magnesium* (Mg) is the lightest metal.
- Alloys are used in structural and non-structural applications.
- Typical uses of magnesium alloys are aircraft and missile components.
- Also has good vibration-damping characteristics.
- Compared with aluminum, magnesium is approximately two-thirds of its weight.

PROPERTIES OF MAGNESIUM :
Specific gravity 1.74
Melts at 651°C
Boiling Point is 1110°C
It is silver white processing high lustre

Properties and Typical Forms

	Composition (%)				
Alloy	Al	Zn	Mn	Zr	Typical forms
AZ31B	3.0	1.0	0.2		Extrusions. Sheet and plates.
AZ80A	8.5	0.5	0.2		Extrusions and forgings.
HK31A[a]			0.7		Sheet and plates.
ZK60A		5.7		0.55	Extrusions and forgings.

USES

- Magnesium is a commercially important metal with many uses. It is only two thirds as dense as aluminum. It is easily machined, cast, forged, and welded. It is used extensively in alloys, chiefly with aluminum and zinc, and with manganese. Magnesium alloys were used as early as 1910 in Germany. Early structural uses of magnesium alloys were in aircraft fuselages, engine parts, and wheels. They are now also used in jet-engine parts, rockets and missiles, luggage frames, portable power tools, and cameras and optical instruments. Duralumin and magnalium are alloys of magnesium. The metal is also used in pyrotechnics, especially in incendiary bombs, signals, and flares, and as a fuse for thermite. It is used in photographic flashbulbs and is added to some rocket and missile fuels. It is used in the preparation of malleable cast iron. An important use is in preventing the corrosion of iron and steel, as in pipelines and ship bottoms. For this purpose a magnesium plate is connected electrically to the iron. The rapid oxidation of the magnesium prevents the slower oxidation and corrosion of the iron.

MAGNESIUM METAL END-USE STATISTICS[1]
U.S. GEOLOGICAL SURVEY
[Metric tons]
Last modification: September 15, 2005

Year	Cans and containers	Chemicals	Iron and steel desulfurization	Iron and steel foundries	Machinery	Nonferrous metal production	Transportation	Other	Apparent consumption
1975	12,000	10,000		9,000	38,000	9,000	38,000	4,000	120,000
1976	12,000	11,000		8,000	33,000	6,000	32,000	4,000	106,000
1977	14,000	11,000		8,000	33,000	5,000	35,000	3,000	109,000
1978	16,000	10,000		8,000	36,000	6,000	37,000	5,000	118,000
1979	17,000	10,000		5,000	35,000	8,000	40,000	6,000	121,000
1980	19,000	7,000		5,000	34,000	10,000	36,000	6,000	117,000
1981	20,000	8,000		5,000	34,000	13,000	38,000	6,000	124,000
1982	17,000	6,000		4,000	33,000	7,000	25,000	4,000	96,000
1983	20,000	7,000		3,000	35,000	6,000	32,000	6,000	109,000
1984	23,000	8,000	10,000	4,000	29,000	9,000	36,000	8,000	127,000
1985	23,000	5,000	12,000	3,000	22,000	12,000	38,000	8,000	123,000
1986	22,000	3,000	12,000	3,000	27,000	9,000	33,000	8,000	117,000
1987	39,000	2,000	13,000	2,000	19,000	5,000	38,000	7,000	125,000
1988	39,000	1,000	15,000	3,000	20,000	11,000	38,000	11,000	138,000
1989	42,000	1,000	15,000	2,000	17,000	12,000	36,000	9,000	134,000
1990	46,000	1,000	16,000	1,000	20,000	11,000	38,000	13,000	146,000
1991	42,000	1,000	13,000	1,000	21,000	7,000	37,000	12,000	134,000
1992	40,000	1,000	20,000	2,000	25,000	9,000	34,000	11,000	142,000
1993	38,000	1,000	19,000	2,000	20,000	10,000	47,000	11,000	148,000
1994	48,000	1,000	21,000	5,000	16,000	2,000	43,000	12,000	148,000
1995	50,000	1,000	21,000	5,000	18,000	2,000	55,000	15,000	167,000
1996	45,000	1,000	21,000	5,000	18,000	3,000	53,000	18,000	164,000
1997	45,000	1,000	25,000	5,000	23,000	3,000	64,000	19,000	185,000
1998	43,000	1,000	26,000	4,000	22,000	3,000	65,000	20,000	184,000
1999	43,000	1,000	17,000	3,000	23,000	1,000	70,000	21,000	179,000
2000	37,000	1,000	22,000	3,000	25,000	2,000	53,000	17,000	160,000
2001	30,000	1,000	16,000	3,000	20,000	1,000	38,000	11,000	120,000
2002	26,000	1,000	14,000	4,000	17,000	2,000	34,000	12,000	110,000
2003	25,000	1,000	15,000	4,000	23,000	2,000	40,000	10,000	120,000

[1]Compiled by G.R. Matos and D.A. Kramer.

Table 1 - Common magnesium alloys

Alloy Designation	Alloying Additives	Uses	Reasons for use
AZ91	9.0 % Al 0.7 % Zn 0.13 % Mn	General casting alloy	Good castability, good mechanical properties at T<150°C.
AM60	6.0 % Al 0.15% Mn	High pressure die casting alloy	Greater toughness and ductility than AZ91, slightly lower strength. Often preferred for automotive structural applications.
AZ31	3.0 % Al 1.0 % Zn 0.2 % Mn	Wrought magnesium products	Good extrusion alloy.
ZE41	4.2 % Zn 1.2 % RE 0.7 % Zr	Specialist casting alloy	Rare earth addition improves creep strength at elevated temperatures. Pressure tight.
AS41	4.2 % Al 1.0 % Si	General casting alloy	Better creep resistance than AZ91 at elevated temperatures but lower strength.

Magnesium role in the plant

- Magnesium is an essential component of the chlorophyll molecule, with each molecule containing 6.7 % magnesium.
- Magnesium also acts as a phosphorus carrier in plants. It is necessary for cell division and protein formation. Phosphorus uptake could not occur without magnesium and vice versa
- Magnesium is essential for phosphate metabolism, plant respiration and the activation of several enzyme systems.

ICL Fertilizers

Magnesium uptake by crops

CROP	YIELD (t/ha)	Mg UPTAKE (kg MgO/ha) *
Corn	6.3	37
Tomato	40	20
Banana	66	80
Potato	30	20
Rice	5.0	23
Cotton	2.5	40
Sugarbeet	10	15
Oilpalm	24	98
Groundnut	1.0	41

Source: IFA Fertilizer Manual
* = Multiply by 0.603 for kg Mg/ha

quicK-Mg Typical Analysis

Potassium	15 %	K_2O	(min)
Magnesium	13 %	MgO	(min)
Chloride	39 %	Cl	
Bromine	0.4 %	Br	
KCl	24 %		
$MgCl_2$	33 %		
$CaCl_2$	0.4 %		
NaCl	4 %		(max)

- $MgCl_2$/KCl (molar ratio): 1.1
- Moisture: 0.5 %
- Insolubles: 0.05 %
- pH (solution 10%) : 6.75

Production figures

*Average annual world primary magnesium production (10^3 t)**

Country	1963-1967	1983-1987
Brazil		3.4
Canada	8.0	7.0
China. People's Republic of	0.9	7.0
France	2.6	13.2
Italy	6.2	9.3
Japan	4.2	7.6
Norway	24.7	48.2
Soviet Union	34.7	87.0
United Kingdom	4.7	
United States	75.3	127.2
Yugoslavia		4.5
World total	*161.3*	*314.4*

** As reported by the U.S. Bureau of Mines, Department of the Interior.*

TABLE 8

MAGNESIUM: PRIMARY WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country	2000	2001	2002	2003	2004[e]
Brazil[e]	5,700	5,500	6,000	6,000	6,000
Canada[e, 3]	80,000 [r]	83,000 [r]	88,000 [r]	54,000 [r]	54,000
China[e]	190,000	200,000	250,000	340,000	426,000
France[e]	16,500	4,000	--	--	--
Israel	31,700	34,000	28,000 [r]	28,000 [r, e]	28,000
Kazakhstan[e]	10,380 [4]	16,000	18,000	14,000	18,000
Norway[e]	41,400 [4]	36,000	10,000	--	--
Russia[e, 3]	45,000	48,000	50,000	52,000	50,000
Serbia and Montenegro	1,270 [r]	1,630	1,695	1,600 [e]	1,600
Ukraine[e]	3	3	3	3	3
United States	W	W	W	W	W
Total	422,000 [r]	428,000 [r]	452,000 [r]	496,000 [r]	584,000

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

-- Zero.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

MAGNESIUM: ESTIMATED PRIMARY WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country	2004	2005	2006	2007	2008
Brazil	6,000	6,000	6,000	18,000	15,000
Canada[3]	54,000	50,000	65,000	16,300	--
China	442,000	470,000	520,000	625,000 [r]	559,000
Israel	28,000	27,853 [4]	24,581 [4]	29,618 [r, 4]	35,000
Kazakhstan	18,000	20,000	21,000	21,000	21,000
Russia[3]	45,000	45,000	35,000	37,000	37,000
Serbia	1,600 [5]	1,500 [5]	1,500	1,500	1,500
Ukraine	3	2,000	2,200	2,500	2,500
United States	W	W	W	W	W
Total	595,000	622,000	675,000	751,000 [r]	671,000

MG

Years 2010
(000's of Tons)

	2010
USA	45(b)
Brazil	16(a)
Canada	0(a)
China	654(d)
France	0(a)
Israel	30(a)
Kazakhstan	20(a)
Norway	0(a)
Russia	40(a)
Ukraine	2(a)
Serbia	2(a)
Total	809
Annual Change	+24%

World Primary Production and Reserves: Mg

	Primary production	
	2010	2011[e]
United States	W	W
Brazil	16	16
China	654	670
Israel	25	28
Kazakhstan	21	20
Russia	37	37
Serbia	2	2
Ukraine	2	2
World total[6] (rounded)	757	780

World Primary Production and Reserves:

	Primary production	
	2012	2013[e]
United States	W	W
Brazil	16	16
China	698	800
Israel	27	28
Kazakhstan	21	21
Korea, Republic of	3	9
Malaysia	5	5
Russia	29	30
Serbia	2	2
Ukraine	2	2
World total[6] (rounded)	802	910

WORLD ANNUAL PRIMARY MAGNESIUM PRODUCTION CAPACITY, DECEMBER 31, 2013[1]

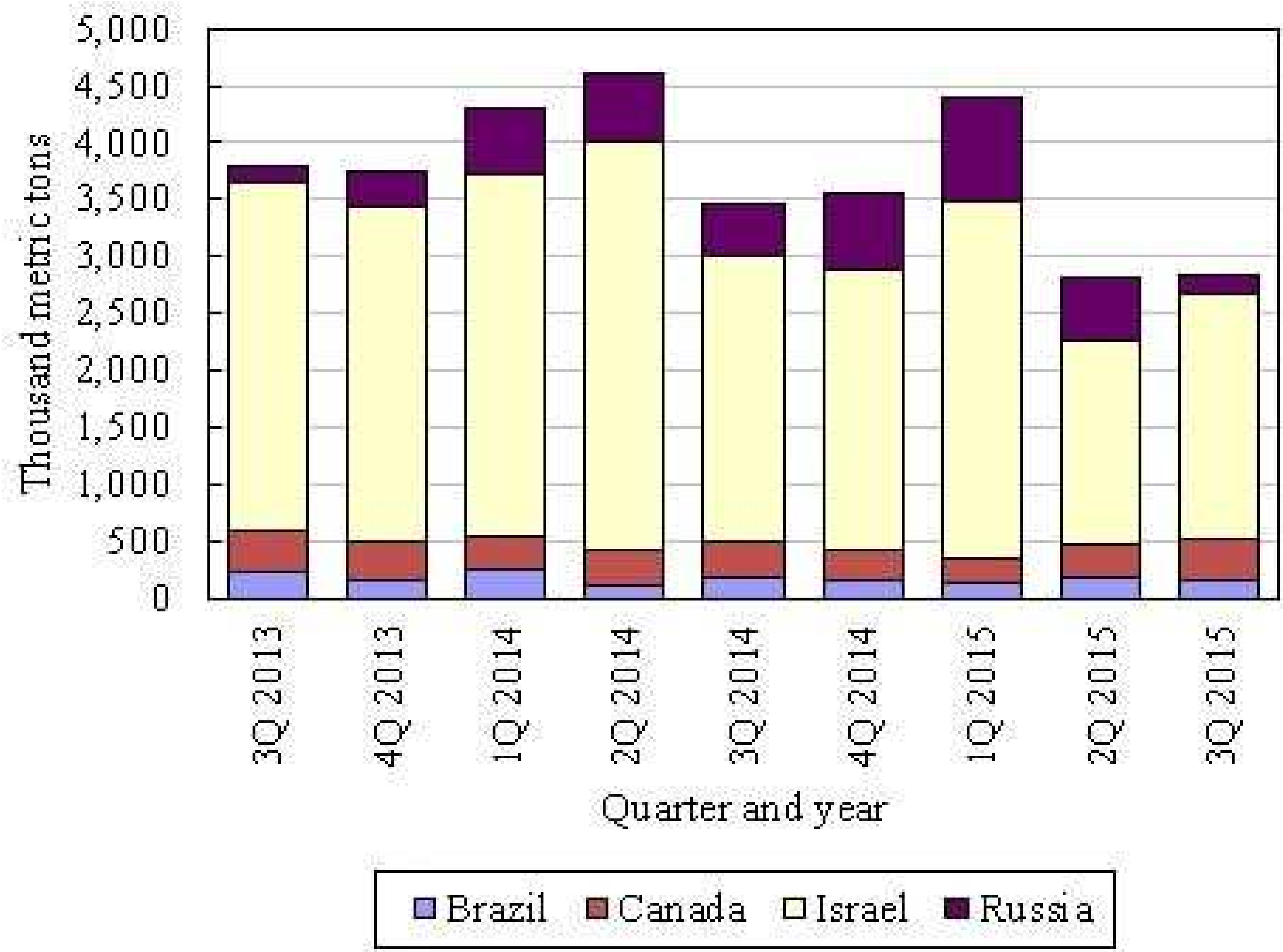
(Metric tons)

Country	Capacity
Brazil	22,000
China	1,540,000
India	900
Israel	34,000
Kazakhstan	30,000
Korea, Republic of	10,000
Malaysia	15,000
Russia	80,000
Serbia	6,000
Ukraine	22,000
United States	63,500
Total	1,820,000

[1] Includes capacity at operating plants as well as at plants on standby basis.

World Primary Production and Reserves:

	Primary production	
	2013	2014[e]
United States	W	W
Brazil	16	16
China	770	800
Israel	28	30
Kazakhstan	23	21
Korea, Republic of	8	10
Malaysia	1	0
Russia	32	28
World total[5] (rounded)	878	907


5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Thousand metric tons
3Q 2013
4Q 2013
1Q 2014
2Q 2014
3Q 2014
4Q 2014
1Q 2015
2Q 2015
3Q 2015
Quarter and year
Brazil
Canada
Israel
Russia

MAGNESIUM RECOVERED FROM SCRAP PROCESSED IN THE UNITED STATES, BY KIND OF SCRAP AND FORM OF RECOVERY[1]

(Metric tons)

	2007	2008
KIND OF SCRAP		
New scrap:		
Magnesium-base	16,600	14,400
Aluminum-base	43,200 r	39,000
Total	59,900 r	53,400
Old scrap:		
Magnesium-base	807	1,210
Aluminum-base	22,700 r	21,100
Total	23,500 r	22,300
Grand total	83,300 r	75,700
FORM OF RECOVERY		
Magnesium alloy ingot[2]	W	W
Magnesium alloy castings	484	385
Magnesium alloy shapes	262	175
Aluminum alloys	66,300 r	60,500
Other[3]	16,300	14,600
Total	83,300 r	75,700

r

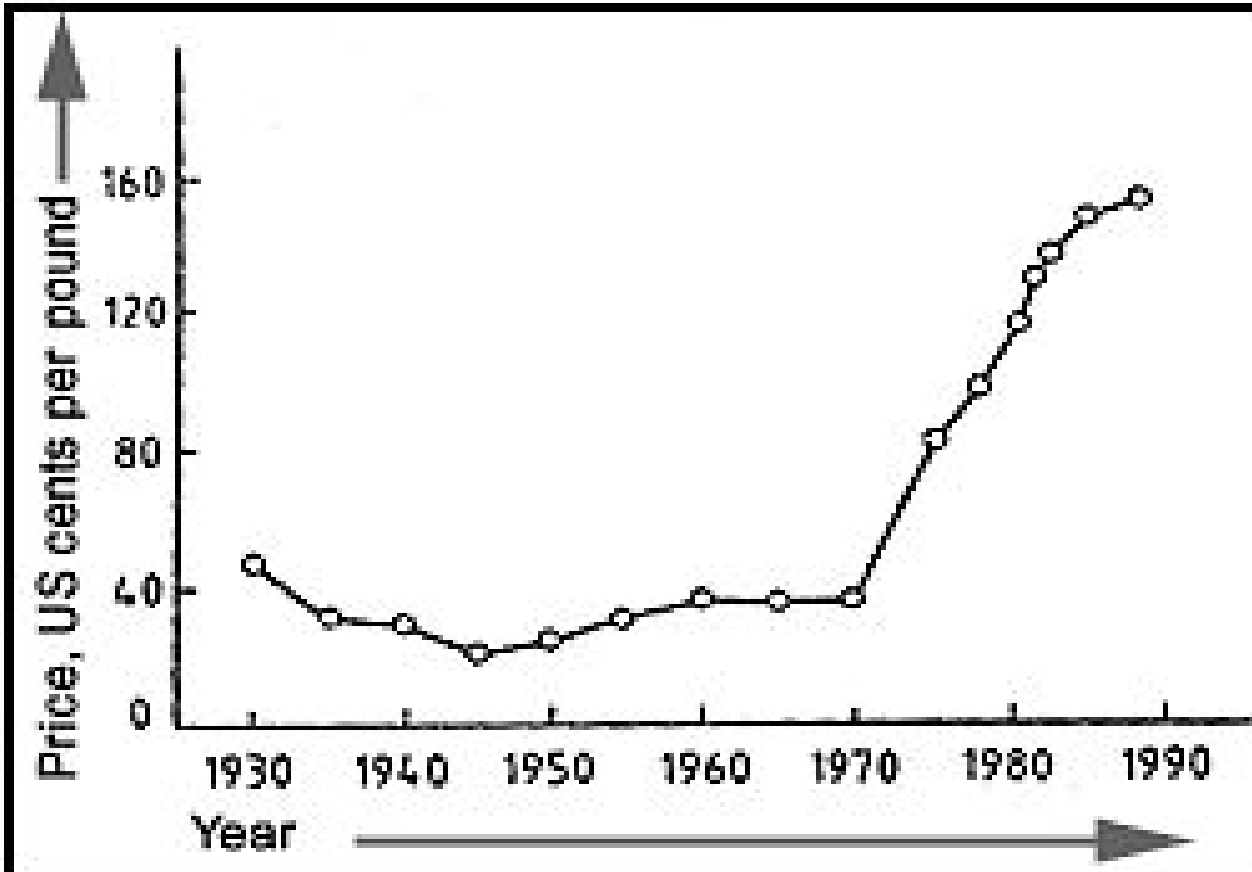
Domestic Production and Use: In 2013, magnesium was produced by one company at a 63,500-ton-per-year plant in Utah by an electrolytic process that recovered magnesium from brines from the Great Salt Lake. The leading domestic use for primary magnesium was as a reducing agent for the production of titanium and other metals, accounting for 34% of primary metal use. Use as a constituent of aluminum-base alloys that were used for packaging, transportation, and other applications accounted for 33% of primary magnesium consumption. Structural uses of magnesium (castings and wrought products) accounted for 18% of primary metal consumption, desulfurization of iron and steel, 11%, and other uses, 4%.

Salient Statistics—United States:	**2009**	**2010**	**2011**	**2012**	**2013[e]**
Production:					
Primary	W	W	W	W	W
Secondary (new and old scrap)	69	72	67	77	80
Imports for consumption	47	53	48	47	45
Exports	20	15	12	17	18
Consumption:					
Reported, primary	53	57	81	72	75
Apparent	[2]80	[2]100	[3]110	[3]110	[3]110
Price, yearend:					
U.S. spot Western, dollars per pound, average	2.30	2.43	2.13	2.20	2.13
China free market, dollars per metric ton, average	2,950	2,925	3,025	3,170	2,590
Stocks, producer and consumer, yearend	W	W	W	W	W
Employment, number[e]	400	400	400	420	420
Net import reliance[4] as a percentage of apparent consumption	33	38	33	27	25

Recycling: In 2013, about 25,000 tons of secondary magnesium was recovered from old scrap and 55,000 tons were recovered from new scrap.

Import Sources (2009–12): Israel, 33%; Canada, 25%; China, 8%; and other, 34%.

Prices



Magnesium Prices

Primary Magnesium Prices

CRU Group

Clark & Marron

Chinese Magnesium Prices

CRU Group

Clark & Marron

TABLE 4

YEAREND MAGNESIUM PRICES

Source		2006	2007
Platts Metals Week:			
U.S. spot Western	dollars per pound	1.35-1.45	2.00-2.50
U.S. spot dealer import	do.	1.35-1.42	1.80-2.30
European free market	dollars per metric ton	2,000-2,100	3,900-4,200
Metal Bulletin:			
European free market	do.	2,050-2,150	4,100-4,500
China free market	do.	2,020-2,080	4,200-4,900

do. Ditto.

YEAREND MAGNESIUM PRICES

Source		2007	2008
Platts Metals Week:			
U.S. spot dealer import	dollars per pound	1.80–2.30	3.00–3.25
U.S. spot Western	do.	2.00–2.50	3.05–3.25
China	dollars per metric ton	NA	2,900–3,000
European free market	do.	3,900–4,200	2,900–3,000
Metal Bulletin:			
China free market	do.	4,200–4,900	2,800
European free market	do.	4,100–4,500	2,800–2,900

do. Ditto. NA Not available.

MAGNESIUM PRICES, FOURTH QUARTER 2013

		Beginning of quarter	End of quarter
U.S. spot dealer import	dollars per pound	1.85–1.95	1.90–1.95
U.S. spot Western	do.	2.10–2.15	2.10–2.15
China	dollars per metric ton	2,550–2,600	2,600–2,630
European free market	do.	2,625–2,725	2,700–2,800

do. Ditto.

Source: Platts Metals Week.


Magnesium Price
2.41 USD/kg
30 Nov '14
Magnesium Price (USD/kg)
2.95
2.9
2.85
2.8
2.75
2.7
2.65
2.6
2.55
2.5
2.45
2.4
2.35
Dec 1 2013
Jan 30 2014
Mar 31 2014
May 30 2014
Jul 29 2014
Sep 27 2014
Nov 26 2014
InfoMine.com

PRODUCTION METHODS

Sources

Sea water and lake brine $MgCl_2/MgSO_4$ (0.13 to 0.8%)

Carnalite $MgCl_2KCl.6H_2O$ (8.6%)

Dolomite $MgCO_3$ $CaCO_3$ (13 %)

Serpentine $3MgO$ SiO_2 $2H_2O$ (24%)

Magnesite $MgCO_3$ (28%)

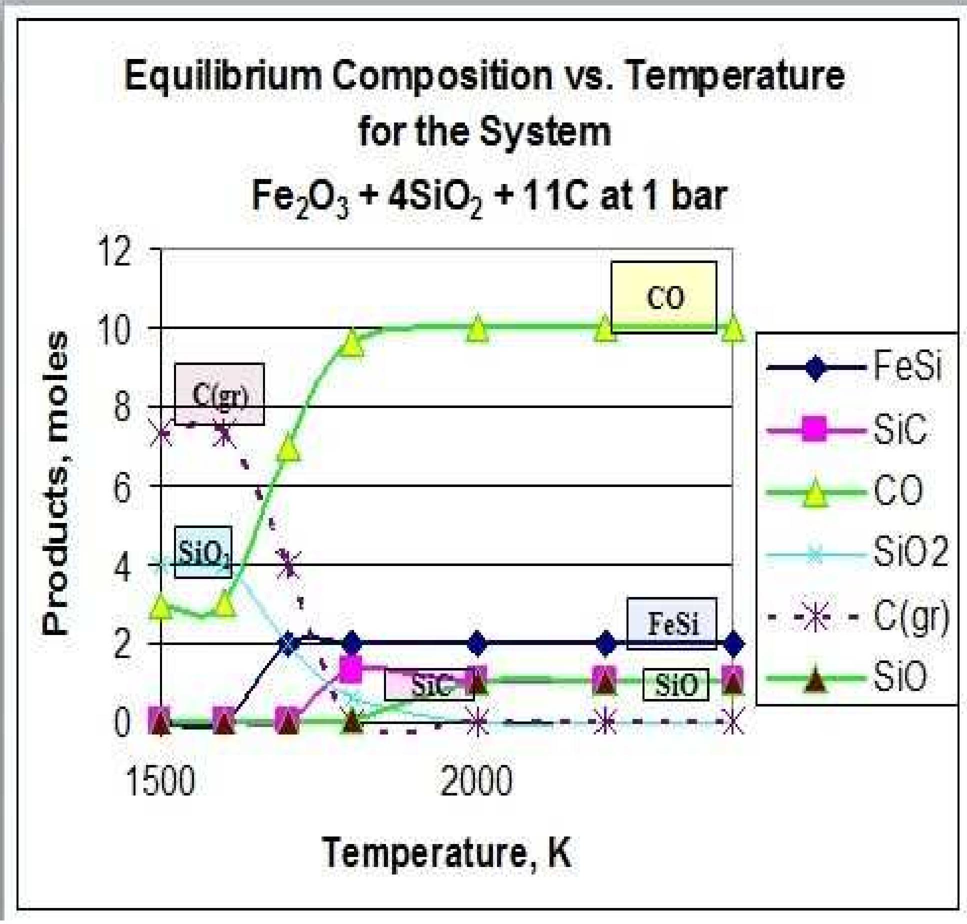
1808, Metallic magnesium was first isolated by Sir Humpry Davy via electrolysis of anhydrous magnesium chloride with a mercury cathode.
1828, Magnesium was extracted by Bussy. He produced magnesium chloride by chlorinating magnesium oxide with chlorine and carbon (as in the later IG-Farben process). The magnesium chloride was reduced with metallic potassium.
1833, Michael Faraday was the first to electrolyse dehydrated liquid magnesium chloride to produce liquid magnesium and chlorine gas.
1852-1915, Robert Bunsen prepared and electrolysed pure anhydrous salt, and the first industrial production of magnesium metal using the Bunsen Cell began in Hemlingen, Germany in 1886. In 1896 this plant was taken over by Griesheim-Electron, later IG-Farben Industrie (1925), and was the sole producer of magnesium until 1915.
1915, During the following decades several plants started production in France (Claveaux, Jarrie, Isere, Saint Auban) and in Germany (Bitterfeld, Stassfurth, Aken), all based on IG-Farben technology. None of these plants are in operation today.
1918, Shawinigan Electro Metals Co. in Montreal, Canada, was built, being the largest magnesium producer in North America, with a daily output of 300-400 kg. The production was based on technology similar to the IG-Farben technology and its patents were sold to IG-Farben in 1920. The general manager was a Norwegian, Christian Backer.

1. Silicothermic production routes

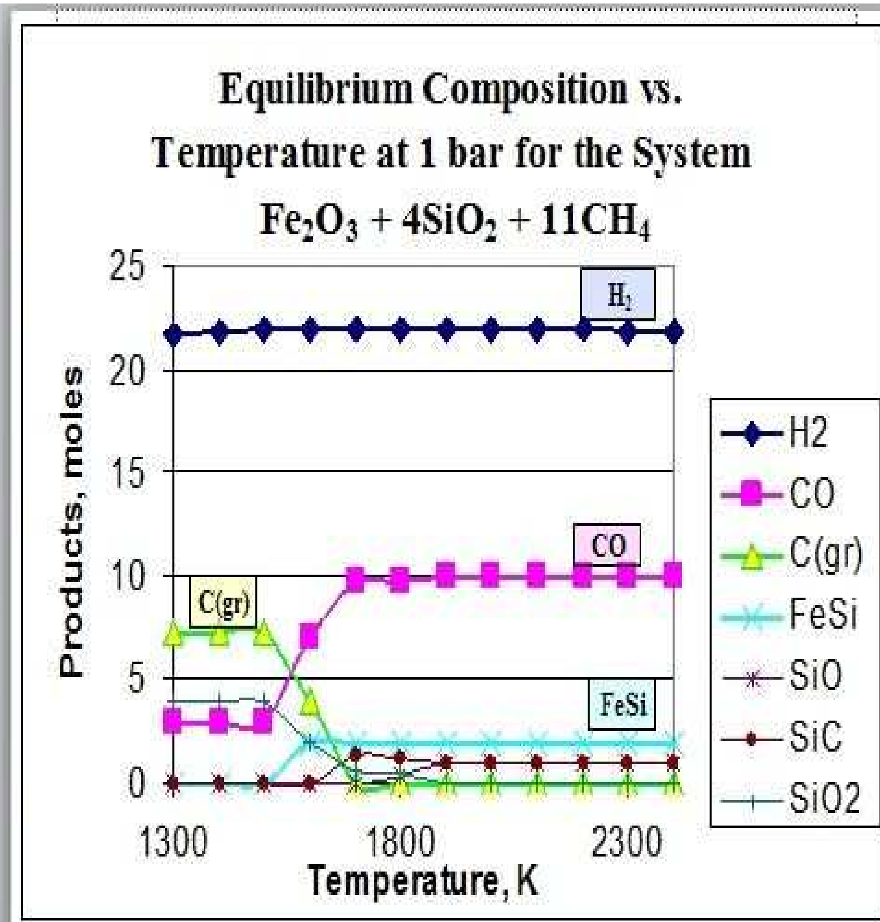
Includes the Pidgeon process, Magnetherm process, Bolzano process

These rely on the use of ferrosilicon to reduce magnesium oxide in a molten slag at temperatures of 1200°C-1600°C under a reduced gas pressure above the slag to produce a magnesium vapour. This vapour is condensed at a location removed from the main furnace. The crowns of condensed magnesium are then re-melted, refined and cast.

These production routes are capable of producing magnesium of purity as high as 99.95%.



Equilibrium Composition vs. Temperature for the System
$Fe_2O_3 + 4SiO_2 + 11C$ at 1 bar
Products, moles
Temperature, K
12
10
8
6
4
2
0
1500
2000
CO
C(gr)
SiO2
FeSi
SiC
SiO
FeSi
SiC
CO
SiO2
C(gr)
SiO



Equilibrium Composition vs. Temperature at 1 bar for the System
$Fe_2O_3 + 4SiO_2 + 11CH_4$
Products, moles
Temperature, K
25
20
15
10
5
0
1300
1800
2300
H_2
CO
C(gr)
FeSi
H2
CO
C(gr)
FeSi
SiO
SiC
SiO2

The **Pidgeon process** is one of the methods of magnesium metal production, via a silicothermic reduction. Practical production requires roughly 35-40 MWh/ton of metal produced, which is on par with the molten salt electrolytic methods of production, though above the 7 MWh/ton theoretical minimum.

Chemistry

The basic chemical equations of this process are:

$Si(s) + MgO(s) \leftrightarrow SiO_2(s) + Mg(g)$ (high temperature, distillation boiling zone)

$Mg(g) \leftrightarrow Mg(liq, s)$ (low temperature, distillation condensing zone)

Silicon and magnesia react to produce silica and magnesium.

Though, according to Ellingham diagrams, this reaction is thermodynamically unfavorable, in accordance with the Le Chatelier's principle of equilibriums, it can still be driven to the right by continuous supply of heat, and by removing one of the products, namely distilling out the magnesium vapor. The atmospheric pressure boiling point of magnesium metal is very low, only 1090 °C, and even lower in vacuum. Vacuum is preferred, because it allows lower temperatures.

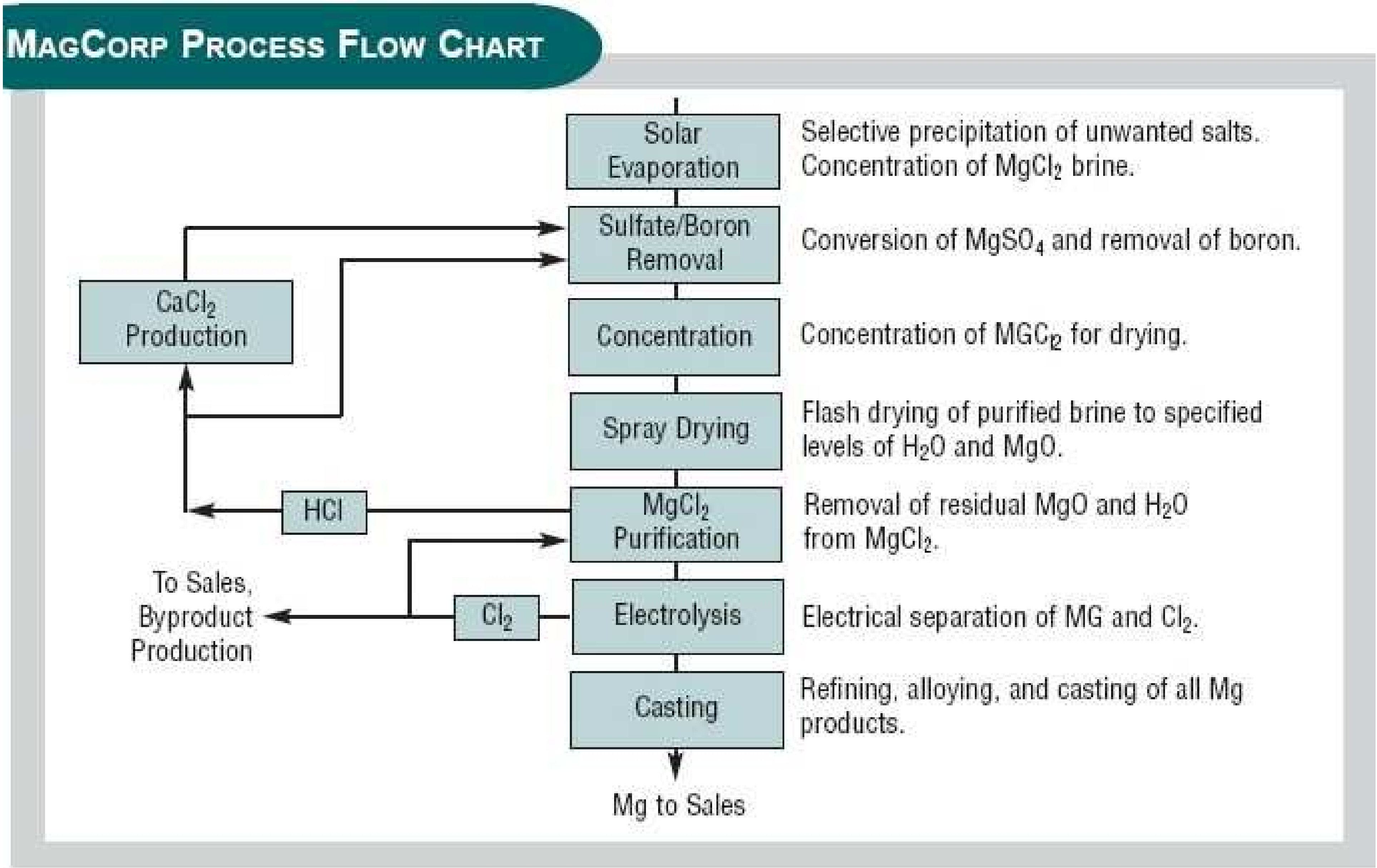
The most commonly used and cheapest form of silicon is as a ferrosilicon alloy. The iron from the alloy is but a spectator in the reactions.

2. Electrolytic processes

Commercial magnesium electrolysis is conducted in a chloride melt of mixed alkali metals at temperatures usually below 700C. The feed to the electrolysis process is either anhydrous magnesium chloride, $MgCl_2.KCl$ produced from dehydration of carnallite or partially dehydrated magnesium chloride.

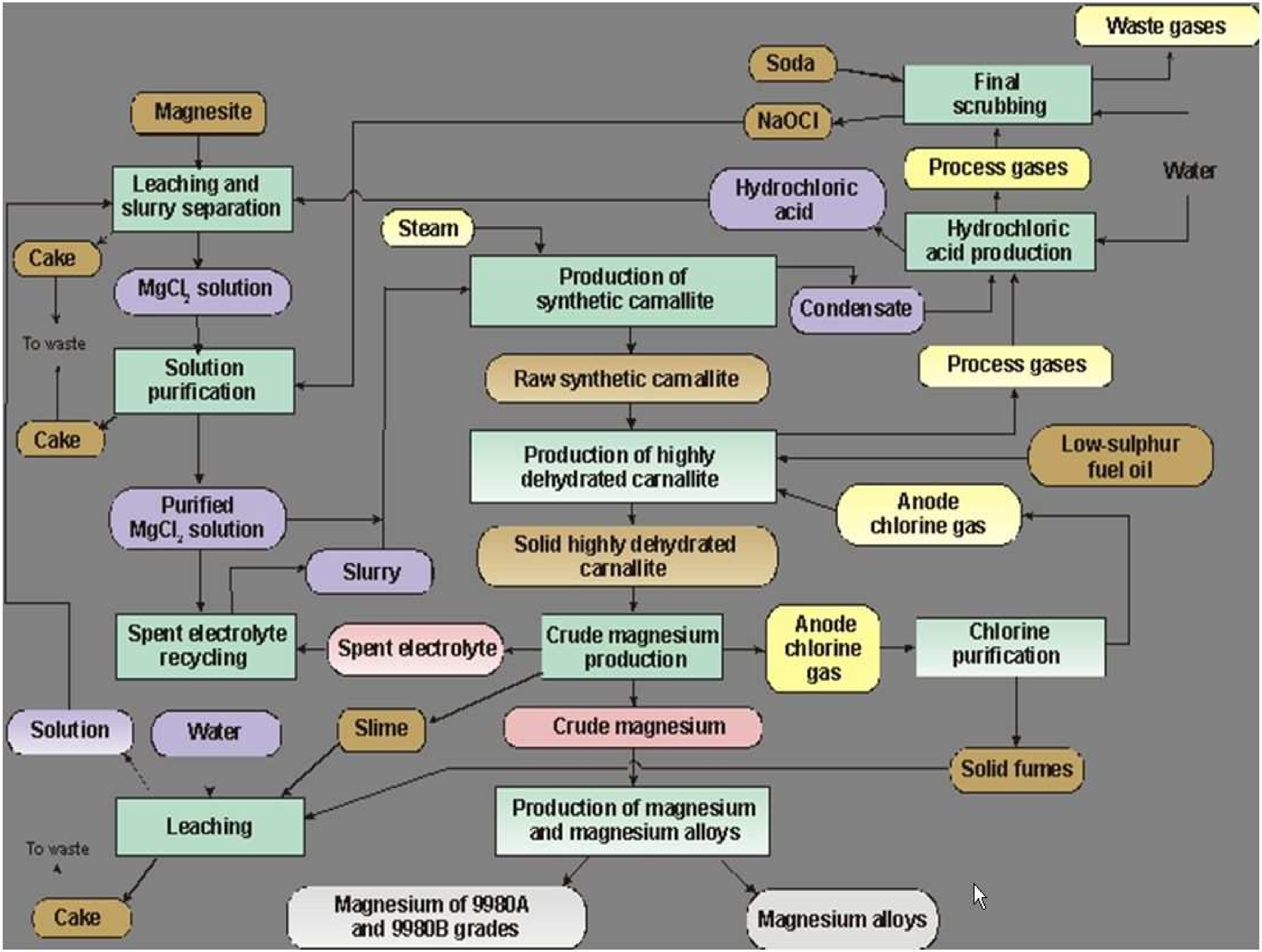
Pure anhydrous magnesium chloride is probably the preferred feed material. However, the production of magnesium chloride with low levels of magnesium oxide is quite difficult, due the hygroscopic nature of magnesium chloride.

Unlike the high temperature production routes, the electrolysis processes have difficulty achieving metal purity greater than about 99.8%. This is due largely to the presence of 300-400 ppm of iron due to contact with steel components in the electrolysis cell. However, for production of greater than 10,000 tonnes per annum, the electrolysis process develops cost benefits over the high temperature processes.


MagCorp Process Flow Chart
Solar Evaporation
Selective precipitation of unwanted salts. Concentration of MgCl2 brine.
Sulfate/Boron Removal
Conversion of MgSO4 and removal of boron.
CaCl2 Production
Concentration
Concentration of MGC12 for drying.
Spray Drying
Flash drying of purified brine to specified levels of H2O and MgO.
HCl
MgCl2 Purification
Removal of residual MgO and H2O from MgCl2.
To Sales, Byproduct Production
Cl2
Electrolysis
Electrical separation of MG and Cl2.
Casting
Refining, alloying, and casting of all Mg products.
Mg to Sales

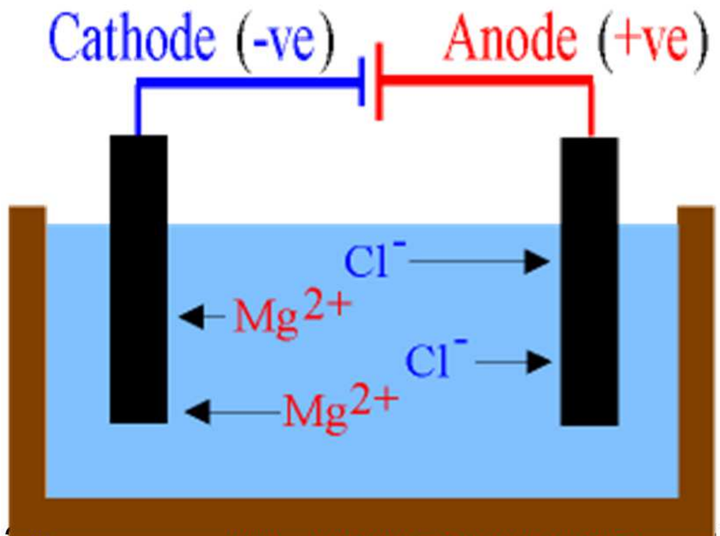
Composition and properties of electrolytes

Electrolyte	Composition, wt%	mp, °C	Properties at 700°C			
			Density kg m3	Conductivity, S m	Viscosity, mPa s	Surface tension, mN m
Potassium	5-12 $MgCl_2$ 70-78 KCl 12-16 NaCl	650	1600	183	1.35	104
Sodium-potassium	10 $MgCl_2$ 50 NaCl 40 KCl	625	1625	200	1.58	108
Sodium-calcium	8-16 $MgCl_2$ 30-40 $CaCl_2$ 35-45 NaCl 0-10 KCl	575	1780	200	2.22	110
Lithium-potassium	10 $MgCl_2$ 70 LiCl 20 KCl	550	1500	420	1.20	
Lithium-sodium	10 $MgCl_2$ 70LiCl 20 NaCl	560	1521	488		
Sodium-barium	10 $MgCl_2$ 20 $BaCl_2$ 50 NaCl 20 KCl	686	1800	217	1.70	110
Magnesium		649	1580			


Waste gases
Soda
Final scrubbing
Magnesite
NaOCl
Process gases
Water
Leaching and slurry separation
Hydrochloric acid
Steam
Hydrochloric acid production
Cake
Production of synthetic carnallite
$MgCl_2$ solution
Condensate
To waste
Solution purification
Raw synthetic carnallite
Process gases
Cake
Production of highly dehydrated carnallite
Low-sulphur fuel oil
Anode chlorine gas
Purified $MgCl_2$ solution
Solid highly dehydrated carnallite
Slurry
Spent electrolyte recycling
Spent electrolyte
Crude magnesium production
Anode chlorine gas
Chlorine purification
Solution
Water
Slime
Crude magnesium
Solid fumes
Leaching
Production of magnesium and magnesium alloys
To waste
Cake
Magnesium of 9980A and 9980B grades
Magnesium alloys

Electrolysis of Magnesium Chloride.

Magnesium chloride must be heated until it is molten
before it will conduct electricity.
Electrolysis separates the molten ionic compound into its elements.



Mg^{2+} + $2e^-$ → Mg (magnesium metal at the (-)cathode).

$2Cl^-$ - $2e^-$ → Cl_2 (chlorine gas at the (+)anode).

Magnesium ions gain electrons (reduction) to form magnesium atoms.

Chloride ions lose electrons (oxidation) to form chlorine atoms.

Refining of magnesium

Magnesium is one of the metals like aluminium where very little post refining of the metal is conducted, other than the removal of physical impurities such as electrolyte and oxide (although some processes are available). The high temperature processes rely on the high vapour pressure of magnesium to transport high purity magnesium vapour. The electrolysis processes all rely on chemically clean feed materials and the operation of the electrolysis cells in a regime that favours magnesium reduction over the reduction of other alkali metal chlorides.

Handling of molten magnesium

Molten magnesium burns in air to produce a brilliant white light and large amounts of heat. Many people who did high school chemistry remember burning magnesium ribbon. This propensity to rapidly oxidise is one of the reasons that magnesium has not had the wider acceptance as a structural material as aluminium.

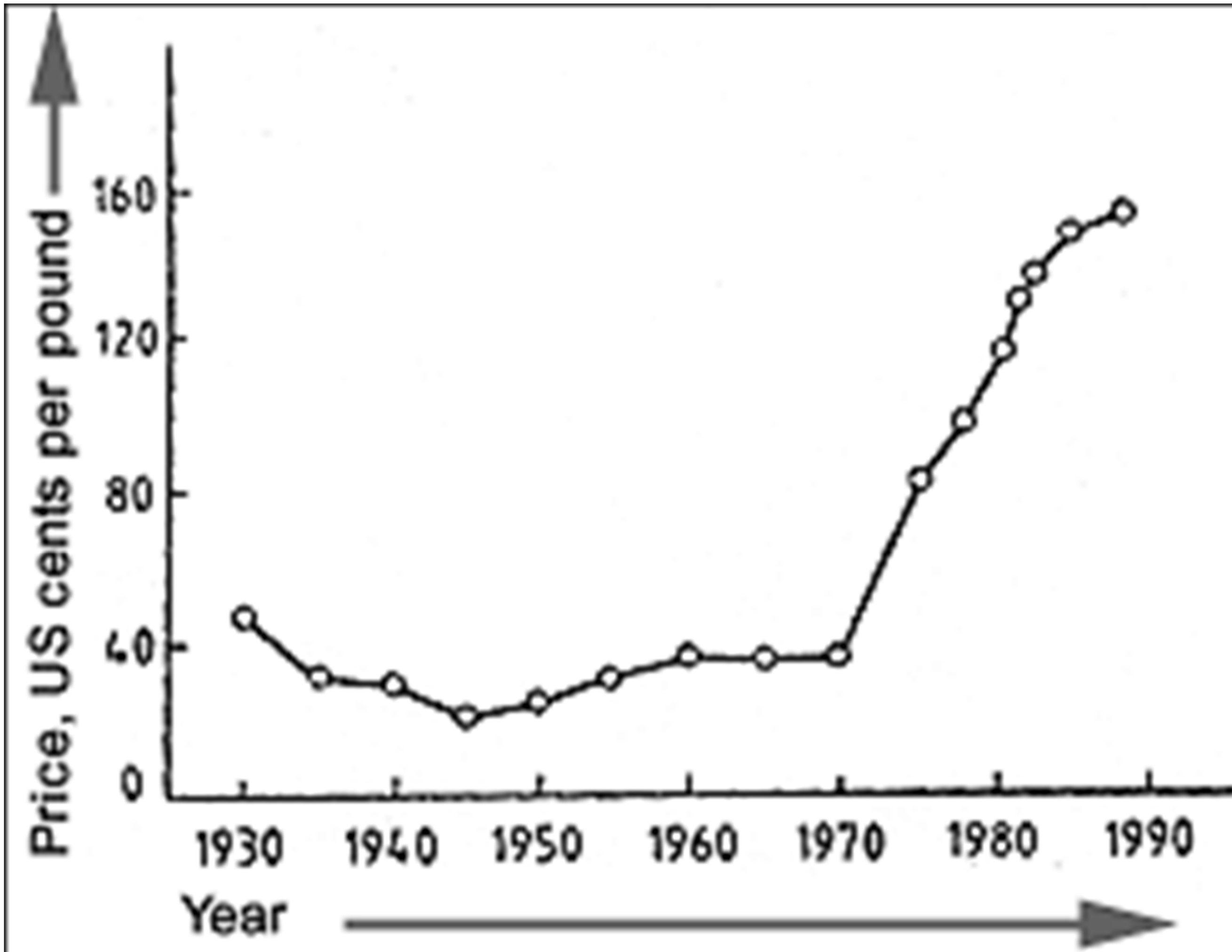
Molten magnesium has been traditionally protected by the use of alkali metal fluxes which melt and form a liquid covering that restricts access of the air to the metal. Alternatively, sulphur dioxide has been used. Whilst both of these methods are effective, both result in significant corrosion of surrounding equipment and present a health hazard to operators.

In recent years, the use of dilute mixtures of sulphur hexafluoride in either dry air and/or carbon dioxide have become the industry norm. Sulphur hexafluoride is colourless, odourless and non-toxic gas. It does result in minor corrosion problems if used in the wrong concentrations and in recent years has come under attention as a greenhouse gas.

One redeeming feature of magnesium is the ability to contain it in molten form in steel containers. The low melting point of 650ºC (even lower for most commercial alloys) and the limited solubility of iron in magnesium at temperatures below 700ºC (about 400 ppm) means that magnesium can be contained in heated steel vessels and pumped in a manner like water, using heated steel pipes.

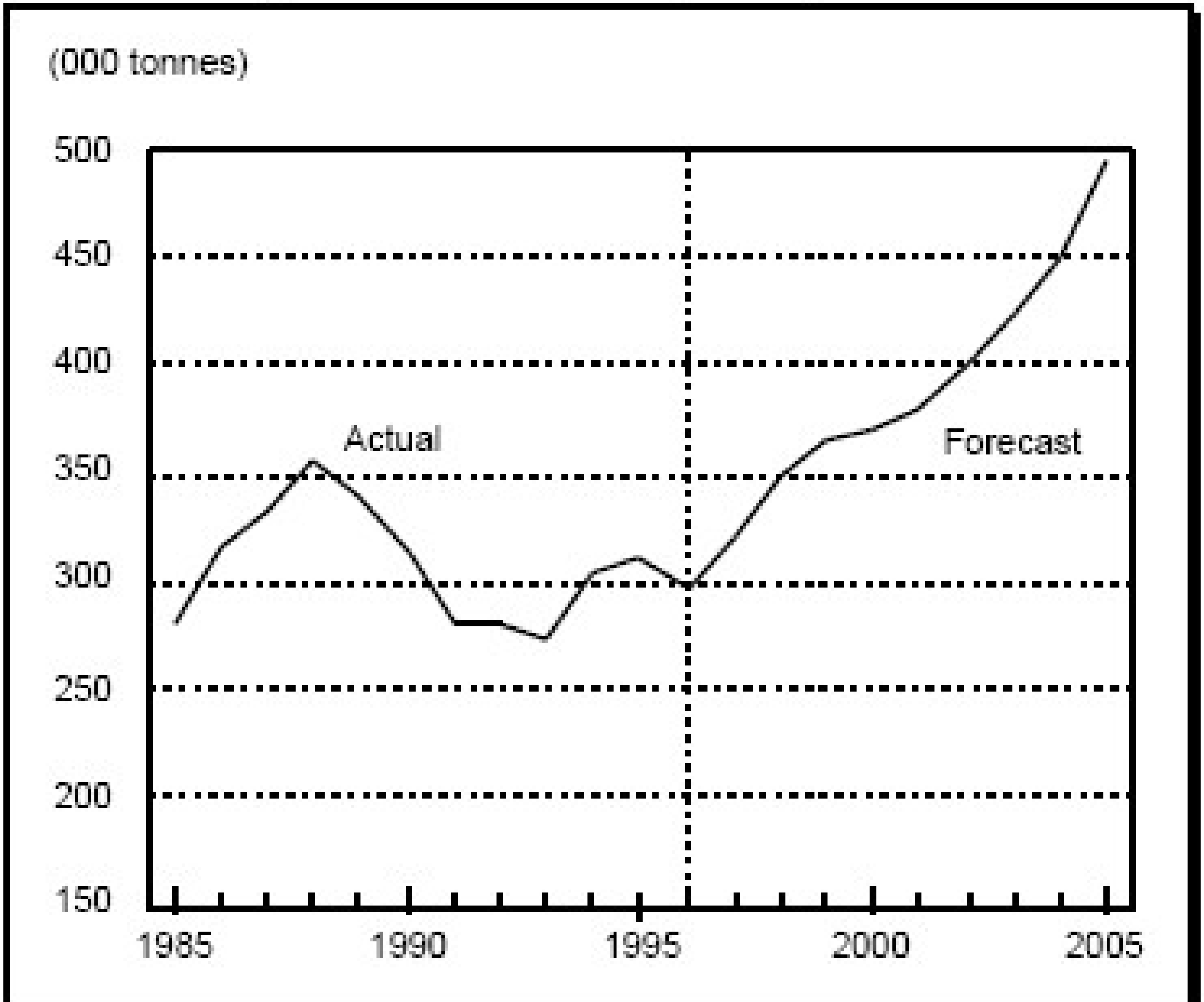
WHY A PLANT IN ISRAEL?

False prophets?

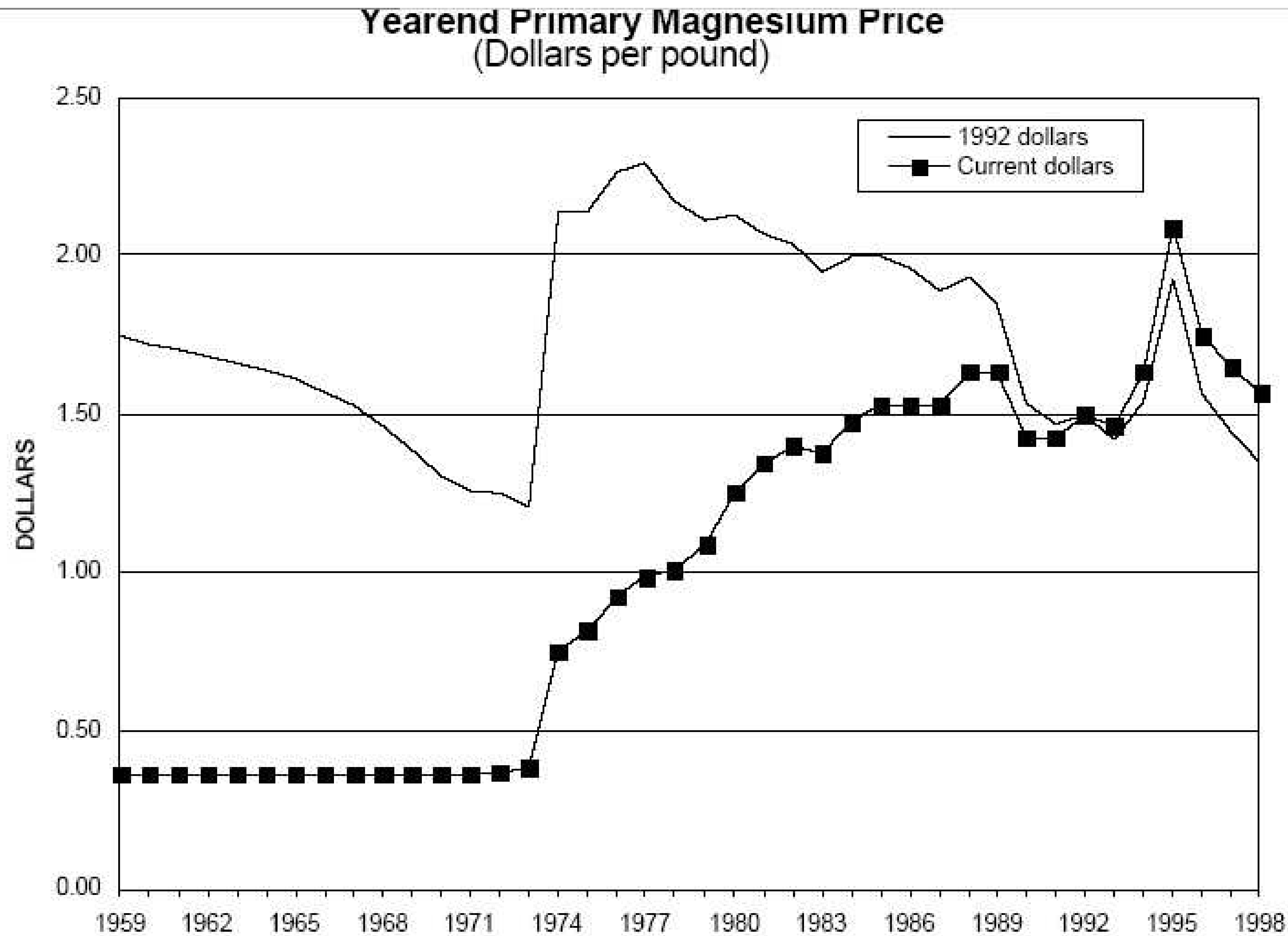


Magnesium Prices

World Magnesium Consumption, 1985-2005



Source: Natural Resources Canada.


Yearend Primary Magnesium Price
(Dollars per pound)
1992 dollars
Current dollars
DOLLARS
2.50
2.00
1.50
1.00
0.50
0.00
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998

New Sources of Magnesium

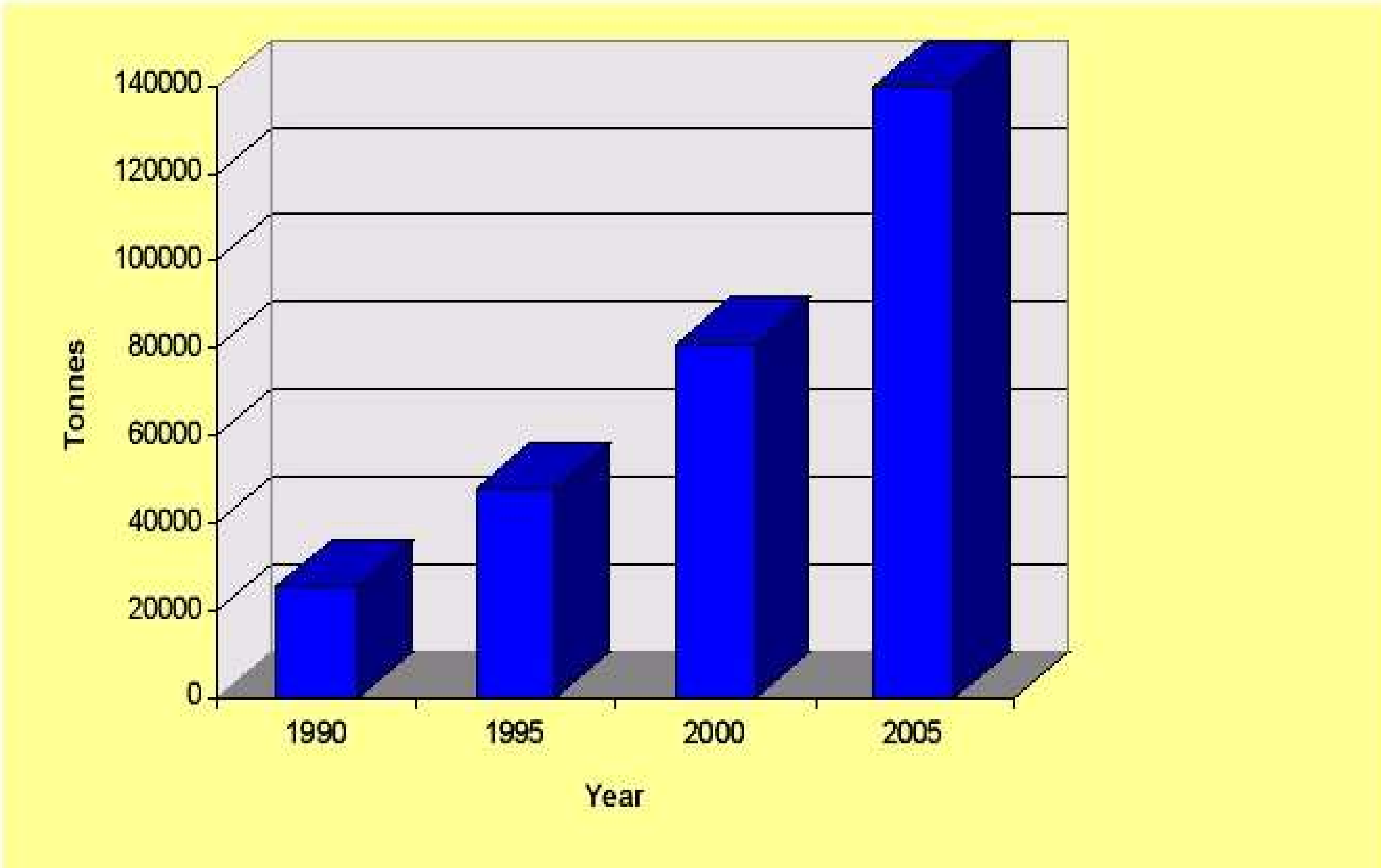
The burgeoning demand for magnesium in automotive applications prompted a new wave of project announcements during the late 1990's - from Australia and Canada to the Netherlands, Iceland, Congo(Brazzaville), and the Middle East.

One new plant has already entered production - the Magnola plant of Noranda in Canada although some difficulties have been experience through the introduction of new technology during a somewhat protracted commissioning period.

A second new plant is now under construction in Queensland, Australia, and scheduled to enter production in 2005 (Australian Magnesium Samag project in South Australia) and, if as expected construction begins in early 2003, this could also enter production in 2005. All three of the new plants are aiming to produce not only pure magnesium but also magnesium alloy, and have their sights clearly focused on serving the structural sector.

Together they will add around 225,000 tonnes per annum of new capacity to the market - a third of world total output in 2001. When other projects, such as the Latrobe Magnesium Project plant magnesium.

Figure 2: Production Capacity and Trend (1990 - 2005)



Source: Canadian Minerals Yearbook: Review and Outlook, Natural Resources Canada, 1998.

2002

Potential new projects

In the mining industry, there has been a resistance in recent years to invest outside the "safe" projects such as gold and base metals. The industrial minerals projects were treated with a caution, especialy magnesium ones involving an investment in the $600-900 million range. The bright prospects perceived for magnesium have given rise to a spate of potential new projects. SSB has identified nine such projects with a combined potential capacity of over 500 000 t/y. Most of them are located in Australia (see the table hereafter, cf Clifford, 2000).

Country	Operation	Capacity	Source	Cap. cost million	Start up
Australia	Stanwell SAMAG Woodsreef Arthur River Main Creek	90 000 52 500 80 000 95 000 80 000	Magnesite Magnesite Serpentine Magnesite Magnesite	US$500 US$375 US$680 US$700	2003 2003 2003
Canada	Magnola	63 000	Serpentine	C$733	2000
Netherlands	Delfzijl	50 000	Carnalite		
Congo	Kouilou	50 000	Carnalite	US$650	2004
Iceland	Sudurnes	50 000	Seawater	US$95	2003
Russia	Solikamsk	22 000	Brucite		
Jordan	Al Safi	25 000	Carnalite		

Other Planned Supply Expansions

- **Many magnesium projects in the planning stages, ~ 550,000 tpa**
  - Additional Australian projects,
    - six locations for a total of ~450,000 tpa
  - Iceland Magnesium Company
    - 45,000 tpa
  - Jordan Magnesia, Dead Sea
    - 25,000 tpa
  - Netherlands, British Columbia, etc…
- **Medium Term Expansion Scenario, introduce new plants at a rate of 1 plant/year, 2005-2013**

1989, Hydro's plant in Becancour, Canada (Quebec), was opened based on new dehydration and high amperage electrolysis technologies developed in-house. Anhydrous magnesium chloride as feed for the electrolysis was produced by drying brine (produced from leaching magnesite with hydrogen chloride) with hydrogen chloride.

1990-91, MagCan, Alberta shut down during start up of a new plant based on a new process producing magnesium chloride by direct chlorination of magnesite and electrolysis.

1995-2000, During the last years of the 90's several smaller producers of magnesium have set up in China using a simple version of the Pidgeon process. The total capacity in China is estimated to have reached 160,000 tpy by the end 2000.

1997, Dead Sea Magnesium started their plant in Sdom, Israel, based on Russian technology. The feed to the electrolysis is made by drying natural brine from the Dead Sea. The plant capacity is expected to reach 33,000 tpy.

1998, Dow Chemical's two plants in Freeport, Texas reached a capacity of 96,000 tpy before plant B was stopped in 1993, and plant A in 1998. Dow no longer is a producer of magnesium.

2001, Start up of Magnola plant in Danville, Quebec, Canada, a J&V between Noranda and SGF. The plant stopped production in 2003.
Pechiney stopped production in Spring 2001, officially closing the factory on July 2nd.

Magcorp filed for Chapter 11 in August 2001.

Alcoa shut down its magnesium production unit, Northwest Alloys, on October 1 2001.

2002, AMC received financing for Australian magnesium project and have started building a plant. The 1.7 billion $ plant was mothballed in 2003.

2003, Métallurgie Magnola Inc. confirmed on March24th, about idling its magnesium plant in Danville, Quebec. The shutdown is for an indefinite period of time until the market conditions allow for a viable operation of the plant.

2004, China has continued to develop into the world's biggest magnesium supplier.

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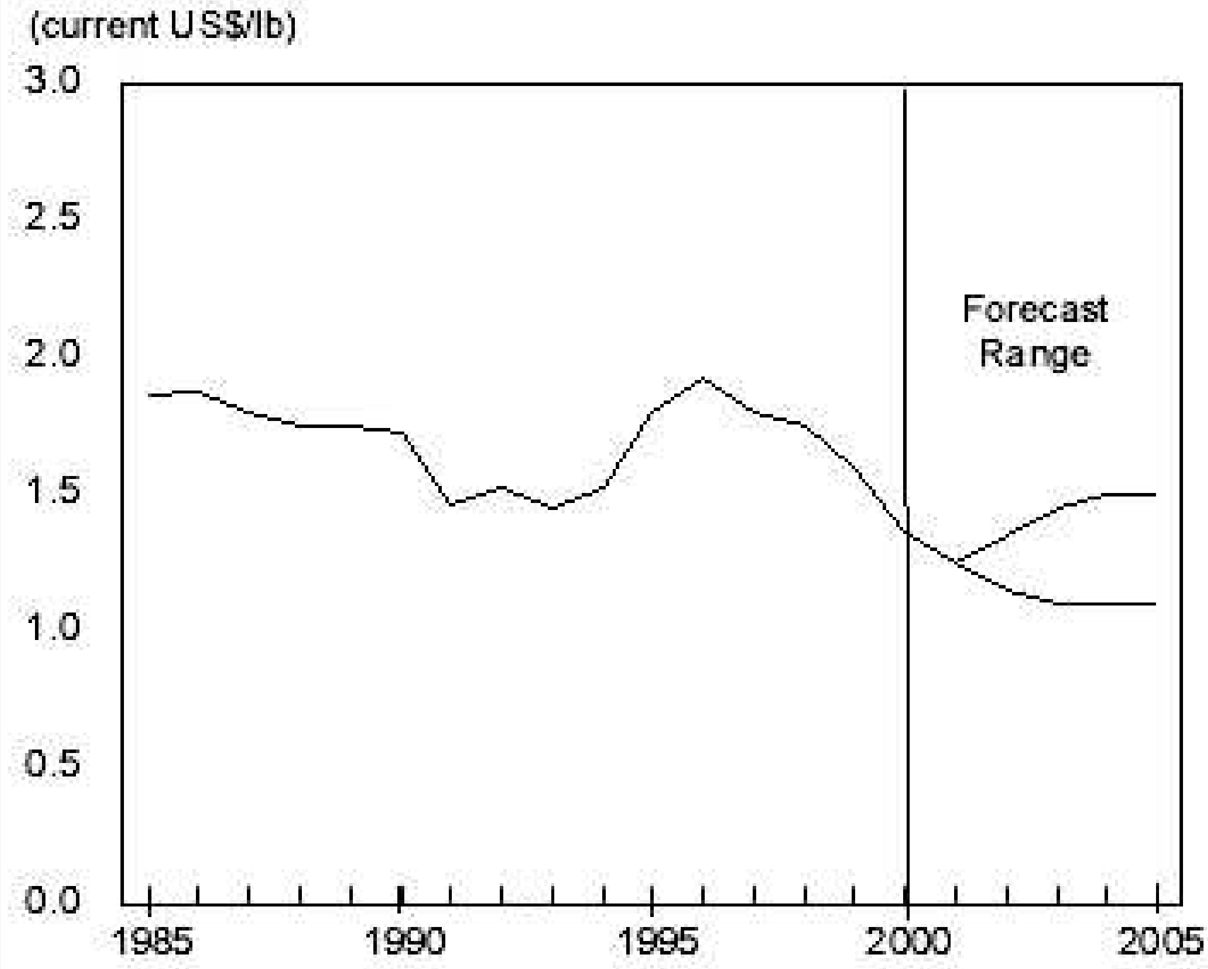
Figure 3
Magnesium Prices, 1985-2005



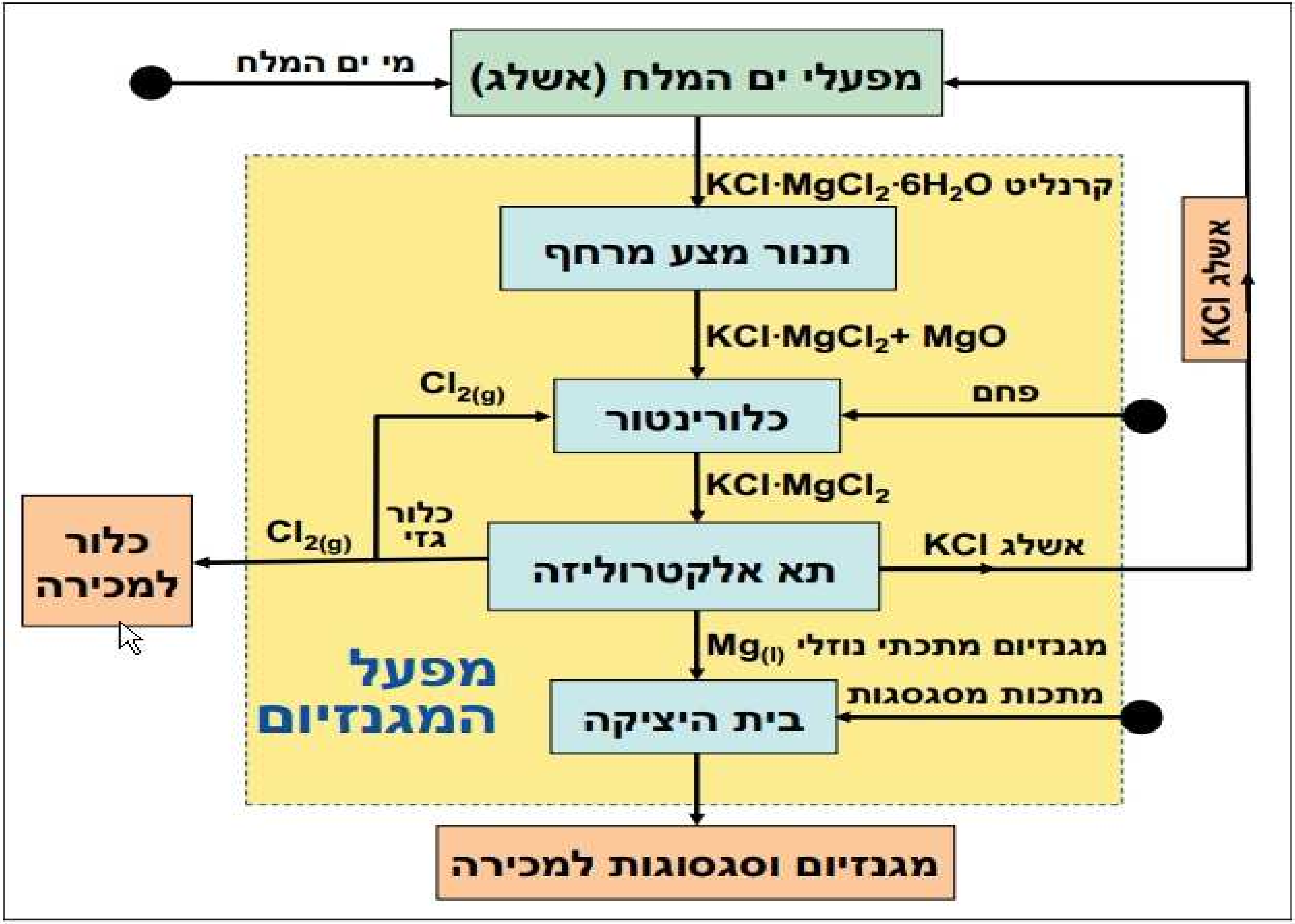
Source: *Metals Week* (U.S. Spot Western Mean).

ISRAEL

Breakdown of revenues and profitability of products and services

The following is an analysis of the revenue and gross profit according to produc

	Revenues ($ million)*	% of ICL Revenues*	Gross profit ($ million)	% of gross profit
2004	88.2	3.0%	5.3	6.0%
2003	73.8	3.0%	(3.6)	(5.0%)
2002	77.4	4.0%	(5.1)	(6.0%)


מי ים המלח
מפעלי ים המלח (אשלג)
קרנליט KCl·MgCl2·6H2O
תנור מצע מרחף
KCl·MgCl2+ MgO
Cl2(g)
כלורינטור
פחם
KCl·MgCl2
כלור גזי
Cl2(g)
כלור למכירה
תא אלקטרוליזה
אשלג KCl
KCl אשלג
Mg(l) מגנזיום מתכתי נוזלי
מפעל המגנזיום
מתכות מסגסגות
בית היציקה
מגנזיום וסגסוגות למכירה

איור 2: מפעל המגנזיום בסדום