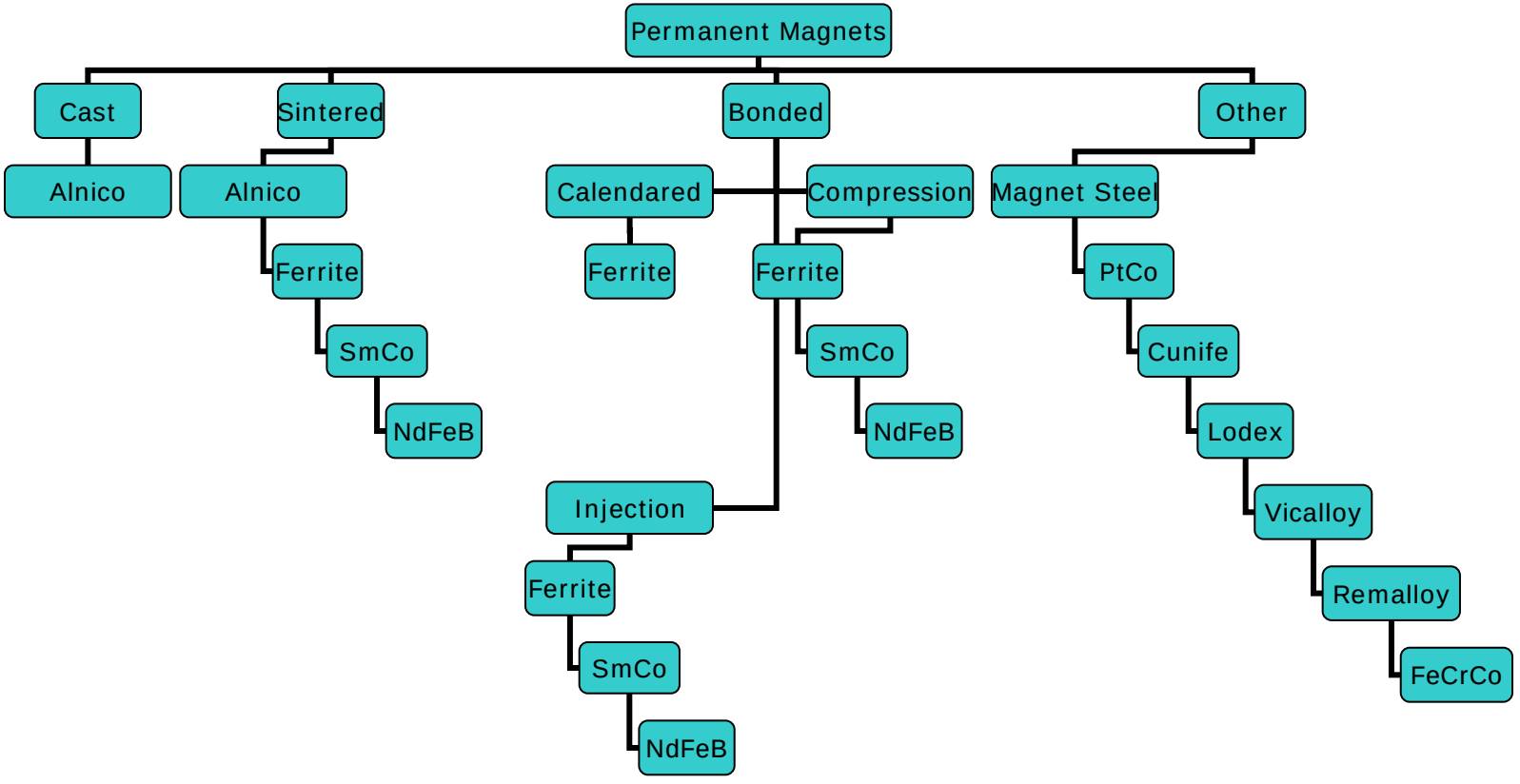
Permanent Magnet Economics

Robert Wolf
Alliance LLC

The Magnet Family



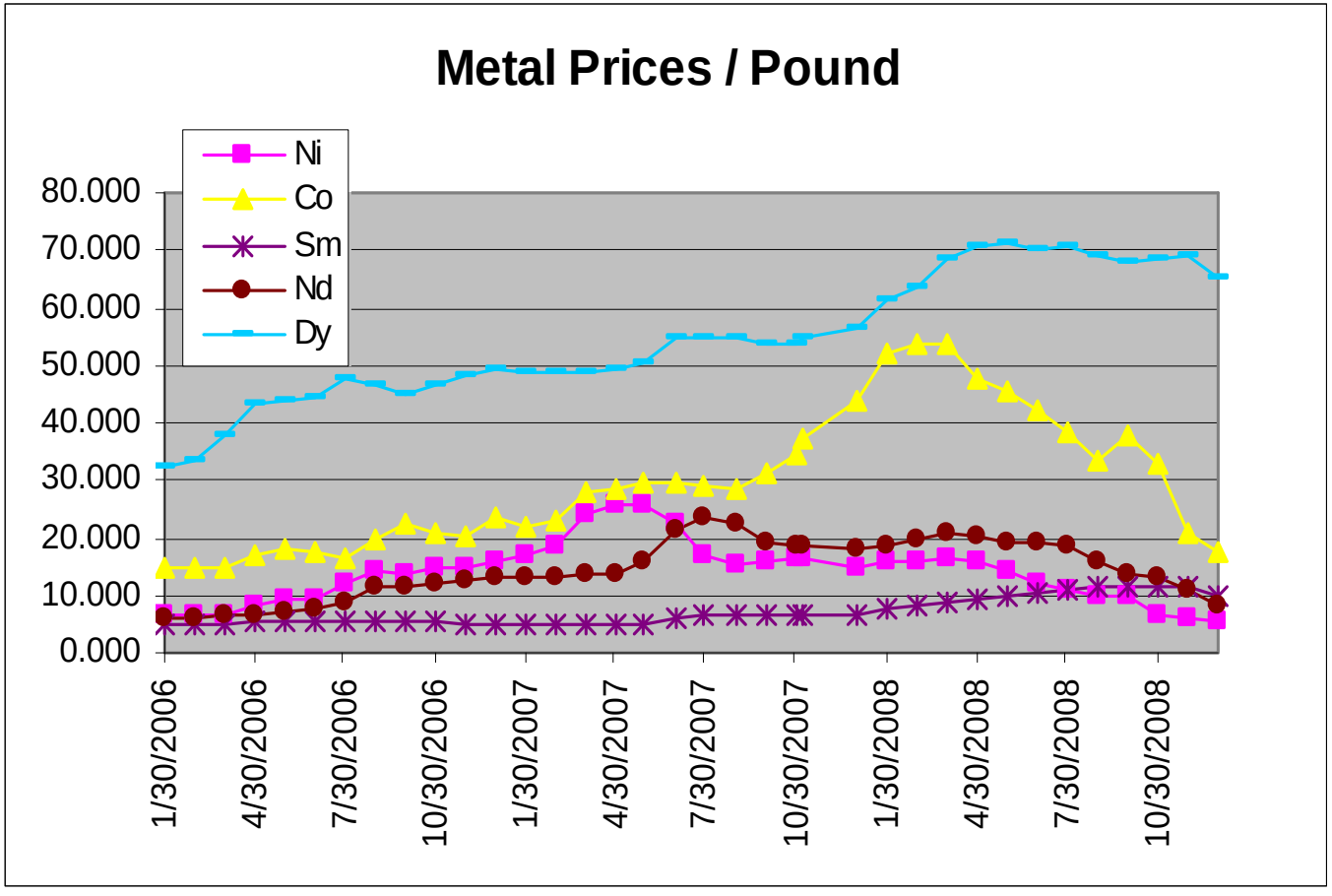
Dollars / Pound for Magnet Material 2007

$/# raw material	Alnico 5 formula	Alnico 8	SmCo	NdFeB	NdFeB-H	NdFeB-SH	NdFeB-UH	NdFeB-EH	NdFeB-AH
01/30/07	$8.622	$11.564	$18.179	$4.552	$5.643	$6.305	$6.846	$7.340	$7.834
02/28/07	$9.155	$12.232	$18.860	$4.593	$5.694	$6.356	$6.905	$7.409	$7.913
03/31/07	$10.431	$13.966	$21.407	$4.710	$5.848	$6.513	$7.094	$7.638	$8.182
04/30/07	$10.779	$14.372	$21.615	$4.819	$5.973	$6.647	$7.236	$7.787	$8.338
05/30/07	$10.640	$14.120	$20.900	$5.468	$6.605	$7.251	$7.836	$8.379	$8.922
06/30/07	$9.590	$12.849	$20.301	$7.389	$8.550	$9.166	$9.772	$10.324	$10.875
07/30/07	$8.819	$11.907	$19.514	$8.003	$9.133	$9.711	$10.306	$10.845	$11.384
08/30/07	$8.213	$11.152	$18.771	$7.669	$8.796	$9.390	$9.976	$10.503	$11.030
09/30/07	$8.770	$12.013	$20.650	$6.659	$7.819	$8.457	$9.056	$9.605	$10.154
10/30/07	$9.412	$12.875	$21.872	$6.394	$7.581	$8.238	$8.852	$9.420	$9.987
11/07/07	$10.053	$13.761	$23.289	$6.446	$7.674	$8.351	$8.990	$9.585	$10.179
12/30/07	$11.644	$16.121	$27.904	$6.299	$7.641	$8.376	$9.085	$9.760	$10.434
01/30/08	$13.153	$18.365	$32.110	$6.404	$7.904	$8.732	$9.528	$10.294	$11.061

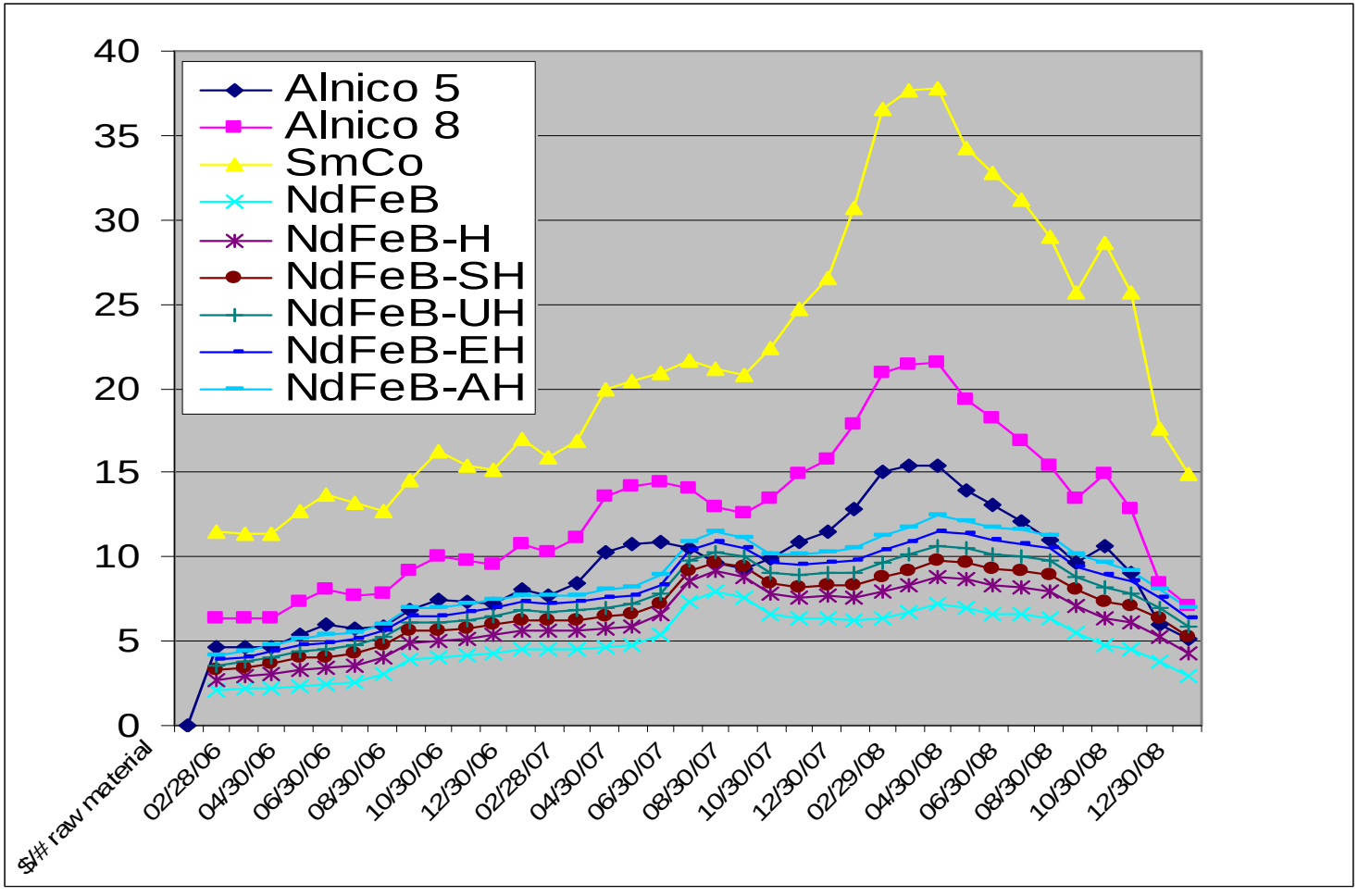
Introduction

- The global economics have significantly affected the pricing and the future of permanent magnet materials and their usage.
- Prices have risen but will this continue or will there be price declines in the future?
- There have been design changes in applications as the price of one material changed relative to another, but is this the correct response to price fluctuations?

Metal Prices per Pound



Materials only costs for magnets



Cost Considerations

- Energy
- Materials
- Labor
- Government Regulations
- Environmental Issues
- Taxes–VAT, import, export, income
- Shipping
- Currency exchange rates

Primary Sources of Energy

- Coal
- Oil
- Wind
- Hydroelectric
- Nuclear
- Solar

Energy used to Mine & Refine Materials

- Aluminum
- Nickel
- Cobalt
- Rare Earth
- Iron Oxide
- Steel

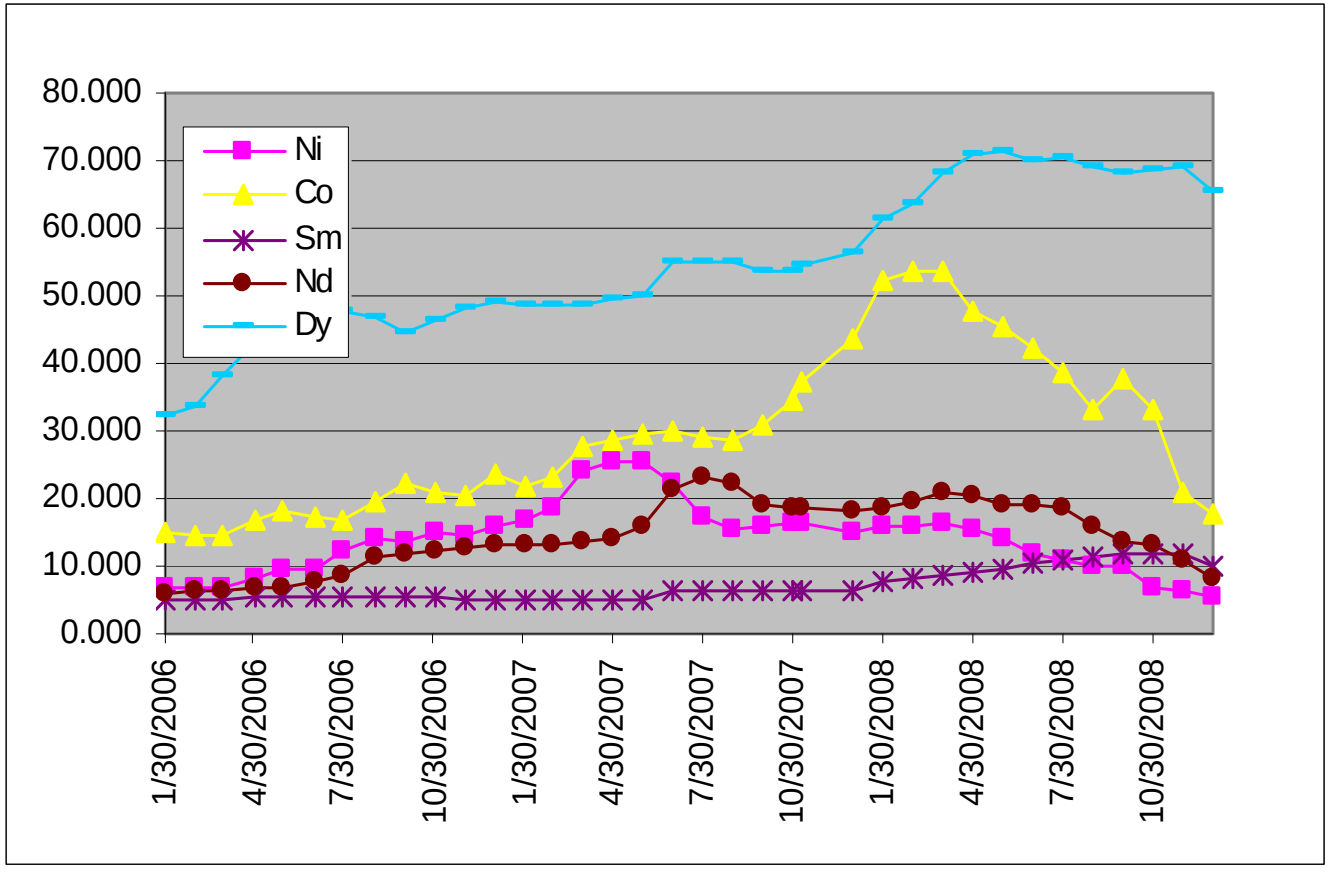
Materials used to manufacture

- Magnets
- Batteries – Lithium ion & NiMH
- Catalysts for
  - a) petroleum refining
  - b) automotive catalytic converters
- Paints & pigments
- Super alloys
- Lighting
- Motors & Generators

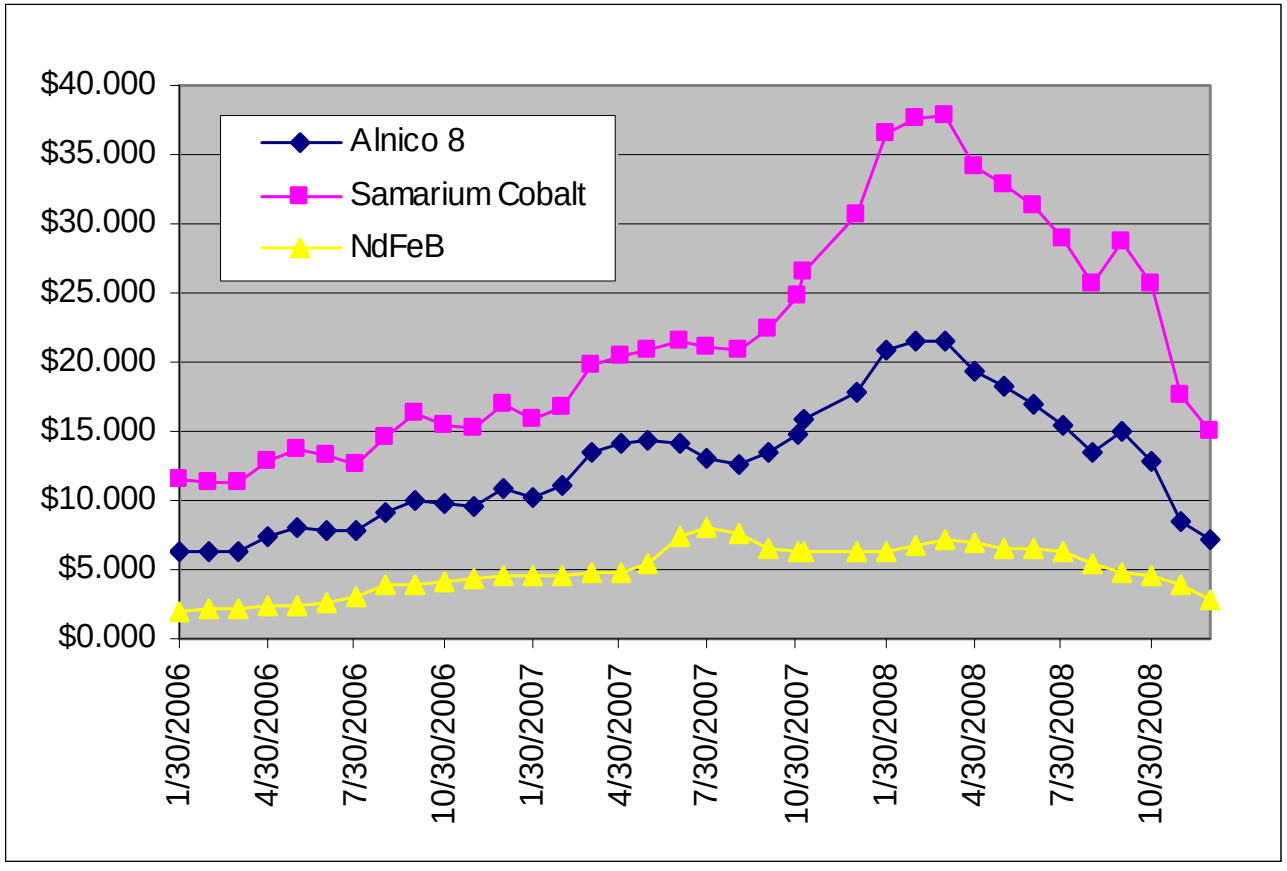
Which are used in

- Transportation – cars / trains / airplanes / trucks / ships
- Construction – home / commercial
- Energy Production – generators / batteries / flywheels
- Environment – air purifiers / water purification
- Military – Defense equipment
- Industrial – motors / sensors

Metal Price / Pound



Permanent Magnet Material Costs / Pound



Mine Production 2008 by Country

	Aluminum	Nickel	Cobalt	Copper	Rare Earth
United States	6.6%	0.0%	0.0%	8.3%	0.0%
Australia		11.1%	8.8%		
Canada	7.8%	15.2%	11.6%		
Chili				35.6%	
China	34.0%	5.3%	2.8%	6.3%	96.8%
Congo			44.5%		
Indonesia		13.1%			
Russia	10.5%	17.1%	8.1%		
Zambia			10.8%		
Other	41.1%	38.2%	13.4%	49.8%	3.2%

Rare Earths

- In 2008, rare earths were not mined in the United States
- Bastnäsite deposits in China and the United States constitute the largest percentage of the world's rare earth economic resources
- cerium compounds used in automotive catalytic converters and in glass additives and glass polishing compounds;
- rare-earth compounds used in automotive catalytic converters and many other applications;
- yttrium compounds used in color televisions and flat-panel displays, electronic thermometers, fiber optics, lasers, and oxygen sensors; and phosphors for color televisions, electronic thermometers, fluorescent lighting, pigments, superconductors, x-ray-intensifying screens, and other applications

Rare Earths

- mixed rare-earth compounds and for rare-earth metals and their alloys used in armaments, base-metal alloys, lighter flints, permanent magnets, pyrophoric alloys, and superalloys.
- rare-earth chlorides used in the production of fluid cracking catalysts used in oil refining.
- The trend is for a continued increase in the use of rare earths in many applications, especially automotive catalytic converters, permanent magnets, and rechargeable batteries for electric and hybrid vehicles.

Aluminum

- During the first half of 2008, domestic primary aluminum production increased owing to smelter restarts.
- In the second half of the year, production was curtailed at two smelters owing to high electricity prices, power supply issues, and a sharp drop in the price of aluminum that took place in August.
- Domestic aluminum requirements cannot be met by domestic bauxite resources. Non-bauxite aluminum resources are abundant and could meet domestic aluminum demand but no processes for using these resources have been economic.

Nickel

- The United States did not have any active nickel mines in 2008
- The U.S. Government sold the last of the nickel in the National Defense Stockpile in 1999.
- Declining metal prices, fears of recession, and the tightening of credit forced nickel producers to halt mining at less profitable operations and delay early stage development projects.

Nickel

- The credit crisis put severe financial pressures on motor vehicle manufacturers, causing them to reassess the post-2010 marketplace. Nickel-metal hydride (NiMH) batteries continue to be widely used in hybrid motor vehicles, despite inroads made by lithium-ion batteries.
- Sales in the United States of hybrid electric passenger vehicles have risen steadily to 350,000 in 2007 from 9,370 in 2000.
- manufacturers were readying prototype plug-in hybrids or fully electric vehicles for commercial production.
- High prices for jet fuel encouraged major air carriers to order more fuel-efficient aircraft, increasing the demand for superalloys.

Nickel

- The nuclear power industry was in the early stages of a renaissance because of high prices for natural gas. U.S. utilities were considering constructing 15 to 33 additional nuclear power plants—facilities that would require sizeable amounts of austenitic stainless steel and other nickel-bearing alloys.
- Construction of new wind farms could require significant numbers of nickel-based batteries for energy storage and load leveling.

Cobalt

- The United States did not mine or refine cobalt in 2008
- China was the world's leading producer of refined cobalt, mostly from cobalt-rich ore imported from Congo (Kinshasa).
- As a result of restrictions on exports of unprocessed cobalt from Congo (Kinshasa), the Chinese cobalt industry is developing more domestic and foreign sources of cobalt supply,
- investing in African cobalt projects,
- increasing the recycling of cobalt scrap,
- And shifting its consumption towards more downstream materials.
- Since 2005, China has been the third- or fourth-ranked supplier of cobalt imports to the United States.

Copper

- The government stockpiles of refined copper and brass were liquidated in 1993 and 1994, respectively.
- Domestic mine production in 2008 increased by about 12% to 1.3 million tons and its value rose to about $9.4 billion. This is 8% of the world production
- Despite numerous announced expansions in mine capacity, estimated global copper mine production was lower than that for the same period of 2007. Numerous factors, including labor unrest, lower ore grades, rapidly escalating production costs, technical problems, and utility and equipment shortages, contributed to lower than anticipated production.
- In October, concurrent with development of the global financial crisis, copper prices plummeted, the LME price falling below $1.70 per pound

World Steel Production 2008 (thousands of metric tons)

EU/Europe/CIS	341,553	26.2%
N America USA	91,350	7.0%
N America Other	34,047	2.6%
Asia China	497,546	38.2%
Asia Japan	118,743	9.1%
Asia other	129,214	9.9%
Other	89,005	6.8%
Total	1,301,458	100.0%

Iron Oxide

- By product of the pickle liquor from production of cold rolled steel
- CR steel used primarily in automotive and white goods markets, both of which are depressed
- Consequently, the production of iron oxide is drastically reduced

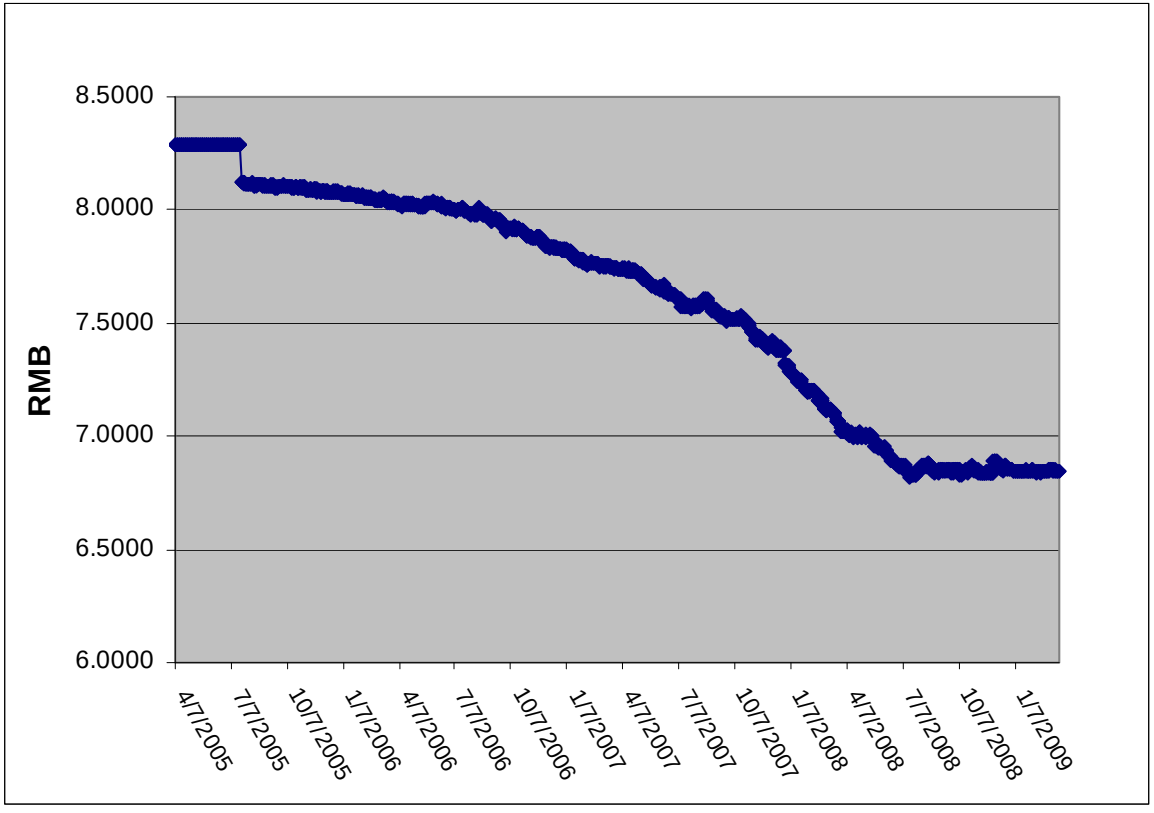
Iron Oxide

- Historically 10% pigment, 20% water treatment and 70% ferrite
- Now 10% pigment, 40% water treatment and 50% ferrite BUT
- CR Steel production off by 50% causing a
- Oxide shortfall of 50%

Iron Oxide

- Water treatment market is increasing
- They used to take ferric oxide and convert to ferric chloride
- Now they buy the ferric chloride directly, in bulk, with no special packaging at the same or higher price as the ferric oxide.
- Consequently, less material or higher prices for magnet production.

RMB vs. USD (data from Oanda)



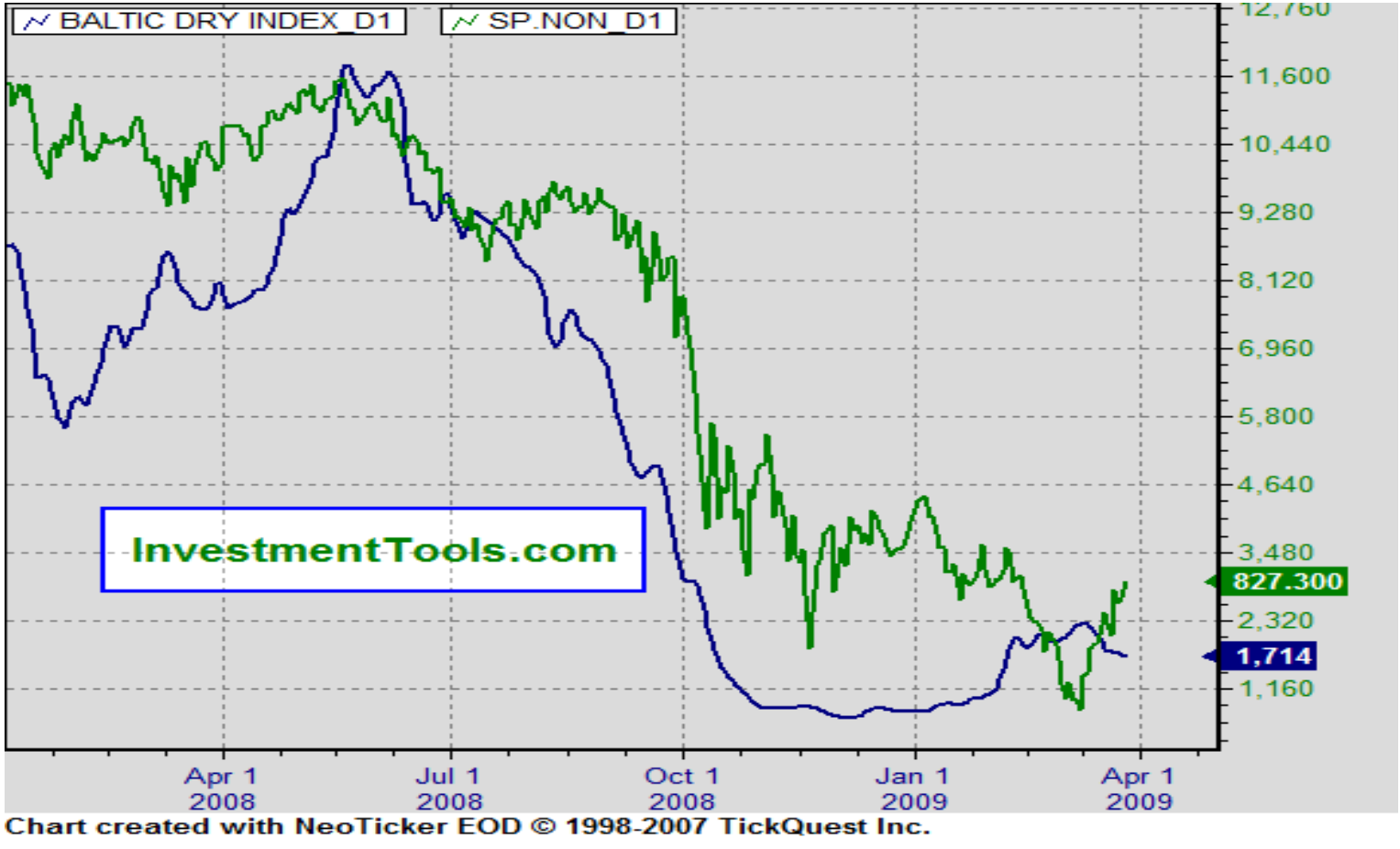
Growth of the public debt

- 1861 – 1918 0
- 1918 – 1939 0 to 1 trillion dollars
- 1940 – 1945 1 to 2 trillion dollars
- 1946 – 1982 2 – 2 trillion dollars
- 1983 – July,2008 2 – 9.6 trillion dollars

U.S. Public Debt (July 2008)

- $9.6 trillion (and increasing at $310 million / day or $215 thousand / minute)
- $4.2 trillion (43.6%) held by U.S. Government in retirement / insurance / trust funds
- $5.4 trillion held by the public of which
- $2.7 trillion held by foreign entities of which
- $1.1 trillion is held by China and Japan (40.7% of the foreign holdings and 11.5% of the total public debt)

Baltic Exchange Dry Index (BDI)& SP500 (green)



Magnet Materials

Materials	Typical Shapes	Pros	Cons
Cast Alnico **AlNiCo**	Rods, Bars, U shape and other cast type	High Br High working T Good T coef.	Very Low Hc High cost High L/D Requires Cast
Sintered Alnico **AlNiCo**	Powder pressed to shape	Complex shapes High Br, T	Requires Tool High cost Low market
Ceramic/Ferrite **$SrFe_2O_3$**	Blocks, Rings, Arcs, Discs	Most flux for $ High usage Low corrosion	Low Br Requires tool Simple shapes
Samarium Cobalt **SmCo**	Blocks, Rings, Discs Arcs, Segments	No corrosion Very low T coef Stable, No tool	Very expensive Simple shapes High Co content
Neodymium **NdFeB**	Blocks, Rings, Discs Arcs, Segments	Highest magnetic properties No tooling	Corrodes Low working T Difficult to Mag
Bonded Grades **All materials**	Difficult geometries Can be insert molded or overmolded	Complex shapes Various resins	High toolings Low magnetics High volumes

Resources

- U.S Geological Survey, Mineral Commodity Summaries, Jan. 2009
- Asian Metal, Metal News
- London Metal Exchange
- World Steel
- Baltic Exchange Dry Index