Other steelmaking raw materials

London

July 2011

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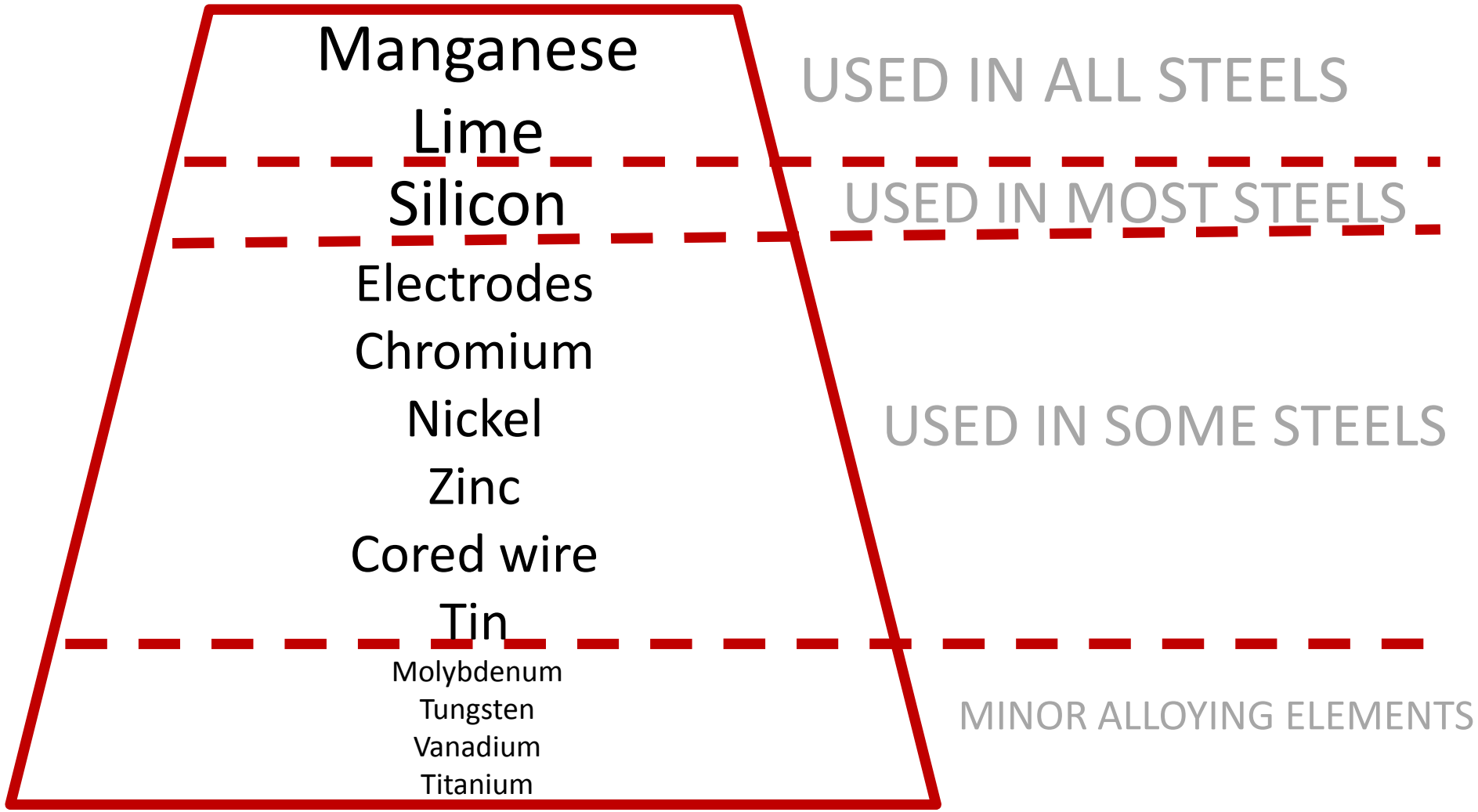
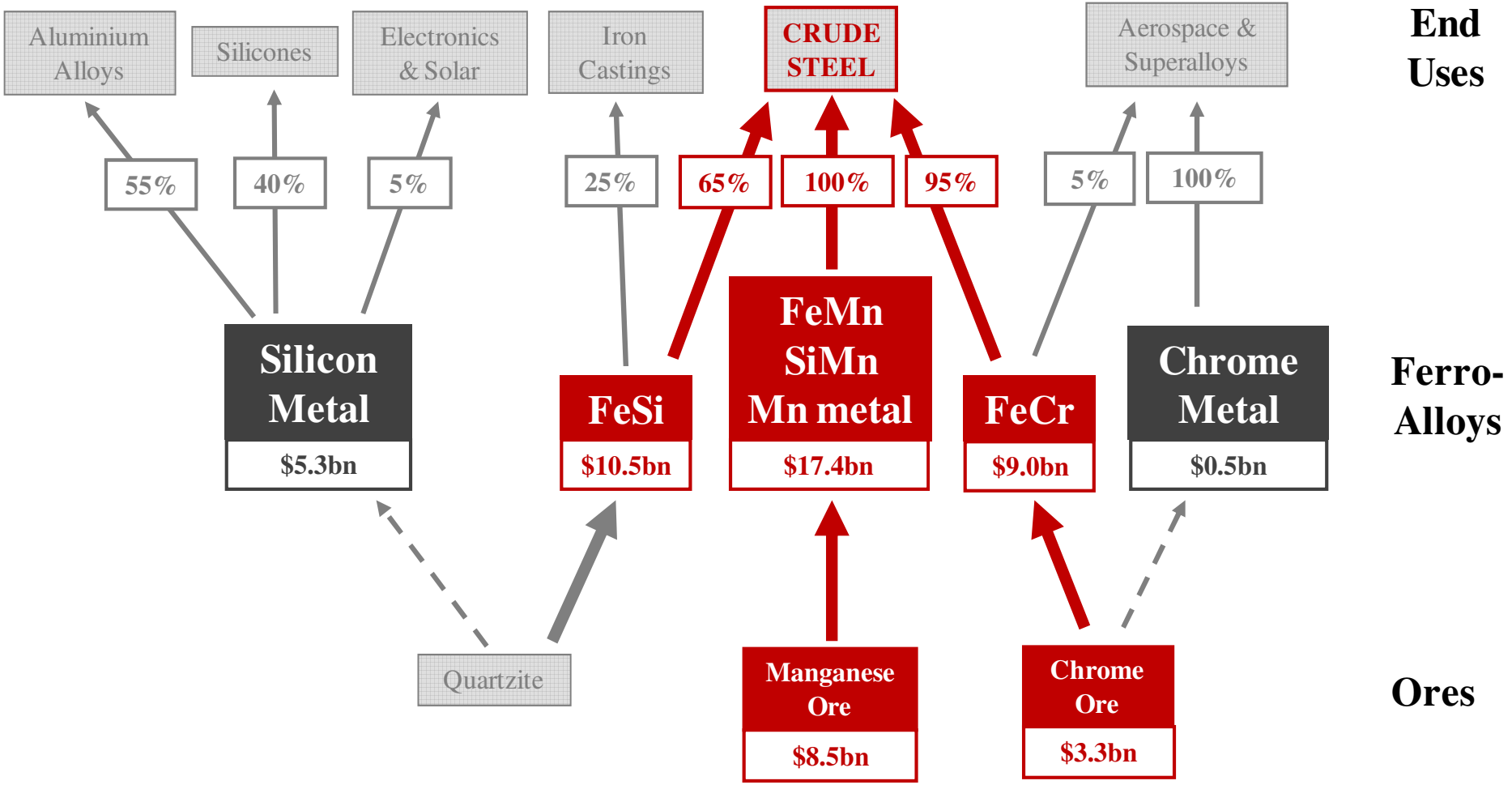


Other steelmaking raw materials –Fairly low % of steel production costs

Manganese	avg. $20/tonne
Lime	avg. $20/tonne
Silicon	avg. $10/tonne
Electrodes	avg. $7/tonne
Iron	avg. $300/tonne
Chromium	avg. $200-400/tonne (stainless)
Nickel	avg. $500-1000/tonne (stainless 300)

80% of ferroalloy revenues are driven by steel



Estimated revenues for 2010

USED IN ALL STEELS - Manganese

- **Manganese** is the world's fourth most heavily consumed metal
- Global mine output of 14 million tonnes in 2010 – over 90% goes into steel
- All steels contain manganese
- Manganese is used to remove sulphur from liquid steel
  (sulphur causes steel to crack)
- There is no viable substitute for manganese as a de-sulphiriser
- Manganese is also used to improve the strength of certain steels
  (structural steels, high strength flat steels)
- Non-steel consumption of manganese includes de-polarisation of dry-cell batteries, and as an additive in certain aluminium and copper alloys

Manganese – consumption in steel

- Manganese content of steel ranges from 0.4% to 2.5%. Average is 0.8%
- Manganese is added to steel in the form of one of four types of **ferroalloy**:
  - Silicomanganese (SiMn)
  - High-carbon ferromanganese (HC FeMn)
  - Medium and low-carbon ferromanganese (MLC FeMn)
  - Manganese metal (Mn metal)
- The choice of manganese ferroalloy is driven by the chemistry of the steel (Mn, Si and C specifications)
- Ferroalloys are added to steel in the ladle furnace after decarburisation in the BOF / EAF, so their carbon content can be critical

Manganese – ore into ferroalloy

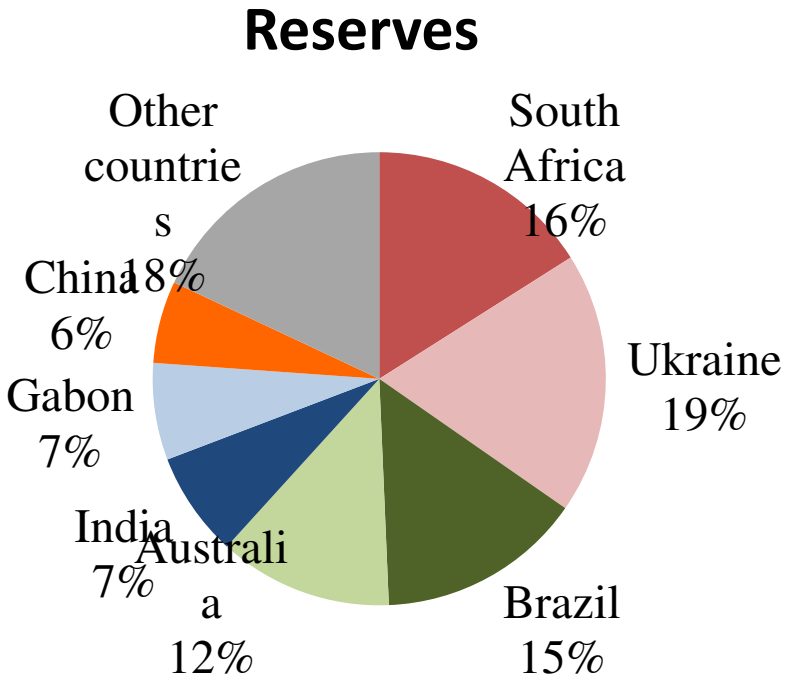
- Manganese ore is usually concentrated at the mine site. Sintering of fines is commonplace, sometimes at mine sites and sometimes at smelters
- Grades of manganese ore range from 20% to 50% Mn content
- Manganese ore is smelted in an EAF, with metallurgical coke as a reductant, to produce silicomanganese and ferromanganese
    - SiMn typically contains 66% Mn , 17% Si, 2% C, balance Fe
    - HC FeMn typically contains 76% Mn , 7% C, balance Fe
    - MLC FeMn typically contains 82% Mn, <2% C, balance Fe
- The production of Mn metal involves dissolving manganese ore into sulphuric acid, and extracting the Mn metal from the solution using electrolysis
    - Mn metal typically contains 99% Mn

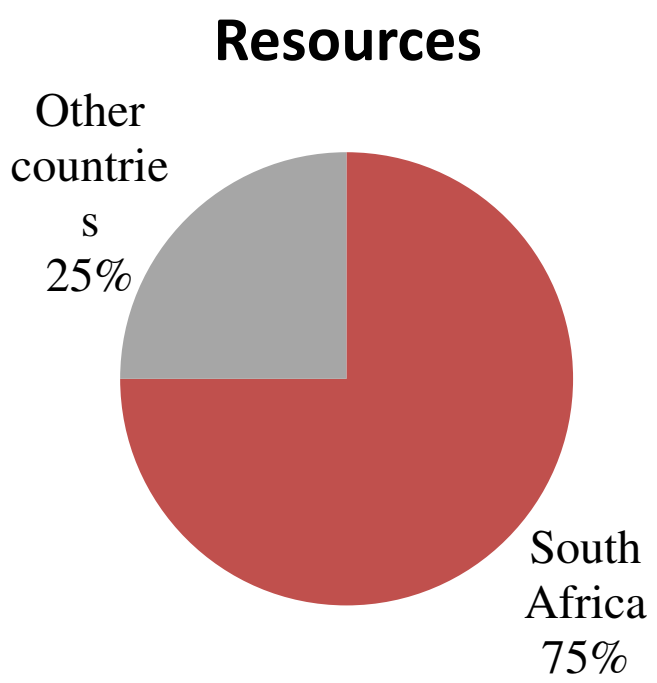
Manganese – ore production

- Manganese ore is a highly concentrated industry. The top 5 producers account for 60% of world output. The top 10 producers account for 75% of world output
- Production is dominated by blue chip mining groups such as BHP Billiton, Vale and Eramet. In this regard, it has great similarity to iron ore
- High grade manganese ore (>40% Mn) is even more dominated by the blue chip companies. BHP Billiton, Eramet and Assmang together account for 85% of high grade production

Manganese ore output by company in 2010 (million tonnes contained Mn):		
Company	*Output*	*Mkt share*
1. BHP Billiton	3.5	25%
2. Eramet	1.5	10%
3. Assmang	1.4	10%
4. Privat	1.4	10%
5. Vale	0.7	5%
6. UMK	0.5	4%
7. MOIL	0.5	3%
8. ENRC	0.4	3%
9. OM Holdings	0.4	2%
10. Buritirama	0.3	2%
Others	3.5	25%
Total world	**14.1**	

Manganese – ore reserves

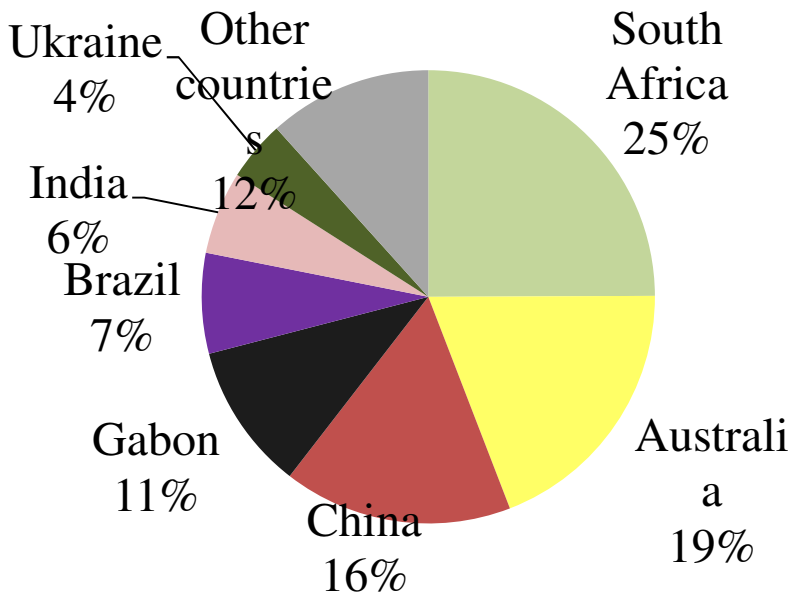




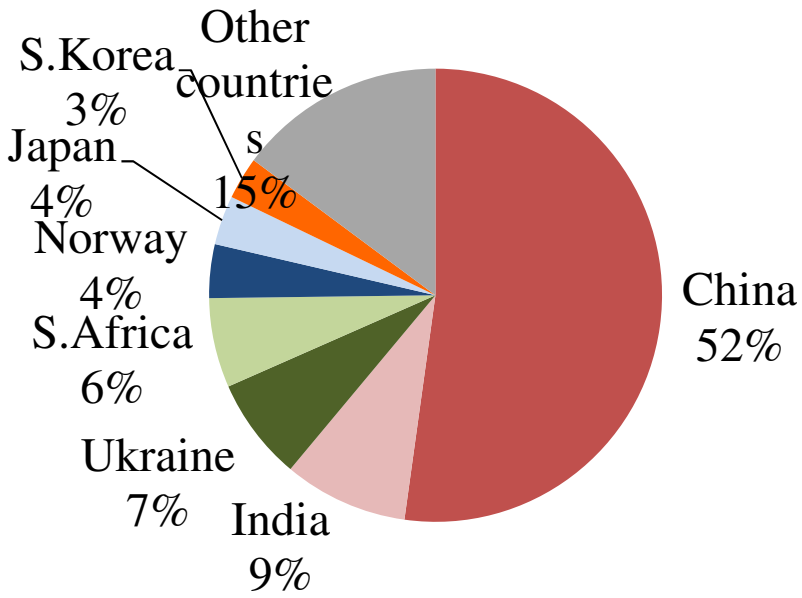
- Around 75% of the world's manganese resource is in the Kalahari basin in South Africa. Most of this is not explored sufficiently to count as reserves
- Ukraine, Brazil, Australia and west Africa also have significant manganese reserves. China has a small reserve of low grade ore which is depleting fast

Manganese – ore vs ferroalloy output

Mn ore output



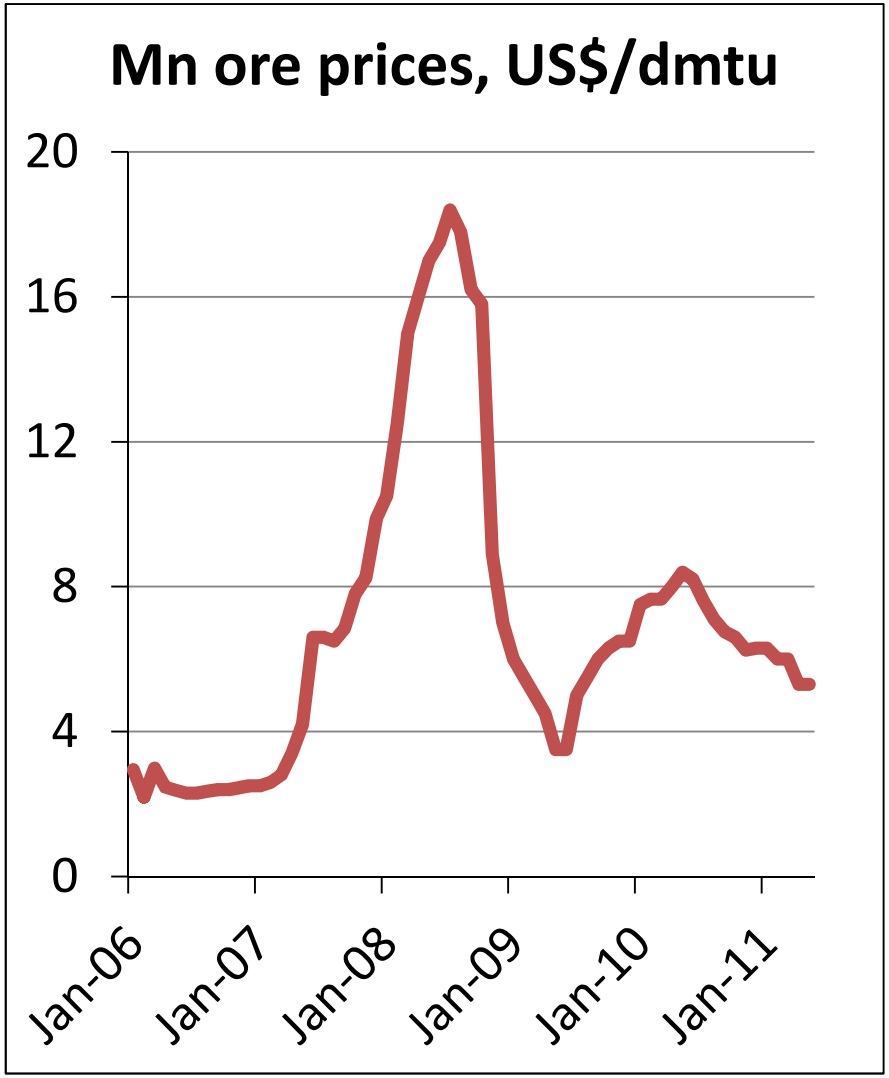
Mn ferroalloy output

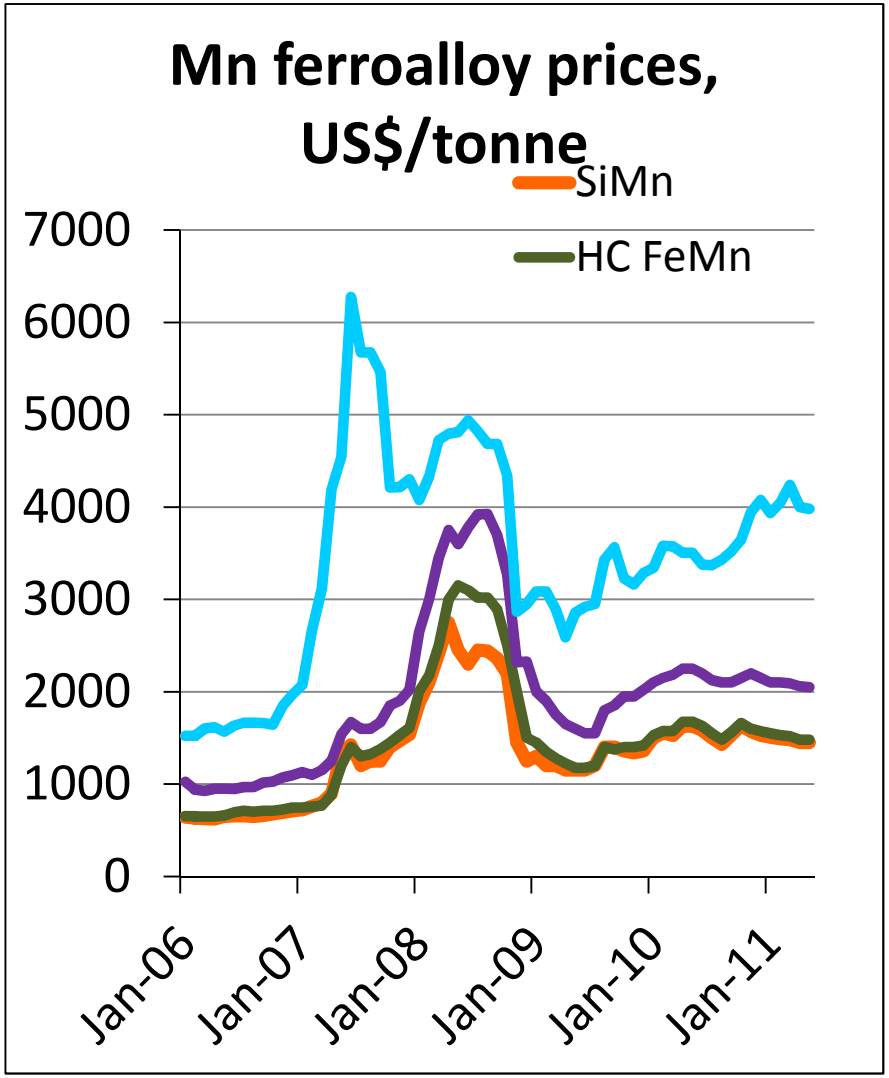


- China accounts for 52% of the world's production of Mn alloys, but just 16% of the output of Mn ore. Thus there is a huge import of Mn ore into China. Other major importers of Mn ore are India and Ukraine

- S.Africa, Australia, Gabon and Brazil are the largest net exporters of Mn ore

Manganese – prices





Manganese – points to watch

- Manganese reserves are plentiful. There are enough world resources to satisfy demand for the next 50-100 years
- Nevertheless, with 75% of world resources, much of future demand will have to come from South Africa
- Logistical constraints in South Africa are chronic. Rail and port links to Kalahari are at capacity levels, unlikely to be eased before 2018-20
- Price bottom of >$5/dmtu, with upside based on potential logistical bottlenecks in South Africa, but as yet these have had little impact
- Grades are deteriorating. High grade premium will most likely increase
- Manganese can be very harmful to health. Exposure linked to brain disease and Parkinson's Disease. Pollution and exposure will become bigger issues, especially for Mn metal production in China

USED IN ALL STEELS - Lime

- **Limestone** is calcium carbonate ($CaCO_3$)
- Calcium is used to remove silica, the major impurity in iron ore, out of molten iron into slag
- Limestone is added into the blast furnace at the iron-making stage.
  The heat decomposes the limestone into lime and CO_2
  ($CaCO_3 \longrightarrow CaO + CO_2$)
- The lime reacts with silica to form calcium silicate
  ($CaO + SiO_2 \longrightarrow CaSiO_3$)
- Calcium silicate rises to the top of the blast furnace and is removed as slag
- On average, 500kg of limestone is used to produce one tonne of pig iron

Lime – Consumption in BOF/EAF

- Lime is also used in the steel-making process, in both the BOF and EAF routes, to remove remaining silica impurities
- At the steel-making stage, lime is usually added as **dolomite** and **quicklime**
- Dolomite is calcium magnesium carbonate ($CaMg(CO_3)_2$). As well as removing impurities into slag, the magnesium helps to separate the slag from the liquid steel, and helps reduce wearing of the lining of the BOF / EAF
- Quicklime is lime which is bought having already been reduced from limestone
- At the BOF / EAF stage, between 35-50 kg of lime is added per tonne of steel
- Fine limestone and dolomite are also used as a binding agent in the production of iron ore sinter

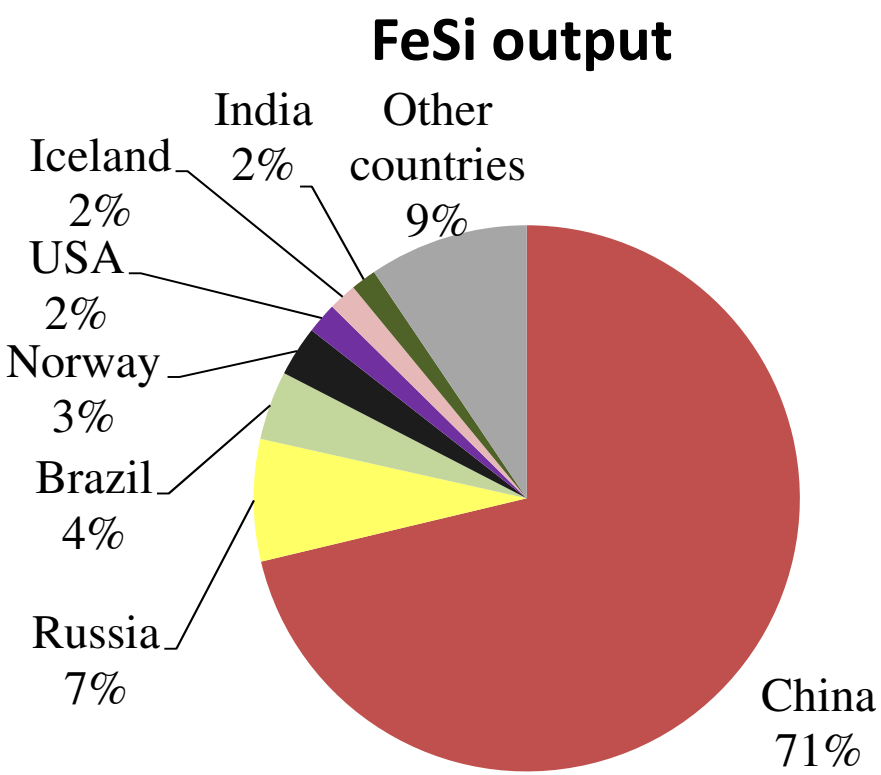
Lime – Cost

- Lime is a very abundant material. Calcium is the fifth most common element in the earth's crust
- Consequently lime is relatively cheap. The prices of limestone and dolomite are mostly within the range $20-120/tonne
- The price range is wide, reflecting the fact that transportation is the main cost component
- Many steel plants are quite close to a domestic lime source, and consequently pay a price at the lower end of the range
- International trade in these products being relatively low, prices fluctuate in US dollars from country to country in response to exchange rate changes

USED IN MOST STEELS – Silicon

- **Silicon** (Si) is the second most abundant metal in the earth's crust. It exists naturally in the form of clay, sand, granite and quartzite. It is so abundant that reserves and resources are not worth calculating
- Most steels contain Si, in order to deoxidise liquid steel after tapping from the BOF / EAF. A minority of steels are deoxidised by Al instead of Si
- Si also adds electrical conductivity to steel. On average, steel is 0.3% Si, whilst electrical steels contain up to 7% Si
- Si is added to steel either as SiMn (already discussed), or as **ferrosilicon (FeSi)**
- FeSi is a ferroalloy usually containing 75% Si, 20-25% Fe. It is produced in an EAF by smelting quartzite together with coke and iron ore
- 75% of FeSi is consumed in steel production. Most of the rest is consumed in the production of foundry castings and magnesium metal

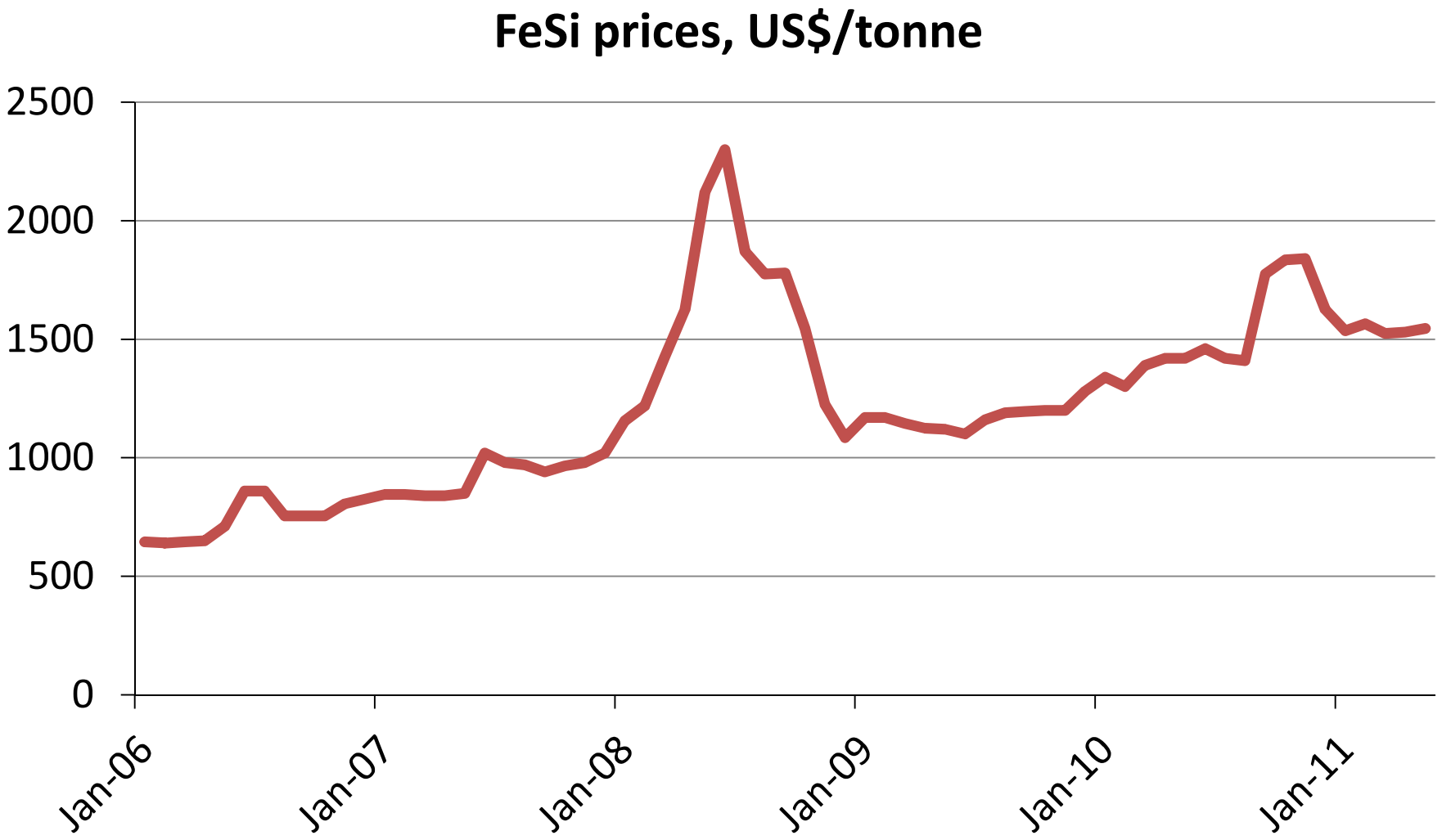
Ferrosilicon – production



Total: 6.9 million tonnes

- China produced 71% of the world's FeSi in 2010. Its share of global consumption was 55%, hence China remains a major net exporter of FeSi, mostly to other Asian countries and the USA
- The major cost component for producing FeSi is electricity
- With high electricity prices and government closures of small ferroalloy plants, it is questionable whether China can continue to export large volumes of FeSi. Exports have fallen substantially already between 2007 and 2010

Ferrosilicon – prices



USED IN SOME STEELS – Electrodes

- Around 30% of global steel output takes place in electric arc furnaces
- Electric arc steelmaking uses electrodes to pass electrical current through the EAF
- The most common form of EAF uses

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