Blast-furnace and steelmaking slags: Which future valorisation in the next 20 years?

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THIRD INTERNATIONAL SLAG VALORISATION SYMPOSIUM

THE TRANSITION TO SUSTAINABLE MATERIALS MANAGEMENT

19-20 March 2013

Leuven, Belgium

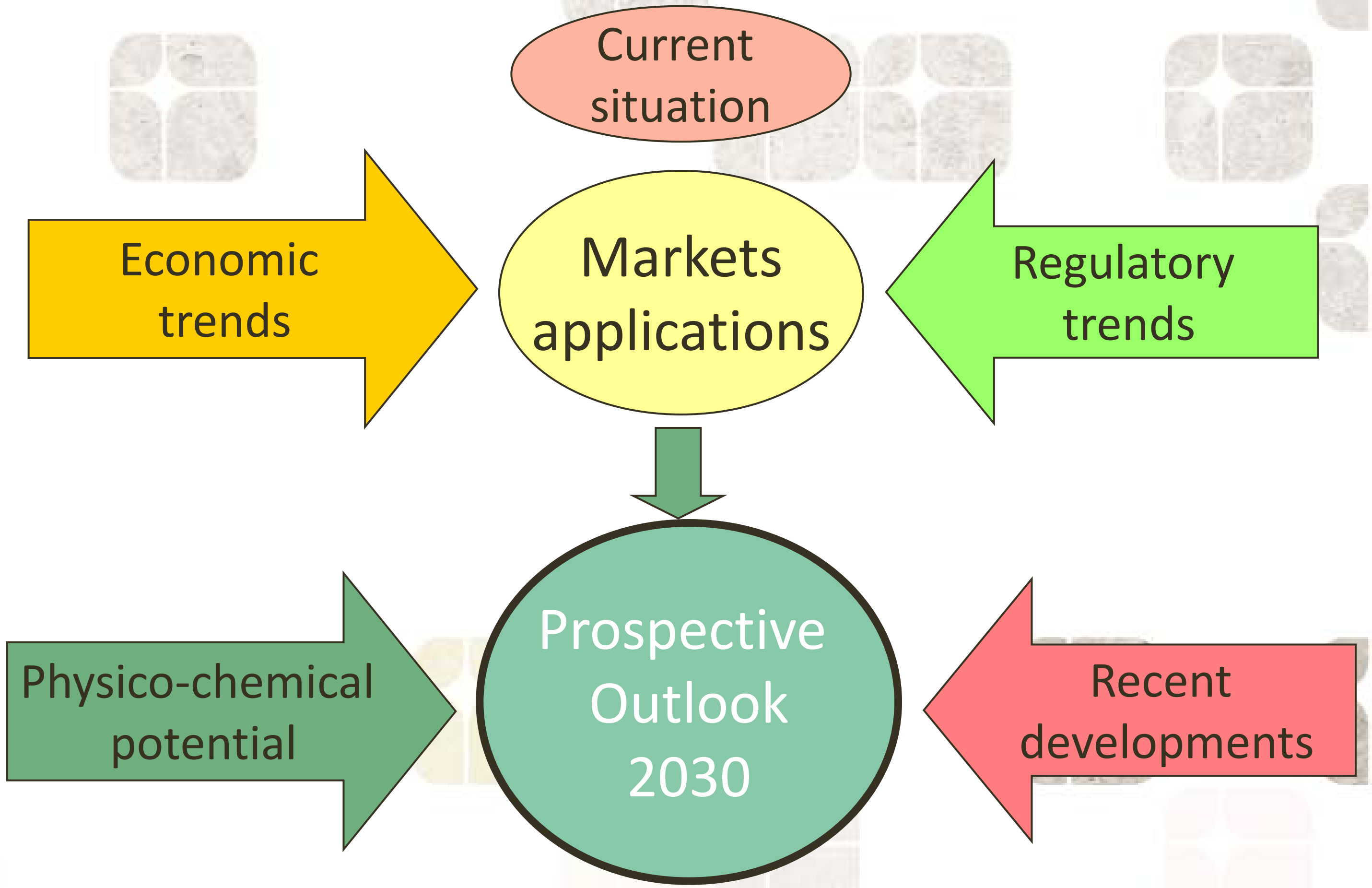
Preamble

ὄνους σύρματ᾽ ἂν ἑλέσθαι μᾶλλον ἢ χρυσόν.

(only) Asses would rather have straw than gold.

Heraclite of Ephesus , Fragments, circa 500 BC

Summary and Methodological approach



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Where we are today





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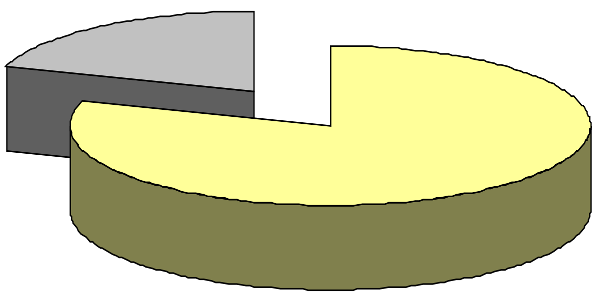
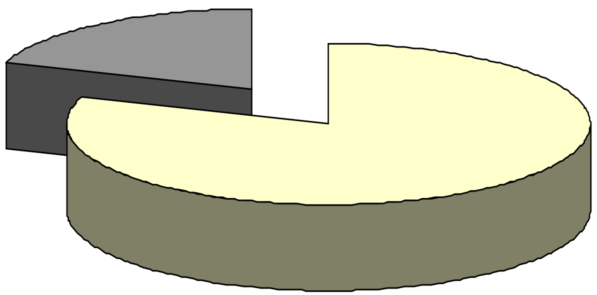
Blast Furnace Slags
One single dominant valorisation: GBFS in cement

Valorisation ratio close to 100%





Source : Worldsteel survey , 2007

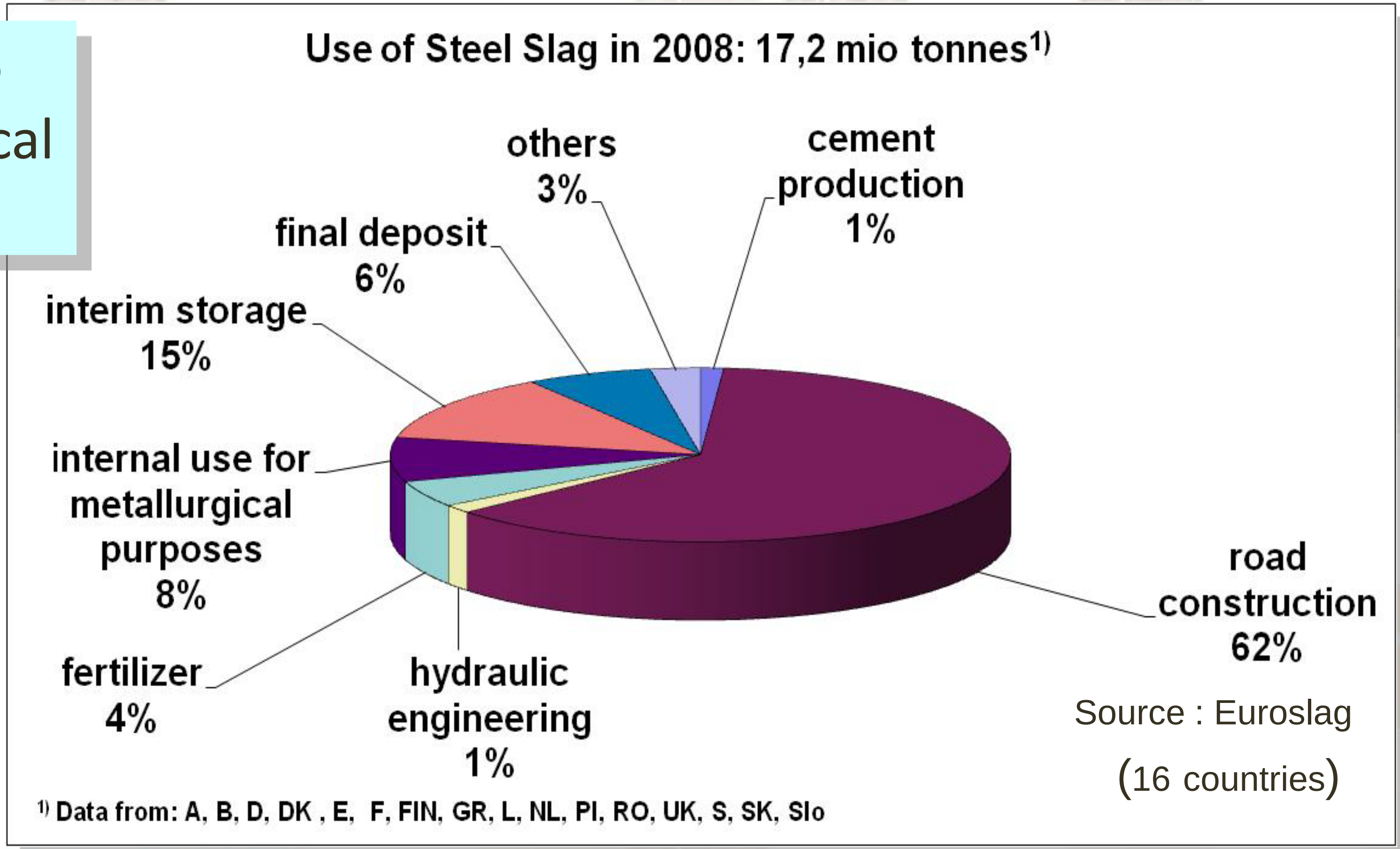
BF Slag common issues

- **One technical drawback in cement** : low early strength
- **Insufficient local cement market volume** :
  - The local market for cement within a competitive distance is often not big enough, due to the size of steel integrated plants.
  - output of one plant ➔ yearly consumption for 18 M inhabitants
  - Cheap local addition materials : Fly ash, limestone, pozzolans
  - Declining or shrinking cement consumption in some areas since 2008 : Europe on the whole (-20%), Spain (-75%)
- **Environment** : CO2 footprint (allocation)

➔ **market diversification needed**

Steel Slags in Europe
79% valorized , 62% in roads

Only 8% to metallurgical recycling !

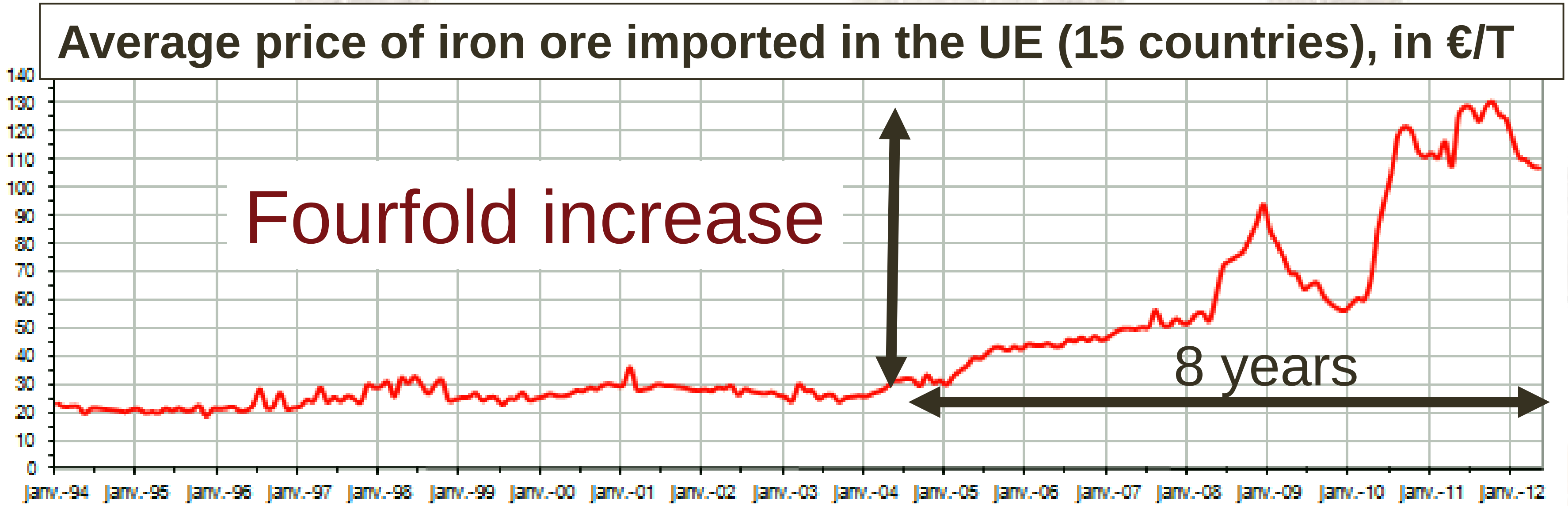


BOF Slag common issues

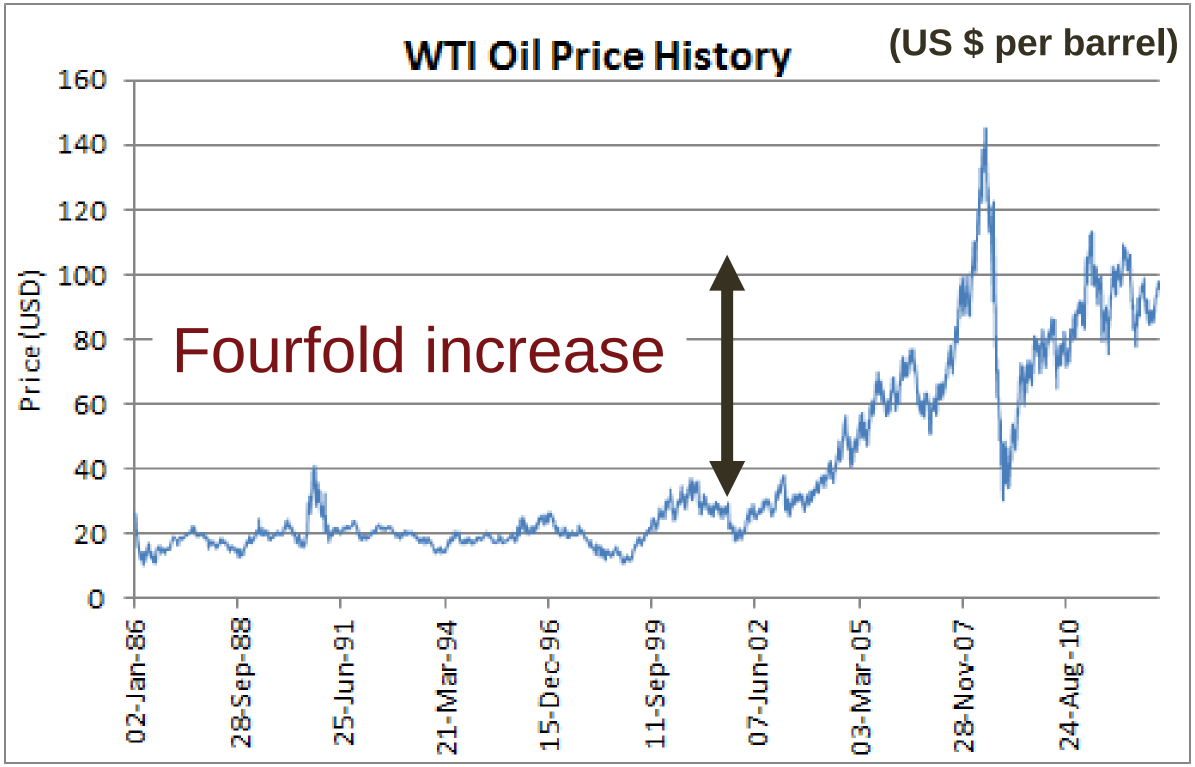
- **Variability : from heat to heat !**
- **Local Market** :
  - demand may be too small, or competition too strong (quarries of natural stone, recycled materials such as demolition wastes)
- **Free lime** :
  - by far the most highlighted issue, as it is the first cause of expansion, which limitates the utilisation as aggregates, today the main destination. But, it is a problem **only for this destination.**
- **Phosphorus**:
  - only 1% in average. Phosphorus is a limitation to internal recycling to sinter plant or BF, depending on operating parameters of the BOF shop.
- **Fluor, Vanadium, pH, may be environmental problems**

Long Term economic trends

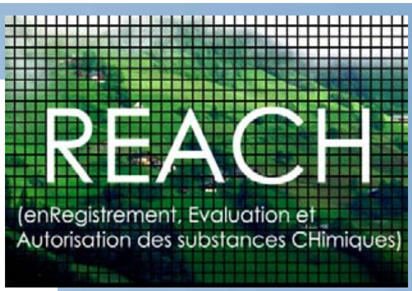
Raw materials : a new era

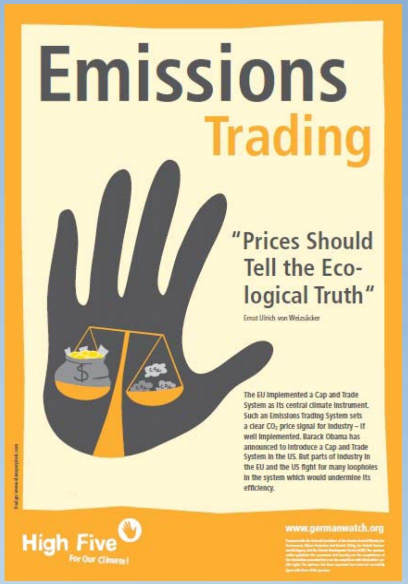


Energy : higher prices and development of renewables

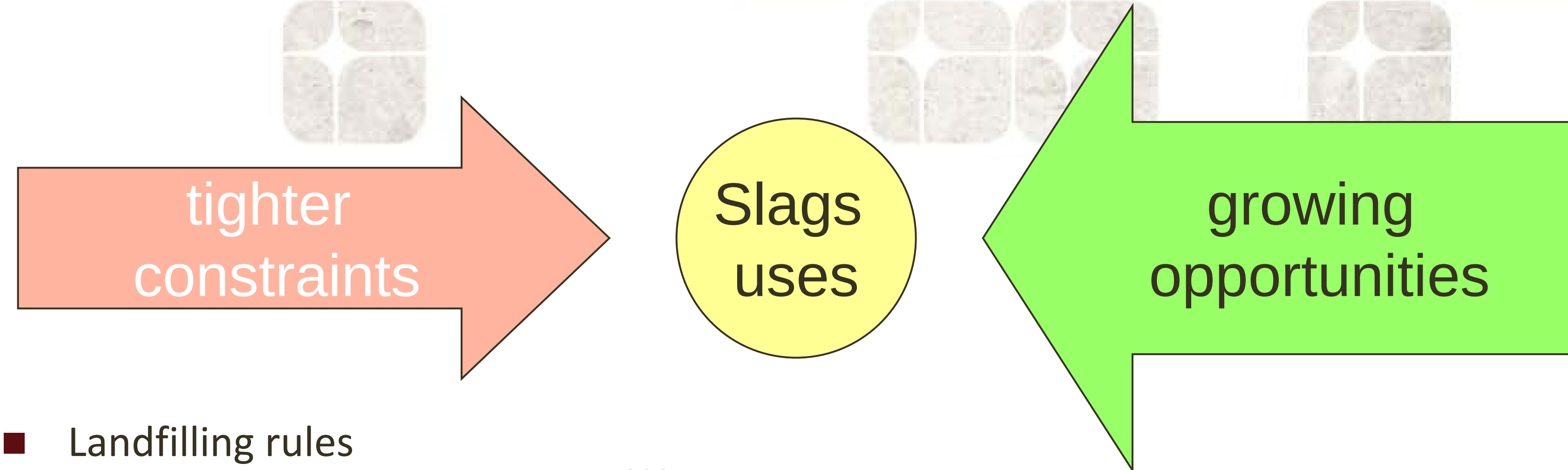


Regulatory trends





Opportunities overweight constraints



- Landfilling rules
- Water quality
- Chemistry (F, heavy metals, pH)
- Leaching

- Wastewater treatment
- Polluted soils and sediments treatment

- Life-Cycle Assessment
- Circular economy
- End of Life recycling
- CO2 emissions quotas
- Sustainable construction
- Sustainable agriculture

Sustainable contruction

- Positive energy buildings
- Environmental footprint (incl. CO_2)
- End of life recycling of materials
- Use of secondary materials

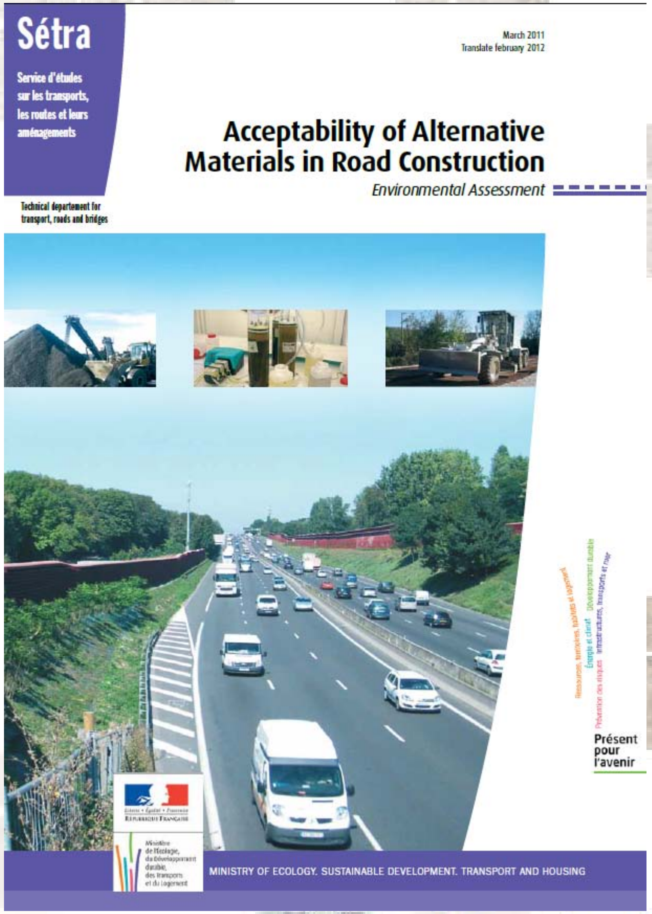
Issues :
legal status of slags
CO_2 footprint

Other examples:

- **Agriculture** : less chemicals (fertilizers, pesticides)
- **Wastewater quality** : less phosphorus
- Management of **dredging sediments and contaminated soils**

Reed bed for wastewater treatment

A more rigorous regulatory framework for slags , ...but clearer and more stable (hopefully) to move forward



Example : new french guidelines on Acceptability of Alternative Materials in Road Construction

Recent Developments in the last 5 years

EUROSLAG conference Madrid Oct 2010 : topics

Leaching of EAF slags

Micro-structure and release of pollutants

Stability of spinels in high basicity slag

Long term leaching behaviour

High Alloyed and Stainless slags

Cement & concrete

EAF slag as aggregates in concrete

(3 presentations)

Road construction

Soil Stabilization

EAF slag (Egnatia Highway)

EAF slag (Spain)

Innovative uses

Raw material for sinter plant

P sorbent for waste water

Water pollution control

Seaweeds beds (Japan)

Fe-Mn alloy production (Japan)

Overview of major developments at pilot or industrial stage

Industrial

- BOF slag as Hydraulic binder or concrete component (China, France)
- BOF slag stabilisation by hot slag treatment (Germany, Belgium)
- BOF slag short flow process

Pilot

- GBFS for geopolymers
- BOF slag as P sorbent from wasterwater
- GBFS dry granulation
- BOF slag for life support in sea waters

Small « niches » or big volume markets ?

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Physico-chemical potential

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Chemical potential of BF Slag

BF Slag

Element	CaO	SiO_2	Al_2O_3	MgO	S	Alcalis	TiO_2
%	35-45	35-40	10-15	6-8	0.5-1	0.5-1	0.5-1

Total potential value of circled components : 40 to 70 €/T slag

The CaO-MgO-SiO2-Al2O3 combination not only allows the slag to be perfectly liquid and fluid, easily to control, but also to produce by quenching a vitreous material having good cementitious properties.

Chemical potential of BOF slag: Primarily, a good raw material for the ironmaking process

BOF Slag (after usual metal recovery)

Element	CaO total	CaO free	SiO_2	Al_2O_3	MgO	P_2O_5	Fe total *
%	40-60	5-15	10-20	1-3	6-8	0.5-2	10-25

Total potential value of circled components : 80 €/T slag

Steel slag also contains minor elements, which may have a huge value. Some slags contain 1% Vanadium, worth 20 € per kg, which means 200 € / T slag.

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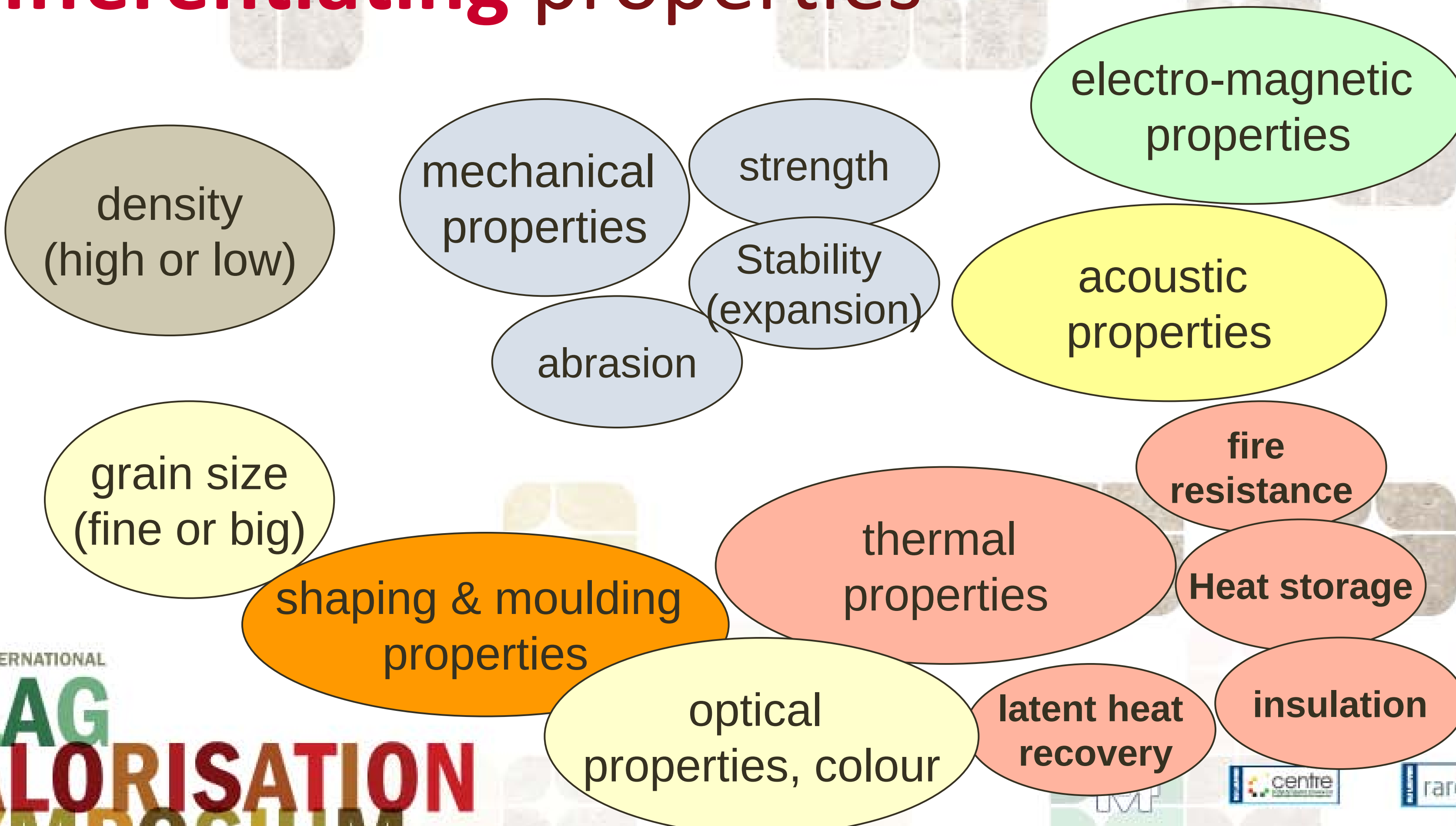
Physical potential : still much to be explored, looking for **differentiating** properties



Future directions

From straw to gold ?

BF Slag : Towards more diversified market driven valorisations

Heat recovery

Air-cooled	Aggregates	clinker rock wool	Heat storage ?
Expanded		Lightweight aggregates	
Granulated	Cement & Concrete	Dry granulation	

Steel Slags :
Better Value from mineral components

Type 3 destinations account today for 25% of all recycling destinations and are likely to grow strongly , driven by rising economical value, and ecological benefits (such as CO2)

1	2	3
Value as Volume (m3)	Value as Stable Volume + aggregate properties (mechanical)	Value as Chemical or Mineralogical components
Earthworks e.g. ports, dykes, Landscaping Civil works Fill	Roads Aggregates Asphalt Pavement Railroad Ballast Blasting material Concrete	**Iron & Steel process** Cement Rockwool Fertilizer Loamy Soil treatment De-pollution

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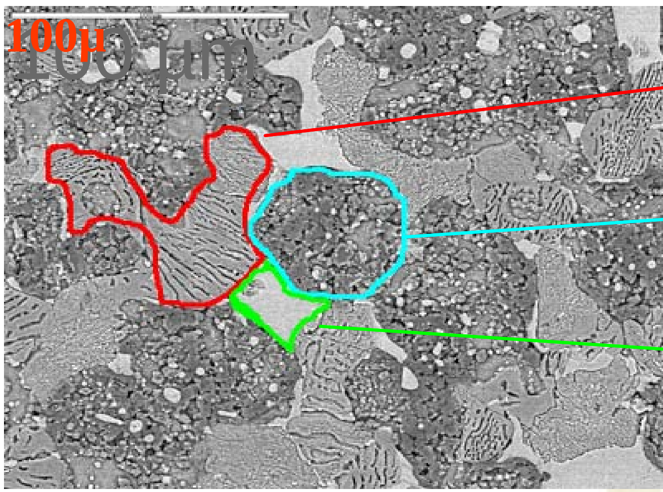
BOF slags : recovery in the steel process should be the priority

- **The first limit to recycle BOF slag is its phosphorus content : → can we extract P ?**



C2S + secondary free-lime
→ external valorization

Primary free-lime + solid solution FeO-MgO → internal recycling

Calcium ferrites
→ internal recyling

Phosphorus is concentrated in this phase

50% of the minerals composing BOF slag are valuable ores

50% are valuable for other applications looking for lime silicates and phosphates

→ slag should be processed like ores : fine crushing, selective separation and enrichment.

Conclusion : slags , a future gold mine ?

- **The 100% recycling target is already achieved** by many leading performers
- The next challenge is to **MAXIMISE THE VALUE** in terms of **SUSTAINABILITY**, ecomically, and ecologically
- This means **making the best out of the minerals**, moving to new diverse destinations, particularly for Steel slags
- **It will take years , but there is the way forward.**

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How to achieve it ?

- associate in **partnership projects** the competencies :
  - of **all the players of the industrial value chain, from the steel maker to the end user.**
  - of **research institutes and universities**

- **Challenges and roadblocks** will have to be overcome, technical, regulatory ones, for sure, but the hardest ones might be the difficulty of access to the market, including standards

« …τὸ μέλλον οὔτε πάντως ἡμέτερον, οὔτε πάντως οὐχ ἡμέτερον… »

« the future is neither wholly ours nor wholly not ours,… »

Epicurus , Letter to Menoeceus, circa 300 BC

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