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SWEREA MEFOS PERSPECTIVE ON METAL RECOVERY FROM SLAGS

Guozhu Ye, Mikael Lindvall, Marcel Magnusson

THIRD INTERNATIONAL
SLAG VALORISATION SYMPOSIUM
THE TRANSITION TO SUSTAINABLE MATERIALS MANAGEMENT

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Outlines

- Background – the drivers
- The IPBM process
- The VILD project
- Conclusion

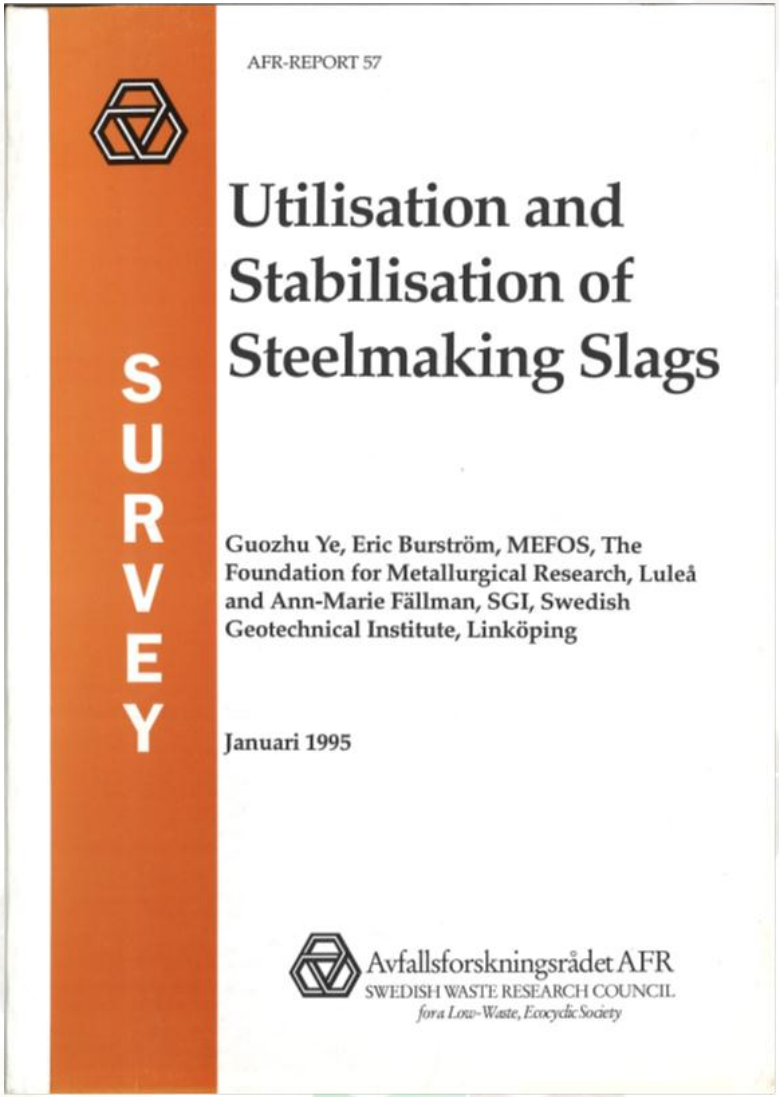
Application and research of steel slags

20 years ago

- Trip to Japan: Prof. Suito, Prof. Iwasa and steelplants Japan
- Tarco AS Denmark (Stålphalt)
- FEhS (Prof Geiselser &Dr. Kuhn)
- Slag seminar Sweden

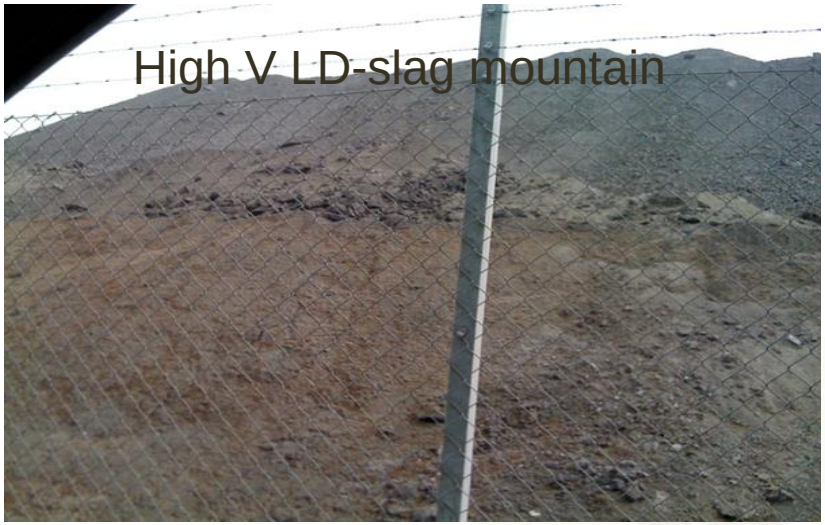
State of the art 1993

- Free lime – volume stability
- Leaching of heavy metal Cr etc
- Phase transformation of the C2S, B-stabilization, ladle and AOD-slag
- C2S/C3P2 separation from LD-slag
- Air granulation for heat recovery

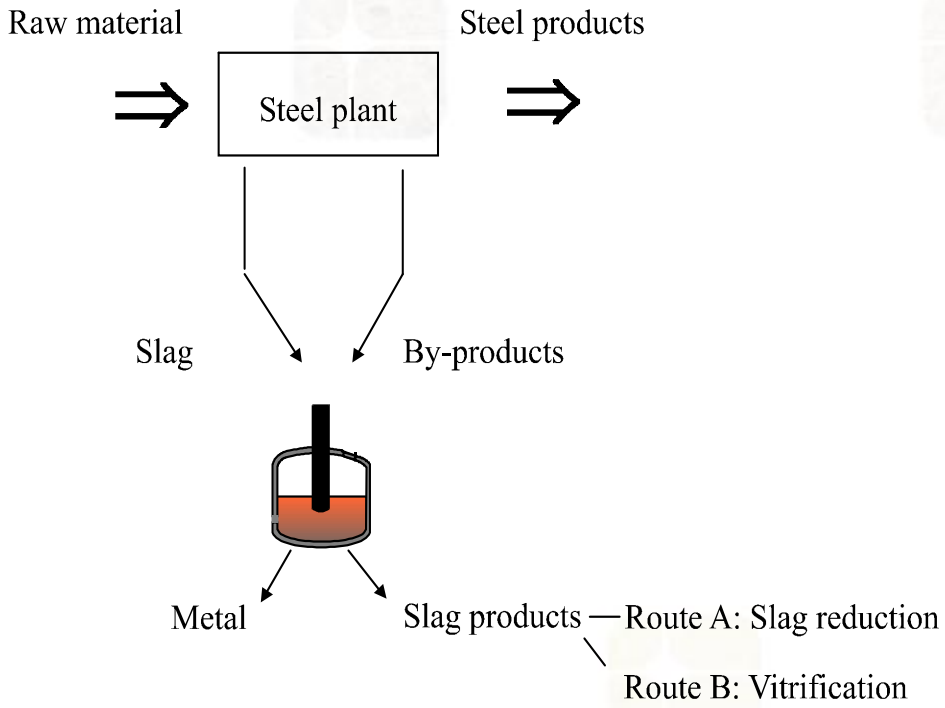


Concerns

- New market/new application, value-added, flexible
- Regulations, lower limits, accidents
- Metal values, the vanadium value in the Swedish LD-slag alone corresponds to about 150 millions US$ per year



IPBM: In-Plant Byproduct Melting

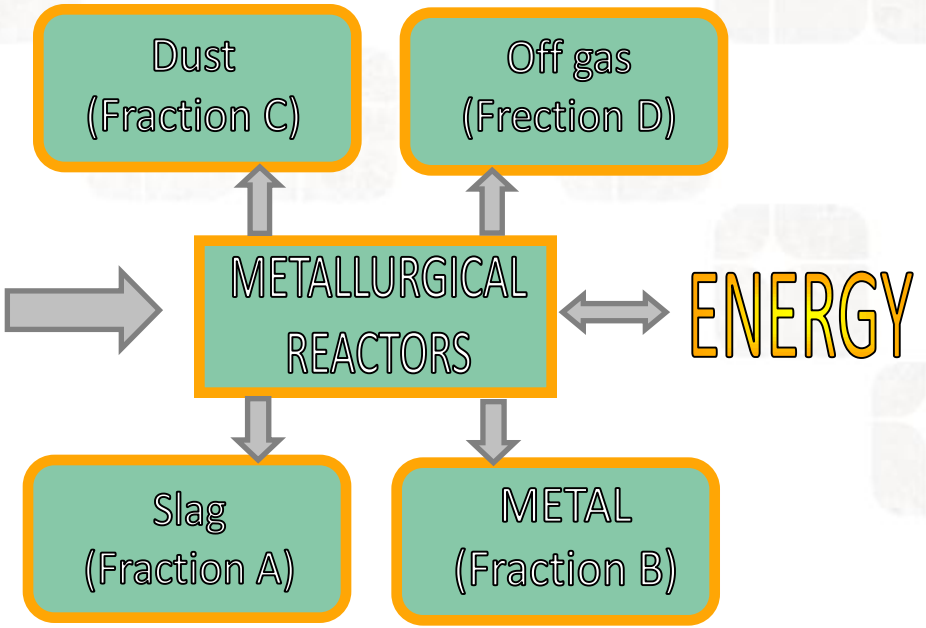


- Stand-alone
- All in one
- Metal recovery
- Clean slag products
- Zero waste

MEFOS - FEhS - CRM - CSM

ECSC - BriteEuram

The metallurgical principle of IPBM



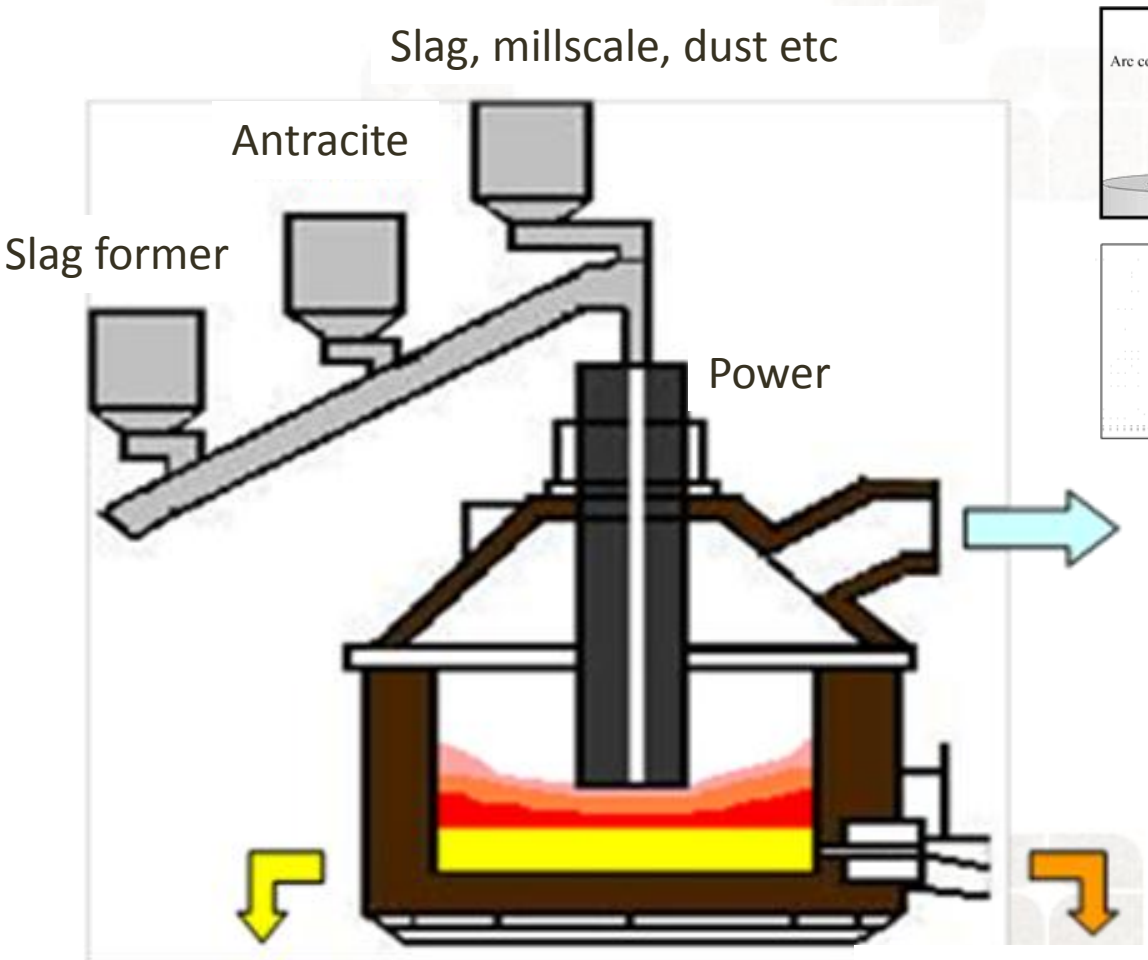
A: CaO, SiO2, Al2O3, MgO

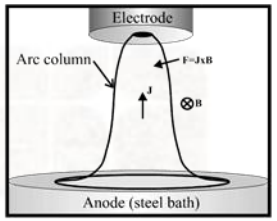
B: NiO, FeO, MnO, V2O3, Cr2O3, P2O5,Cu, Co, Mo

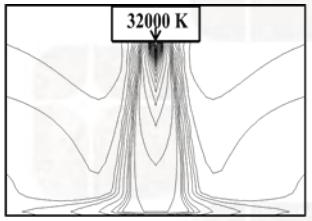
C: ZnO, PbO, Na, K, Cl, Cd, Hg

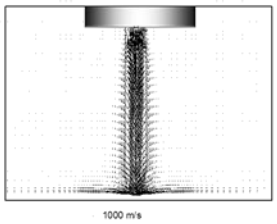
D: C-H-O, plastics/textile/fluff

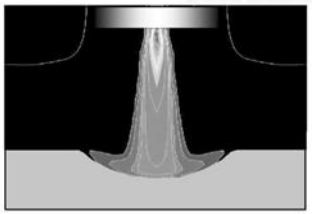
The IPBM flowsheet











1. **Clinker material**
2. **Hydraulic powders**
3. **Metallurgical powder**

Materials treated

Steel work resdiues

- BOF-slag with high VOx
- Normal BOF-slag
- EAF- and AOD-slag
- BOF-dust/sludge
- BF-dust/sludge
- EAF-dust from carbon steelmaking
- EAF-dust from SS
- Millscale
- Pickling sludge

Other residues

- Vanadium rich ashes from power plant
- Fayalite slag from copper smelter
- Bauxite (low quality, iron rich)
- Scrap residue from scrap transportation and handling

Major results – easy to compose!

Test no	Product	Slag modifier		Fe	CaO	SiO_2	MnO	P_2O_5	Al_2O_3	MgO	Cr_2O_3
1	Clinker material	Sand, Bauxite	Target	3.7	62-66	20-21			4.7	<5	
			From test	4-3	54.7	20.8	3.5	2.2	6.9	2.2	0.24
2	Metallurgical powder	Bauxite	Target	<2	50-55	16			22	2-10	
			From test	0.35	56.6	19.6	1.18	0.2	21.9	2.85	0.03
3	Metallurgical powder	Bauxite	Target	<2	50-55				25-30	2-10	
			From test	0.3	54.2	13.6	1.75	0.47	27.3	1.81	0.03
4	Hydraulic binder	Scrap residue Bauxite	Target	<2	45	33			14	2.5	
			From test	1.81	41.8	31.5	51.7	0.06	17.3	4.41	0.08
5	Hydraulic binder	Scrap residue Bauxite	Target	<2	45	33			14	2.5	
			From test	0.45	44.5	34.4	0.93	0.04	14.0	4.41	0.04
-	BOF-slag analysis	-	-	18.4	51.0	11.3	3.67	2.56	1.60	1.20	-

Major results

Specific figures

- DC-power: 1.3 MWh/ton LD-slag
- Anthracite: 130 kg anthracite/ton
- Graphite electrode: 2-3 kg

Metal recovery

- V: 85%
- Cr: 99% (0.02%Cr in the slag)
- Ni and Mo: close to 100%

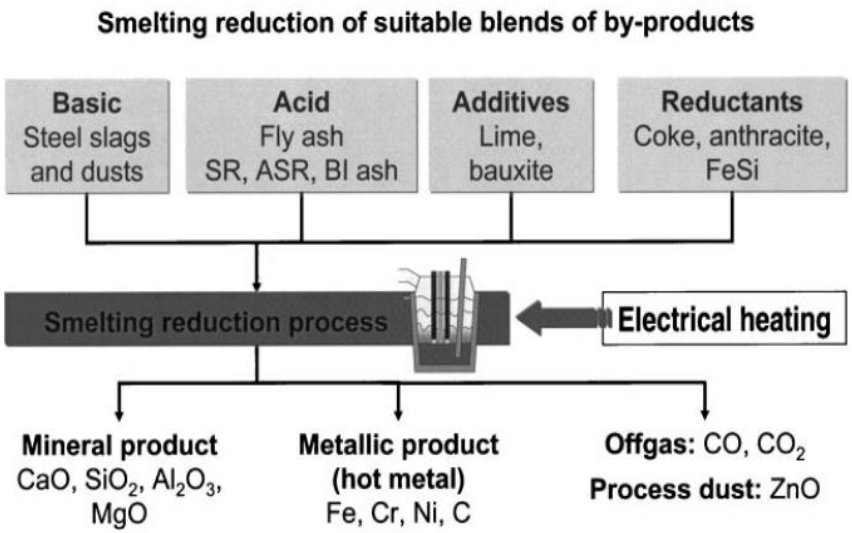
DC furnace – an excellent tool

- High selectivity in reduction degree and in the "to be treated" materials
- Low dust carry-over for treatment of fine grained materials
- High accuracy in control of the final slag composition
- Ability in treating high aggressive slag
- Rapid response time of important process parameters such as energy consumption rate and reduction efficiency
- High energy efficiency

Continuation of IPBM?

ZEWA process (IPBM II)

CRM – VAI -etc



IPBM III ?

Pilot MEFOS 2009

VILD – Recovery of Vanadium in LD-slag 2005-2012

- Vanadium balance
- The VILD activities and results
- The VILD products
- Summary

MISTRA – Swedish Founddation for Strategical Environmental Research
SSAB – LKAB – Ruukki - MEROX

Vanadium Balance at SSAB, 3.8 Mton HM

LKAB Iron ore Pellets
6 300 ton V
0.13 % V
Impossible to decrease

Coke
Coal 0 ton V
Limestone

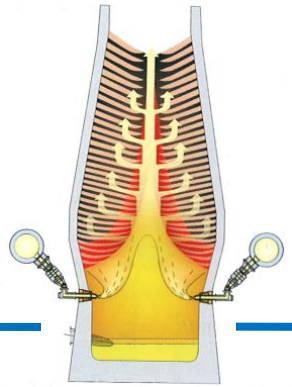
LD-slag
50 % recycled
5 400 ton V
2.7 % V

200 000 ton
LD-slag
50 % disposal
5 400 ton V
2.7 % V
problem-possibility

LD-slag
10 800 ton V
2.7 % V

Scrap
100 ton V

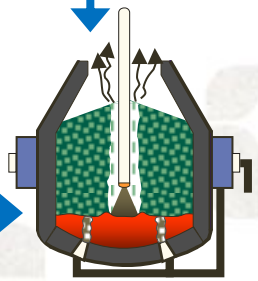
Alloys
400 ton V



Blast Furnace

600 000 ton
BF-slag
400 ton V
0.06 % V
problem

11 300 ton V
0.3 % V

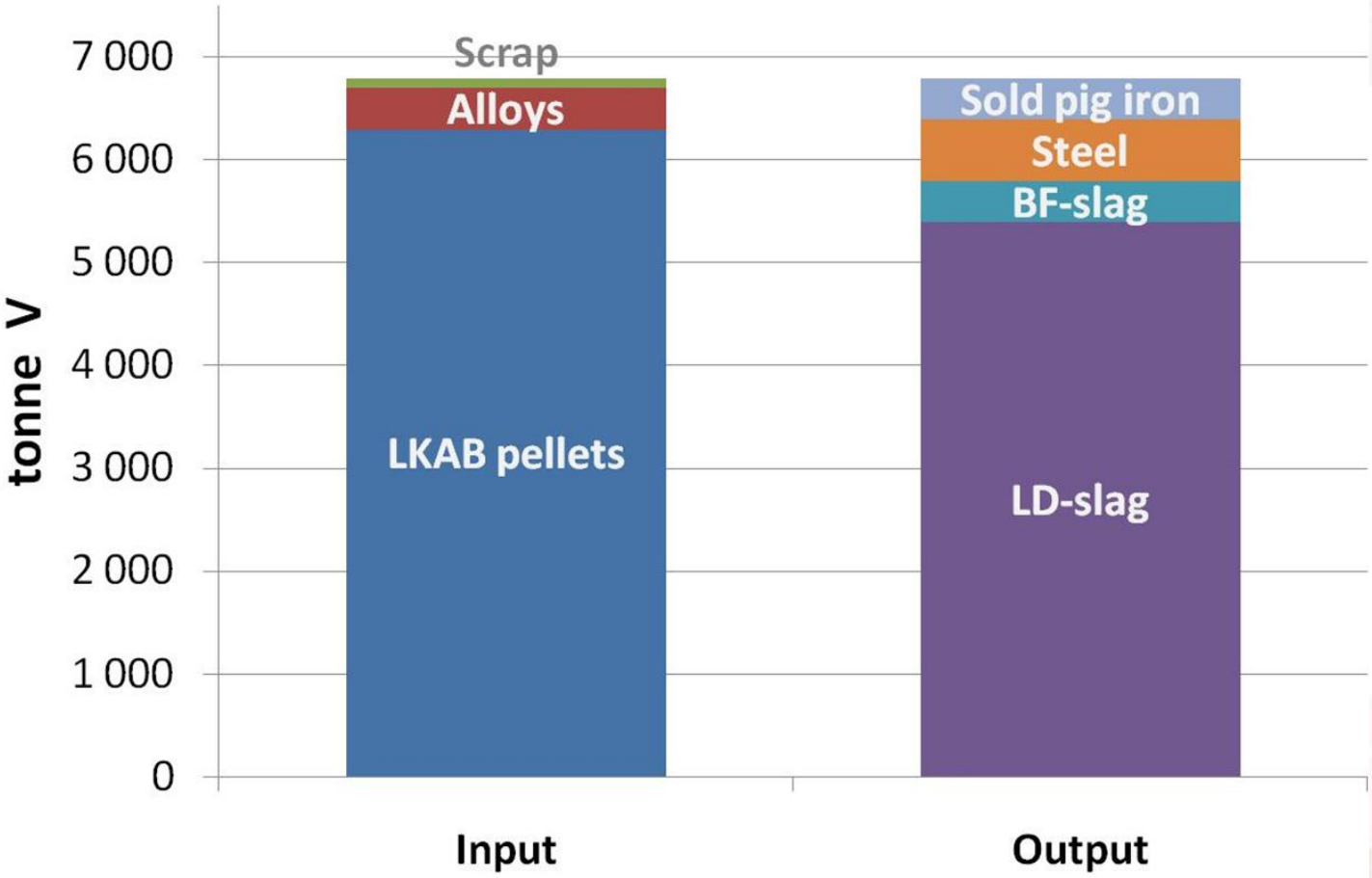


LD Converter

Crude Steel
200 ton V
0.004 % V

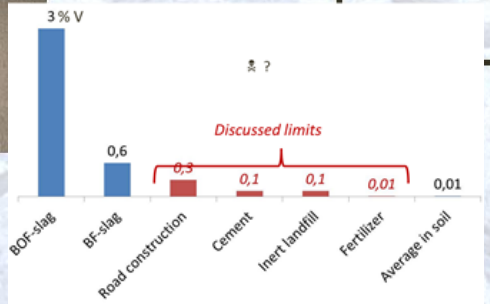
Pig iron sold, 400 ton V

V – balance, feeds and products



Purposes of the VILD project

High V LD-slag

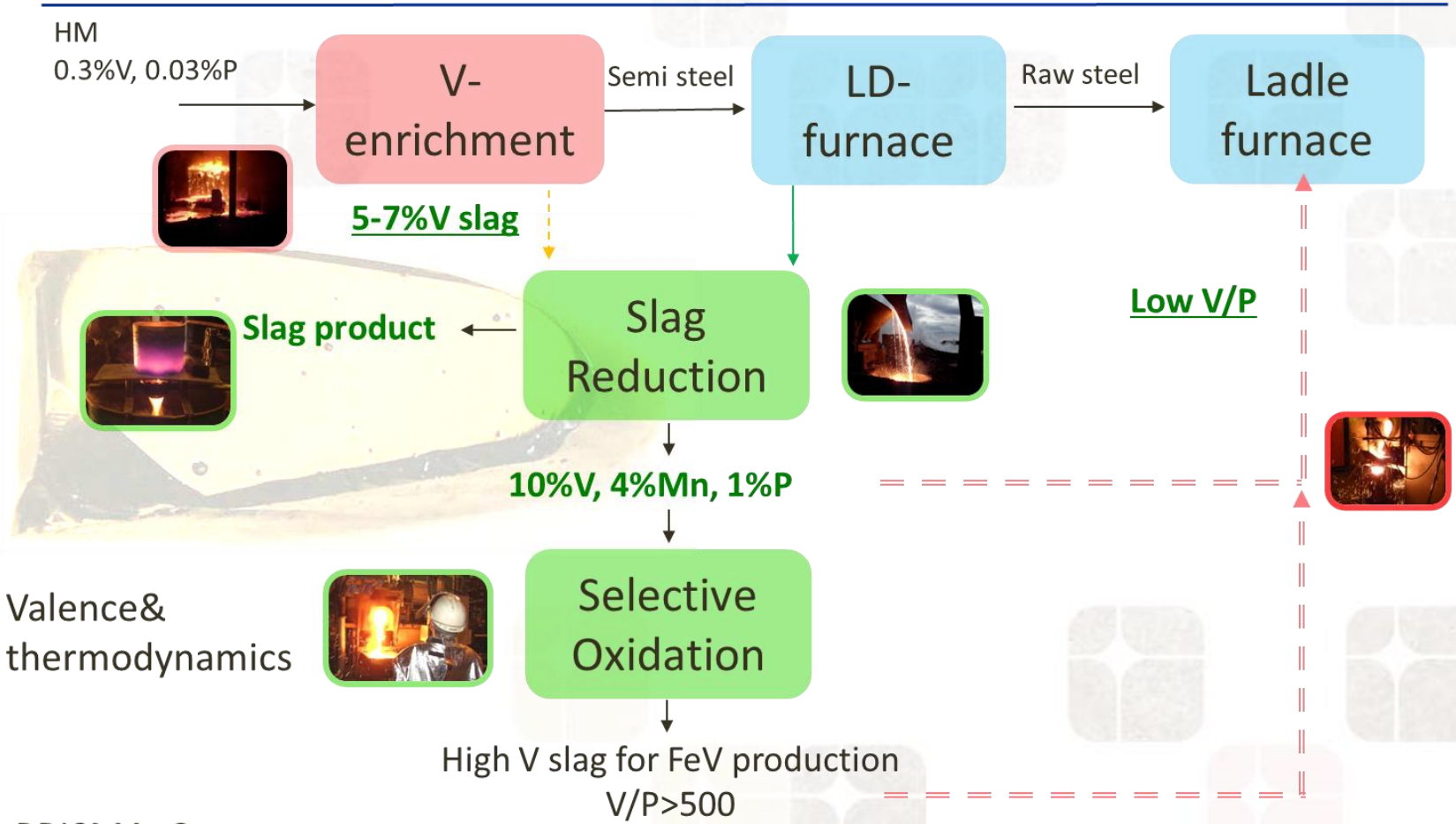


FeV-product

Slag product

- A cost efficient and environmentally sound processing concept
- Two products, zero wastes
- World leading V-research group

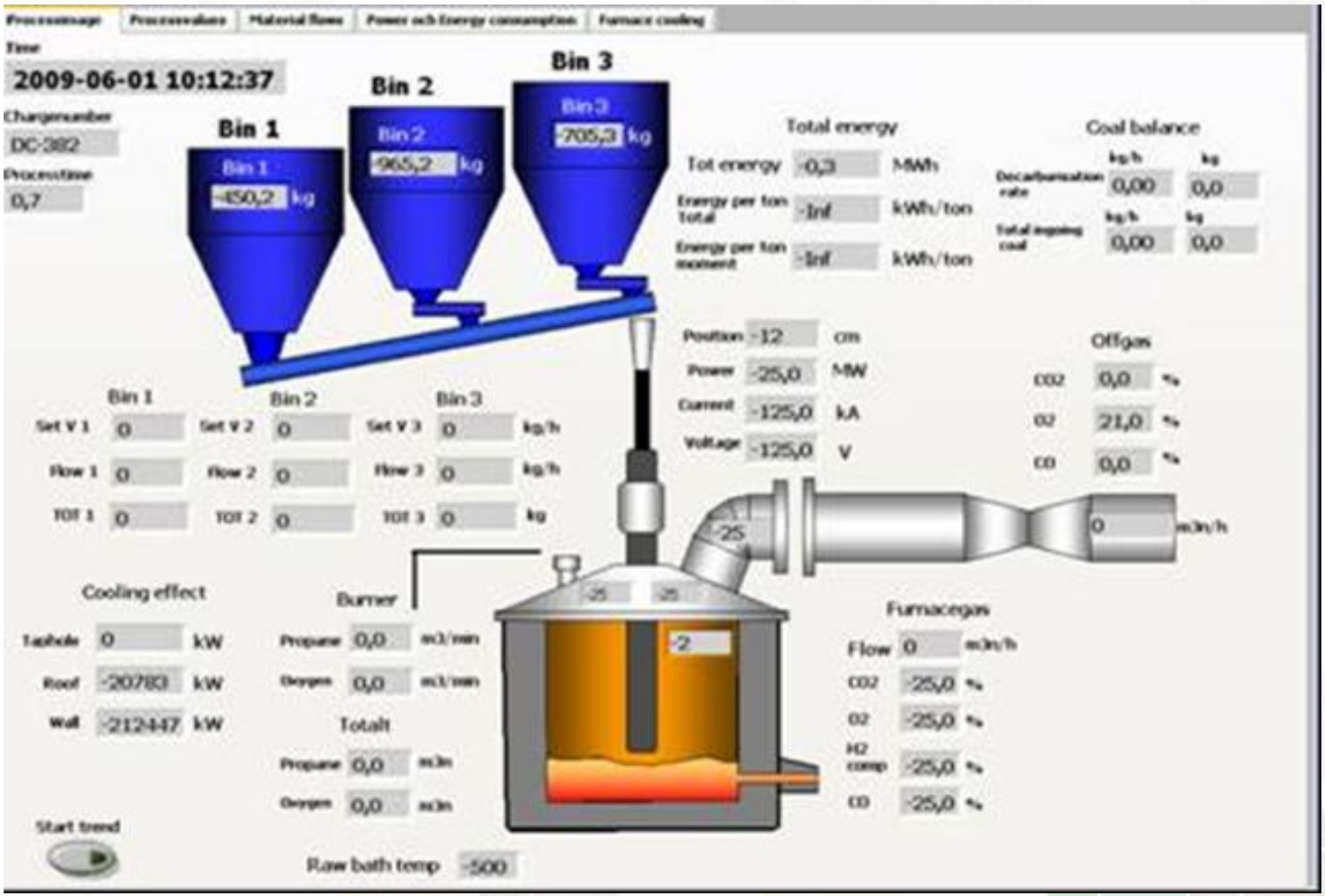
The project activities



PRISMA: Consequences

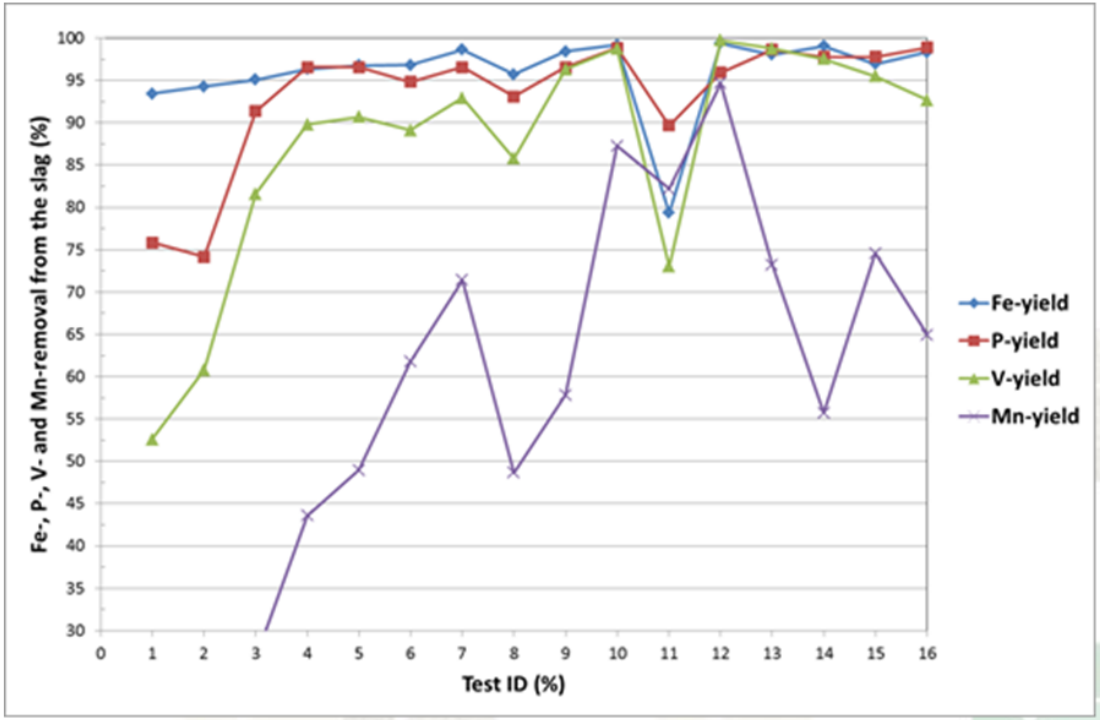
Project by the industrial partners: V in soil, SLU, HTH

Cold slag reduction -
DC furnace set up at Swerea MEFOS, 3 MW



Test results from September 2011

	V-recovery %	Energy cons MWh/ton slag	Flexibility	Reductants
LD-slag	>90%	1.3	Excellent	C, C+FeSi, C+Al, C+SiC
	>90%	0.9	Excellent	SiC
LUVA-slag	>90%	1.2	Excellent	C, C+FeSi, C+Al
	>90%	0.9	Excellent	SiC



Hot slag reduction

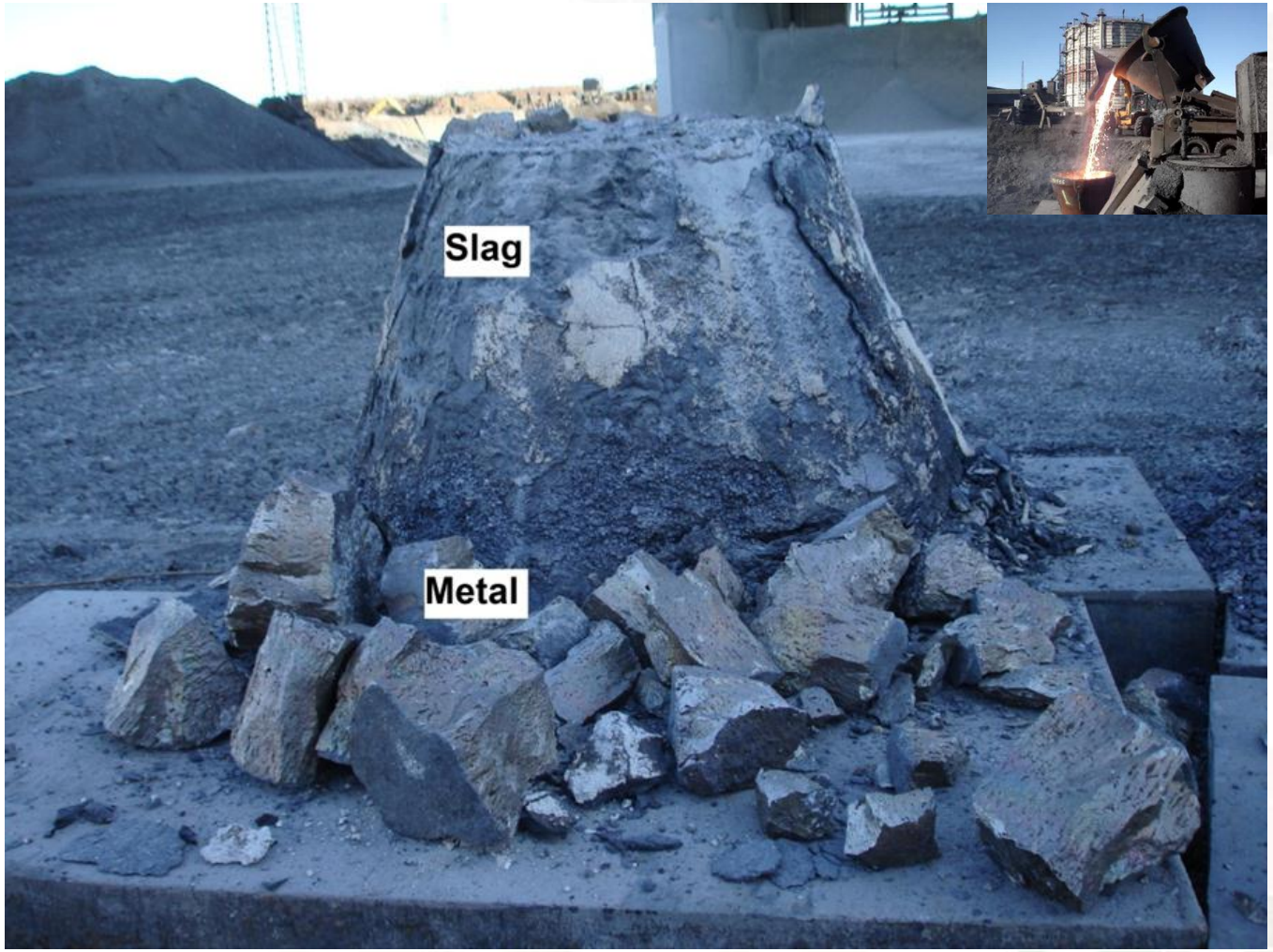
Plant trials - tapping

Plant trials - Injection

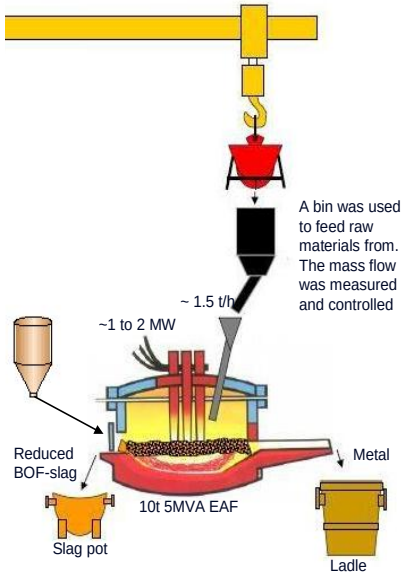
Pilot trials - Kaldo

Pilot trials - Injection

Metal and slag products



Trials in a 10 tons EAF



mass%	Fe	V	CaO	SiO_2	MnO	P_2O_5
Slag 1	0.08	0.03	41.63	37.40	0.32	0.01
Slag 2	0.07	0.03	37.62	14.17	0.21	0.01
Slag 3	0.64	0.04	37.20	23.53	0.34	0.01

Slag Product, MEROX

- Slag from AC- and DC-trials have been granulated, crushed and mixed with OPC
- Strength measured after 2, 28 and 91 days
- MERIT5000 + OPC as reference

	R2162	D413	MERIT5000/OPC
2d	12.8	15.6	16.5
28d	43.6	54.4	52.2
91d	56.7	60.2	61.0
Glashalt	73.2	97.3	99
Densitet	3018	2961	2924
Blaine	460	466	505

Summary of VILD project

Reduction

- Cold or hot slag
- High V-recovery
- Slag could be used in cement
- What reactor best?

Several products

- Basic high V-slag
- FeV (10-20%V, 1%P)
- Acid high V-slag
- Pig iron
- Reduced clen slag

Inspiration Prize 2011 by the Swedish Recycling Industry

Summary

There are a wide range of options for economic and ecological recovery of metals, minerals and energy from metallurgical slags:

- The IPBM-project has shown that the **metal recovery and diversity of the slag products are the key issue**s for the future slag utilisation to meet the ever increasing demands of the mechanical and environmental properties of the slag products and the ever increasing raw material prices.
- The VILD-project alone has a potential of savings of more than half million tonnes CO2 and metal value alone corresponds to more than 150 million US$ each year. **High economic and environmental potentials**
- It is possible to make slag money with **innovative ideas and technologies**
- **Pilot testing** is the key for innovation
- **Post-furnace treatment** of molten slag for metal recovery, control of the slag chemistry and mineralogy will most likely be **a necessity** for the metal producers and smelters in the near future.

Thank you and questions?

MISTRA - SSAB - LKAB - Ruukki - MEROX