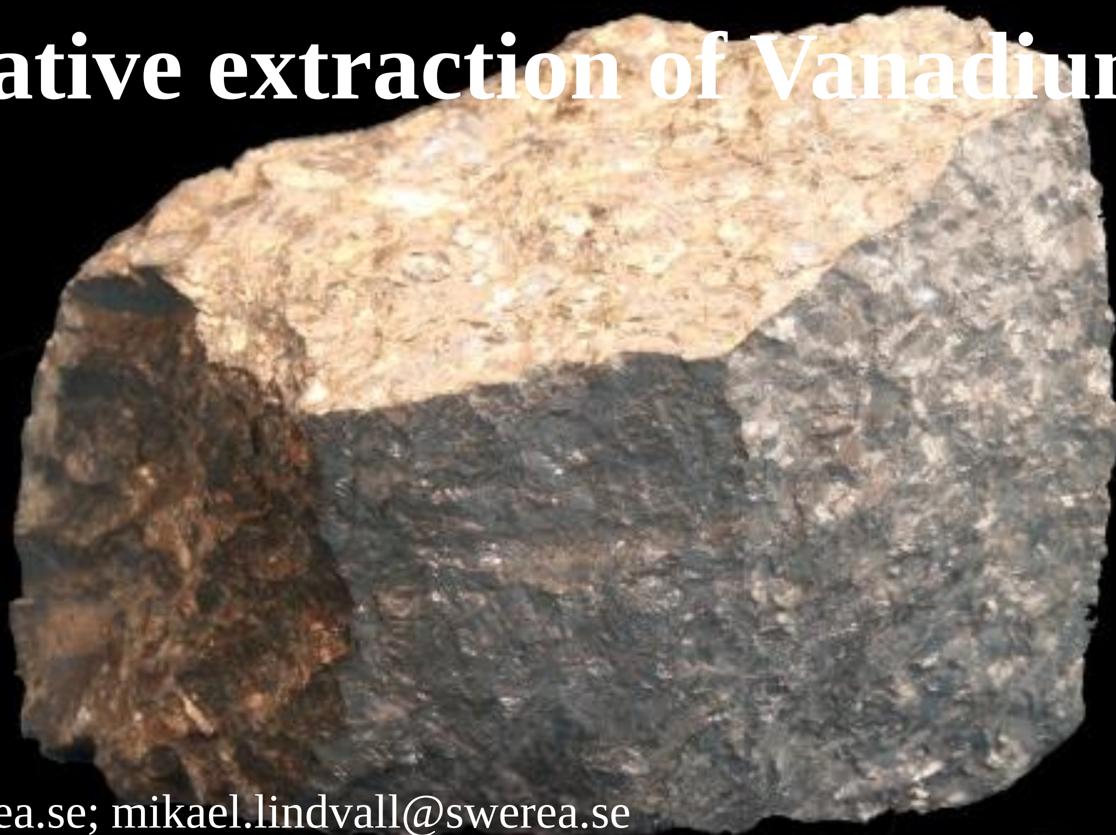
OVERVIEW on the EXTRAVAN – Innovative extraction of Vanadium



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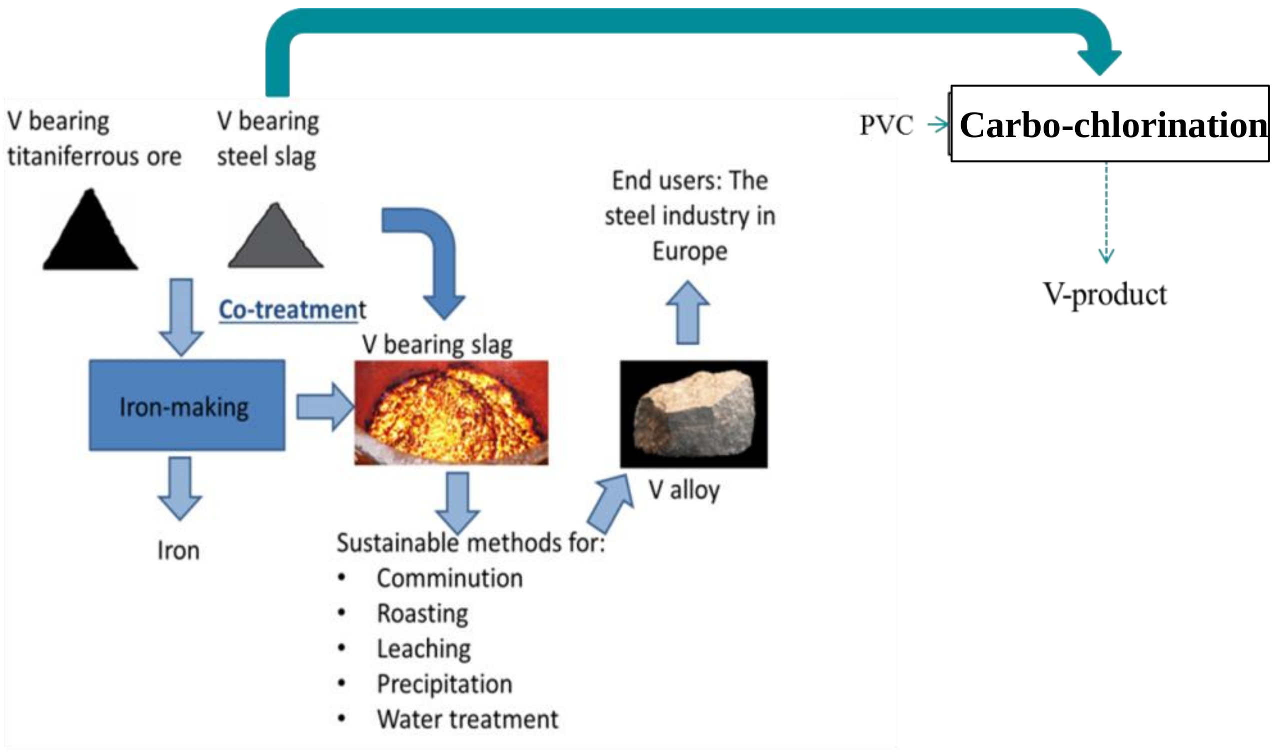
Budget € 1.2 million
From 2014-12 to 2016-12

Background and approaches

Objectives

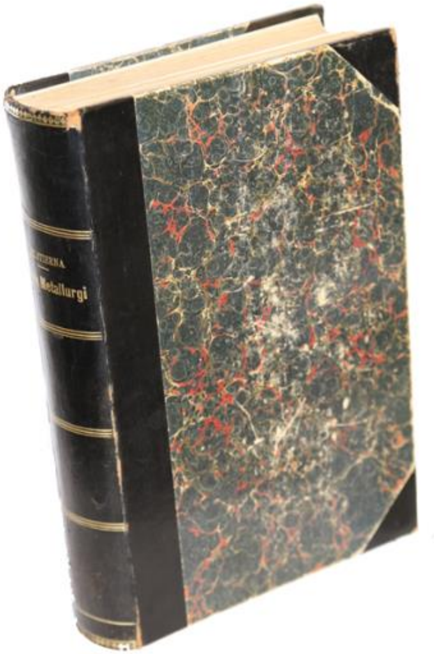
- V independent
- Sustainability
- Primary and secondary
- Innovative solutions
- Create jobs

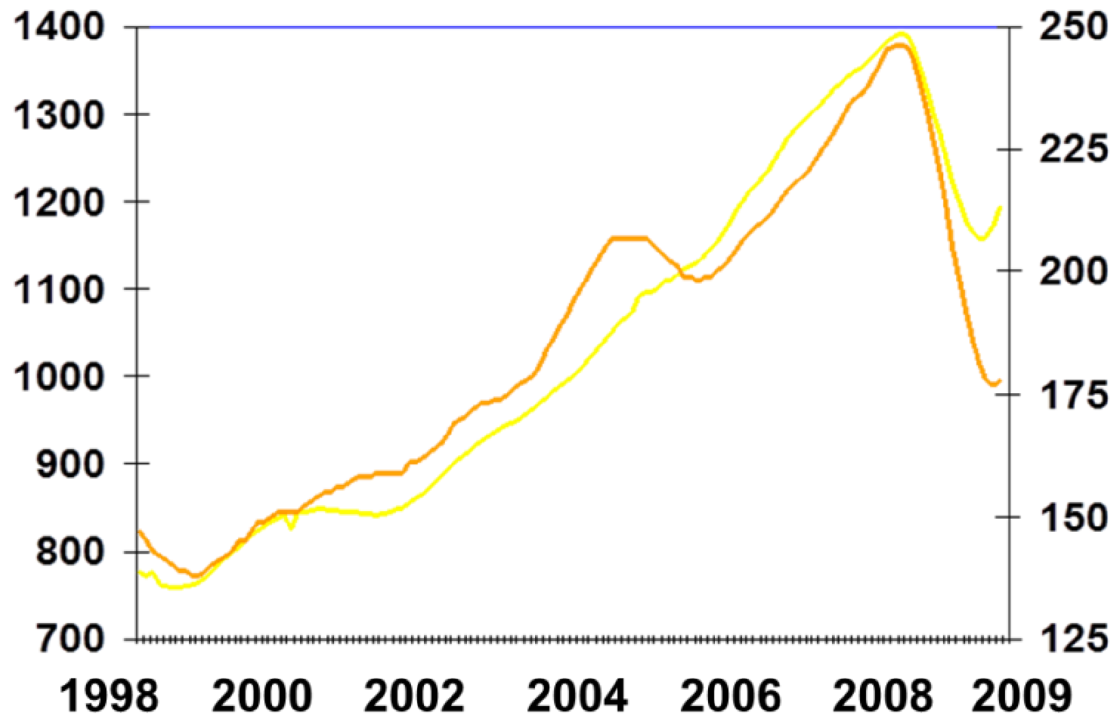
Approaches



WhyVanadium?

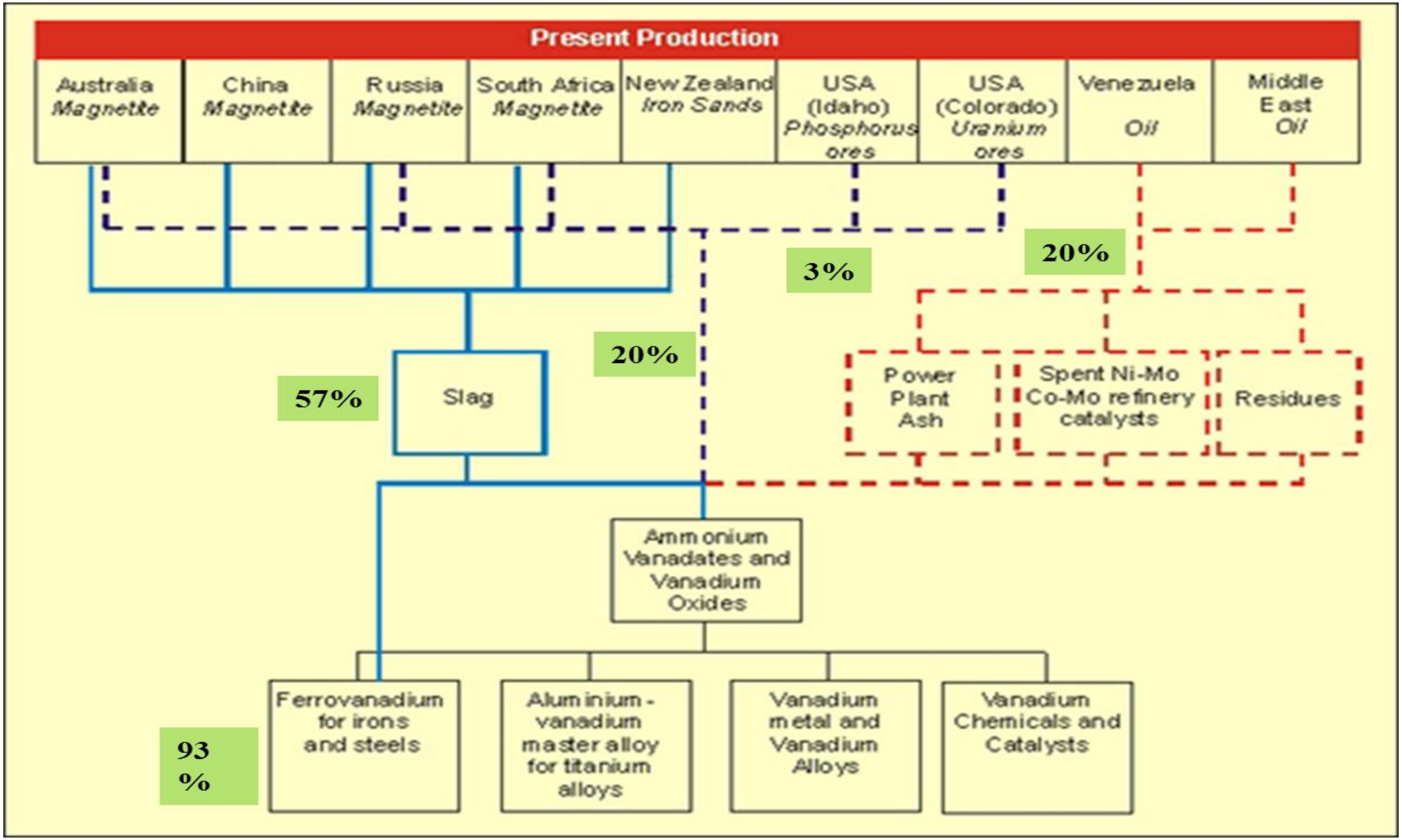
Järnets metallurgi: **from 0.29 % to 0.75 %V improving the yield strength by 44 %.**



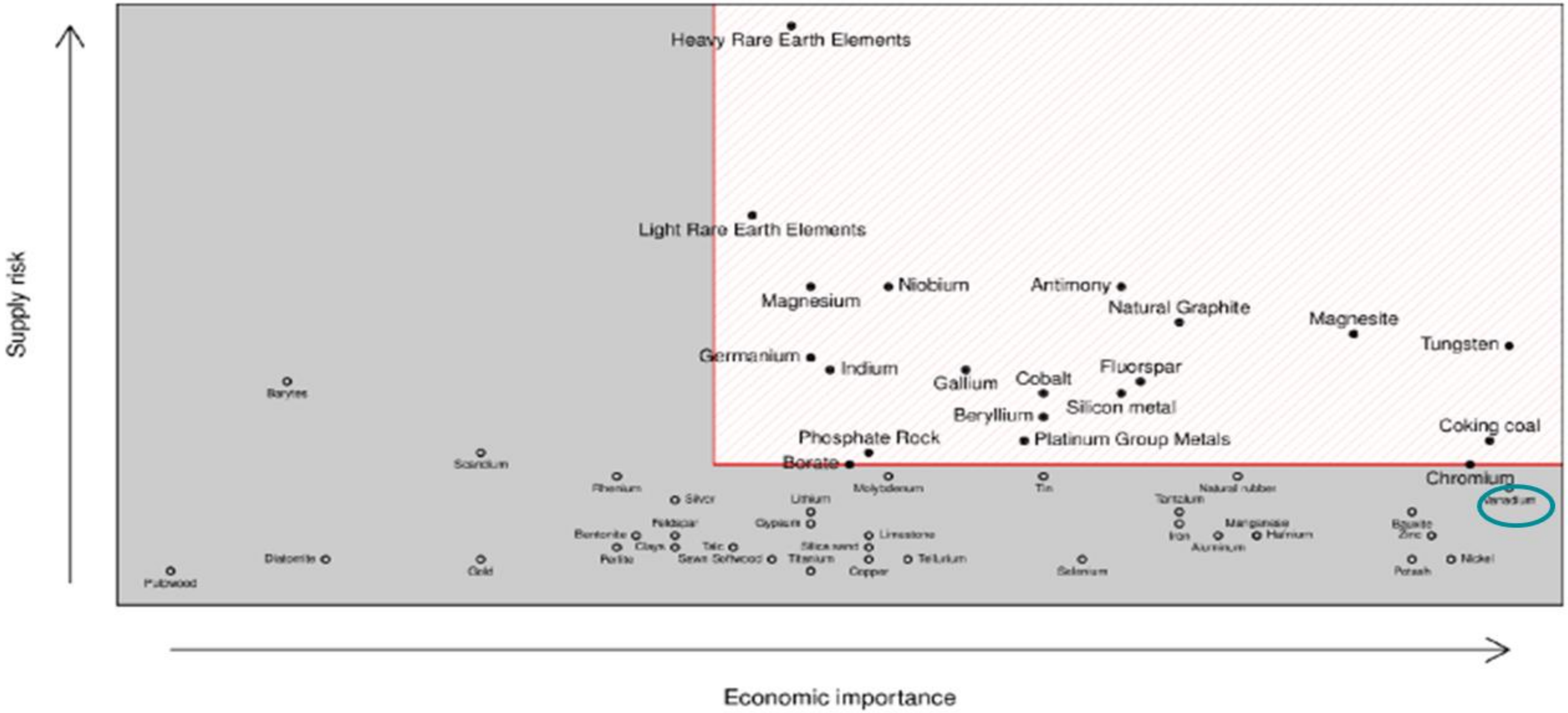


- **95% Steel**
- **5% Chemical and Ti-alloy**

Vanadium Sources and Production



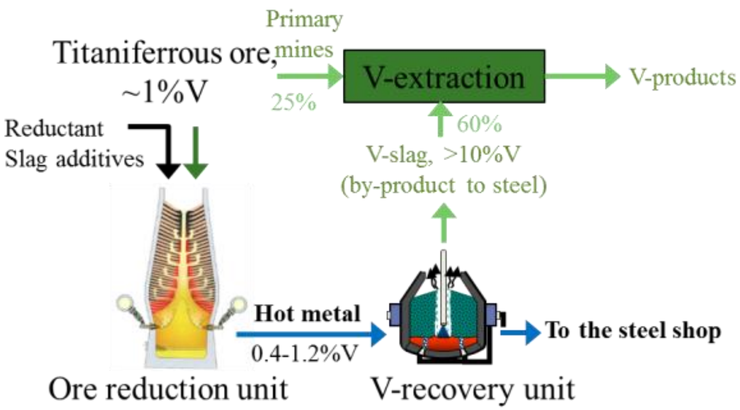
V – an important metal for the EU



EU V (FeV, V2O5) = 10 000 tons; all raw materials imported!!!!

Do we have V-resources in EU?

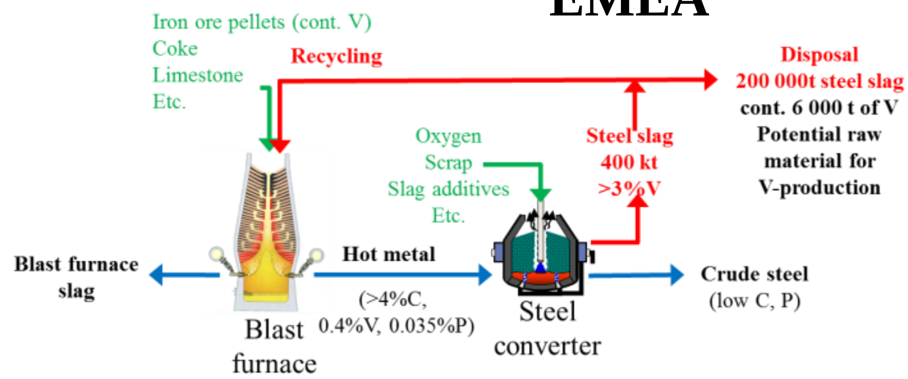
Primary source

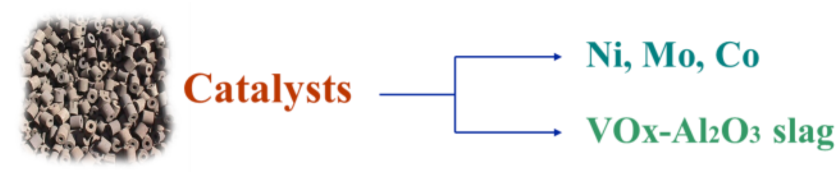


Mustavaaran Kaivos Oy

Secondary sources

SSAB, EMEA





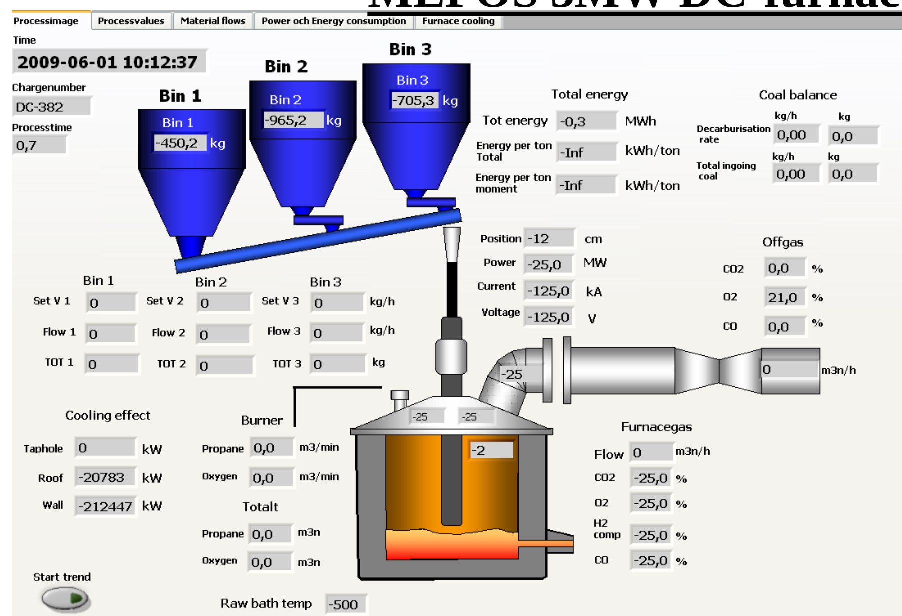
Background, Reduction trials to obtain a high V-pig iron

	Fe_{tot}	V_{tot}	MgO	Al_2O_3	SiO_2	P_2O_5	CaO	TiO_2	MnO
Concentrate	62.2	0.84	0.67	1.11	3.03	0.003	1.10	7.19	0.23

- **Ore concentrate + 20 % V-rich (2-3%V) steel slag (SSAB)**
- **39.5 tonnes of hot metal was produced containing <u>1.86%V</u>**

<u>MKOy - MEFOS</u>

<u>MEFOS 3MW DC-furnace</u>

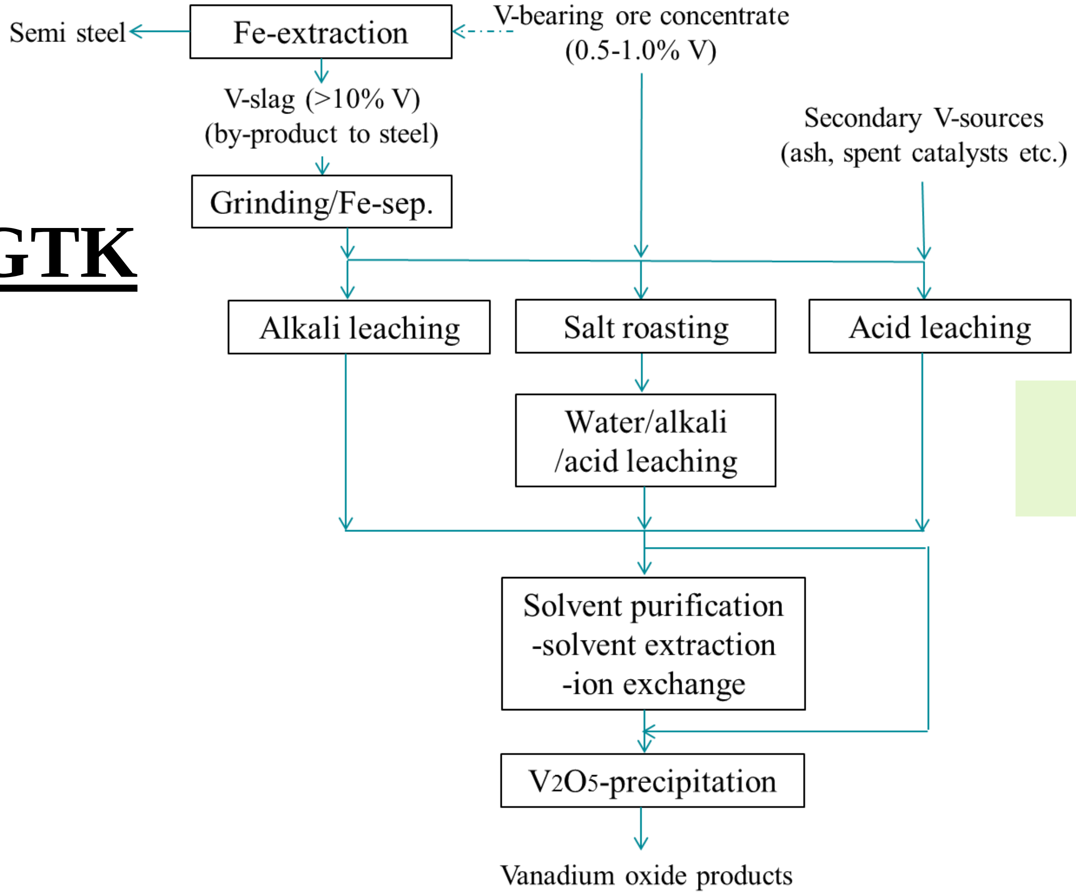


Background, V-slag produced from the obtained high V pig iron

- The hot metal produced in the DC campaign was oxidized using MEFOS 6 tonnes converter
- **<u>The V-slag</u>** was composed of **<u>16.8-20.1% V</u>**, 0.014-0.028% P, 5-6% MnO, less than 18% SiO2 and 24-30% Fetot

<u>MKOy - MEFOS</u>

Standard routes for production of V-products from ore concentrate directly, from V-slag and secondary sources



<u>MKOy- GTK</u>

Leachable sodium vanadates

High T roasting and leaching of V slag

=>Conventional low T processing was found not suitable for V-slag with very high V content

- **Development of a new salt roasting technique – HIGH T ROASTING**
- **Optimization of leaching procedure, e.g. time, pH, temperature, particle size etc.**

Leaching

Water Leaching
- crushed V-slag -4.0 mm
- boiled water
- decanter 0.5-3.0 L
- mixing 150-200 rpm

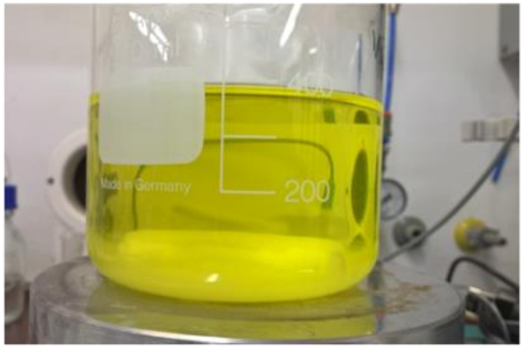
Leaching procesure I
- 4 steps (4x20min)
- 4 filtrate → merge together to get 1 PLS solution

Leaching procesure II
- 1 step (120min)
- 1 filtrate → PLS solution

→ Results of leaching tests gave evidence of succesfull vanadium extraction: The highest vanadium recovery was 97 %

Precipitation

Feed
pH 8



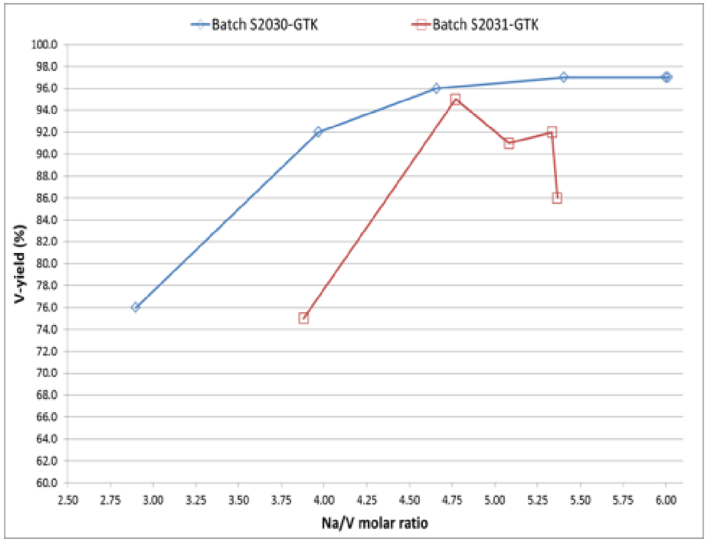
Reaction time 1min, precipitation has been started

Reaction time 7 h, nice yellow precipitate

Yellow vanadium precipitate and filtrate

Almost complete vanadium recovery was achieved

High T roasting and leaching of V slag



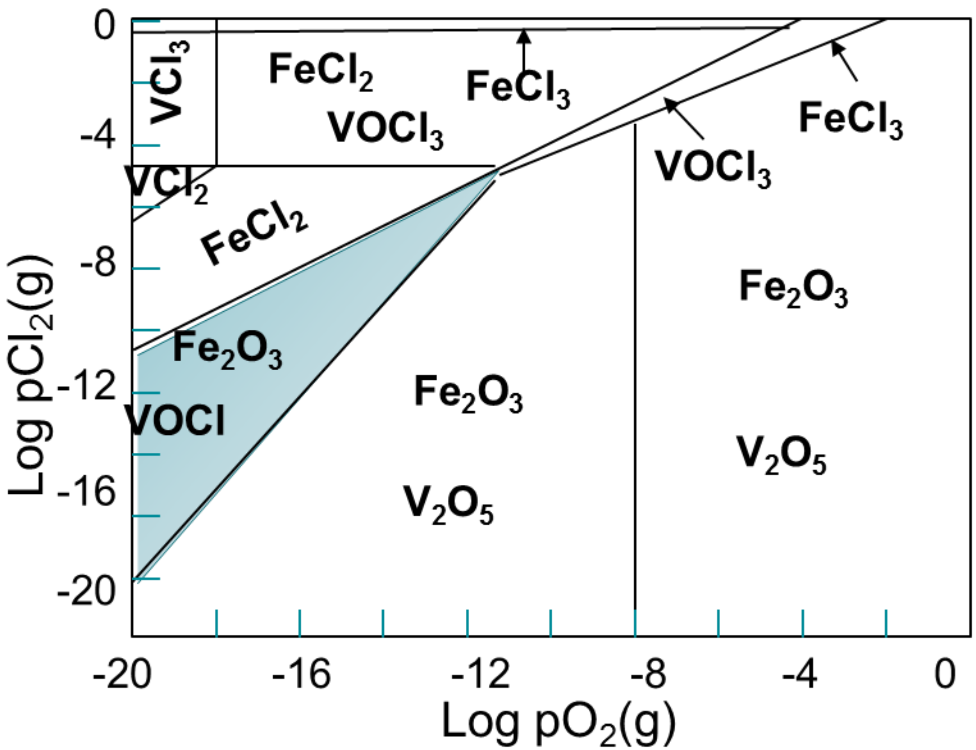
Amonium Metavanadate
NH4VO3

75.5%V, 0.42%C, 0.08%P, 0.22%Si, 1.53%Al, 0.31%Cr, 0.13%Na

Principle of carbo-oxychlorination

	Al	Ca	Mg	Si	Cr	Fe	Mn	P	Ti	V	C
%	1.1	28.6	6.0	5.1	0.2	17.5	2.4	0.1	1.4	2.7	0.6

$$MeO + C + Cl_2(g) \Rightarrow MeCl_x(g) + CO/CO2(g)$$

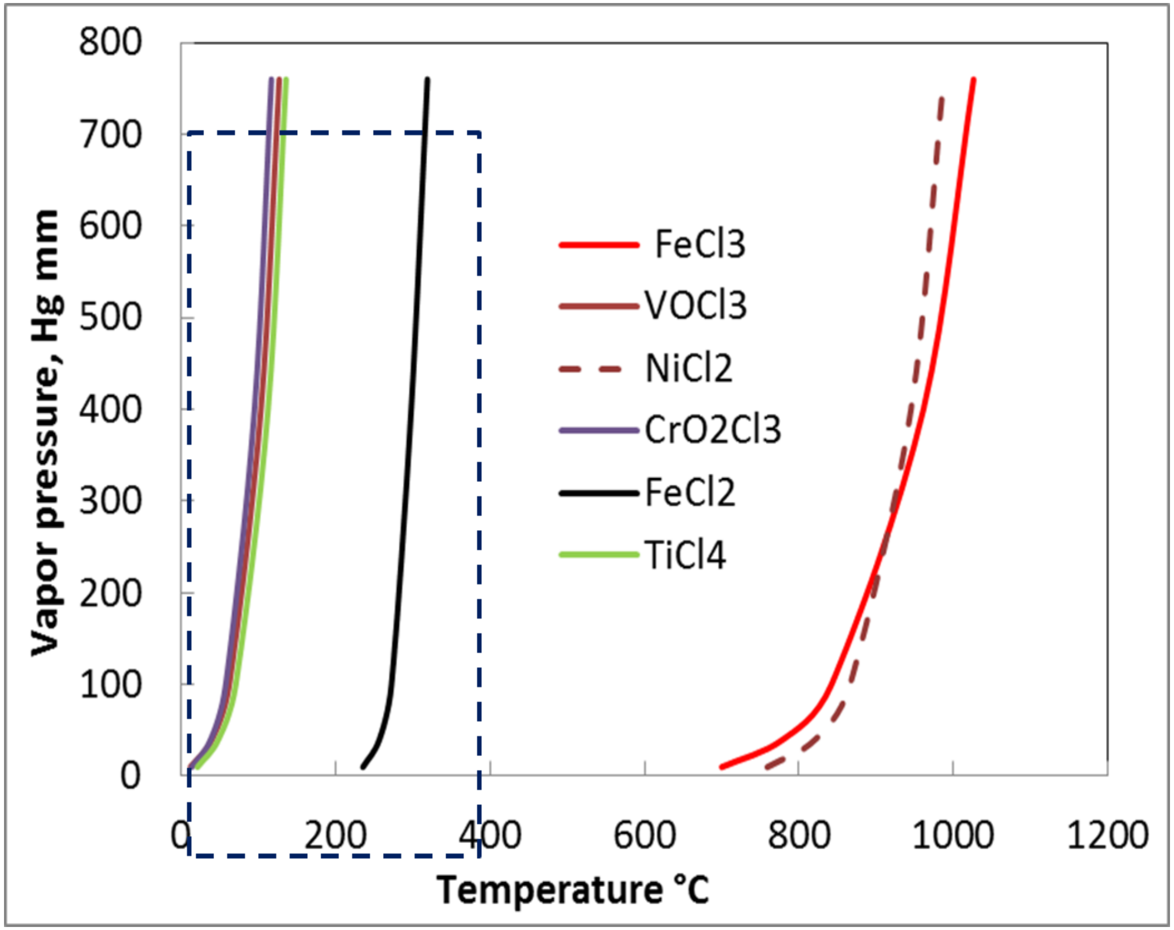


Selectivity

P_{Cl2} vs P_{O2}

Thermodynamic considerations

Vapor pressures of some metal chlorides (Metals contained in BOF slag)

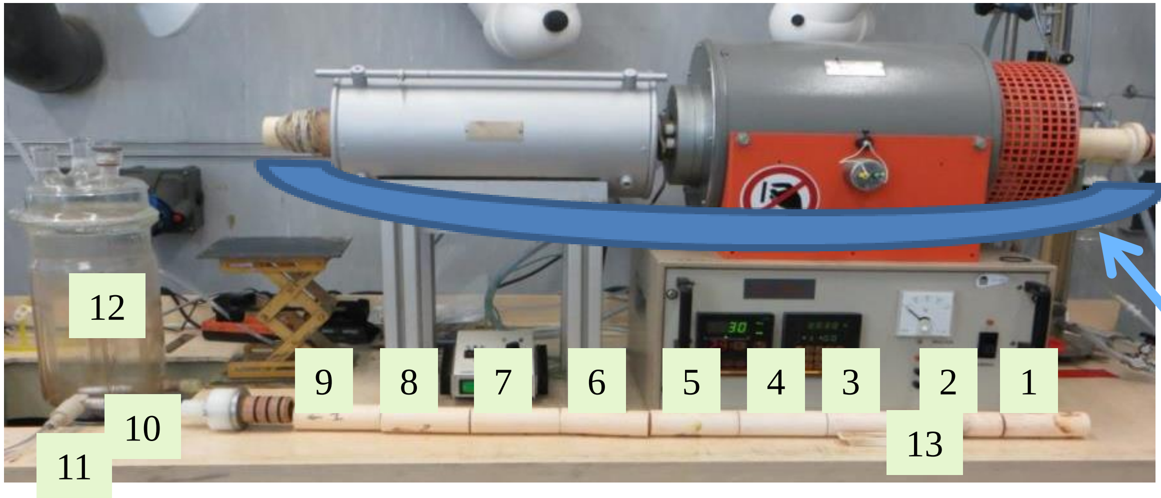


Fe(III) and Ni(II) chlorides have an ebullition points above 700°C, while Fe(II) chloride and Cr(VII) and V(V) oxychlorides have ebullition points below 200°C

Experimental set-up and procedure

Vanadium extraction
by carbo-oxychlorination

Condensation areas:
- Alumina condensers from 1 to 9,
- Connector tube 10
- Tube going into the reactor 11 (NaOH)
- Gas cleaning reactor 12 (water)
- Residue collecting: crucible 13



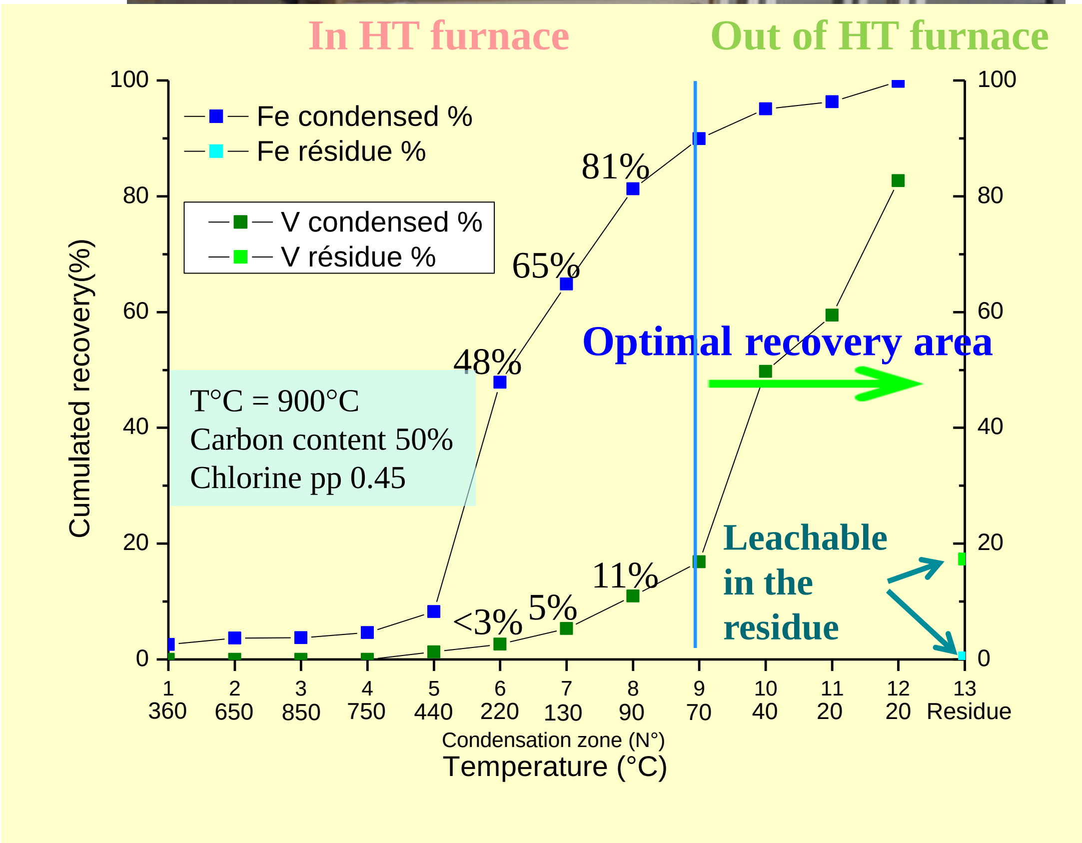
Large area of condensation for recovery of V and Fe compounds

Steps of carbo-oxychlorination procedure:
- Mixing BOF sample and carbon,
- Heat-treatment of the mixture (up to 1000°C, 90 min, Air + chlorine)
- Washing condensation areas (condensed chlorides)
- Analysis of washing solutions (recovery yield)

Experimental results

Selectivity of the process

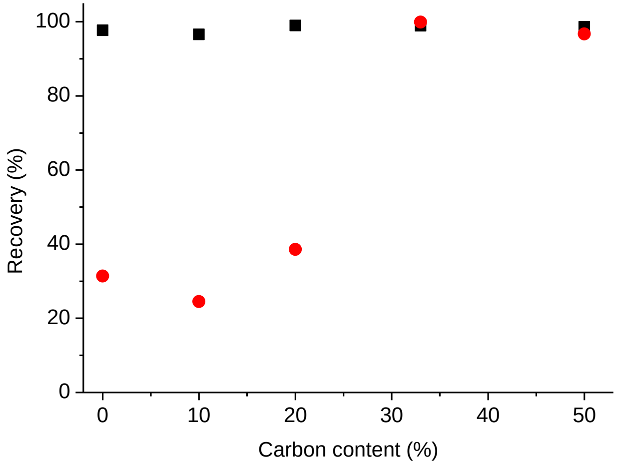
Selective recovery of vanadium depends on vaporization temperature of chlorides

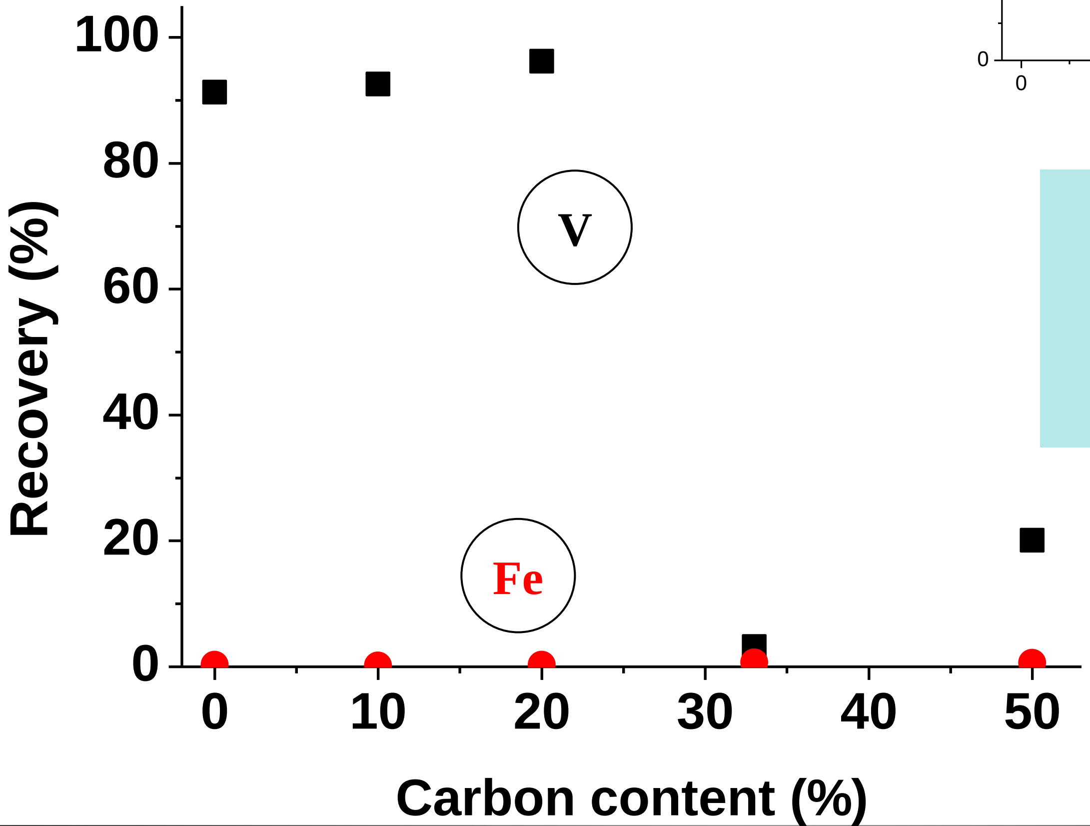


Experimental results

Selectivity of the process

T = 900°C; Residence time 90 min
Particle size 400µm; P_{Cl2} = 0.45





Some processing conditions induce very high vanadium content in residue easily leachable with very low iron content

From 70 up to 95% of vanadium BOF-slag content can be recovered by leaching of residue

Products

clean Ca-Si
slag

CO gas

Ca-Al
slag

Nodular Pig Iron

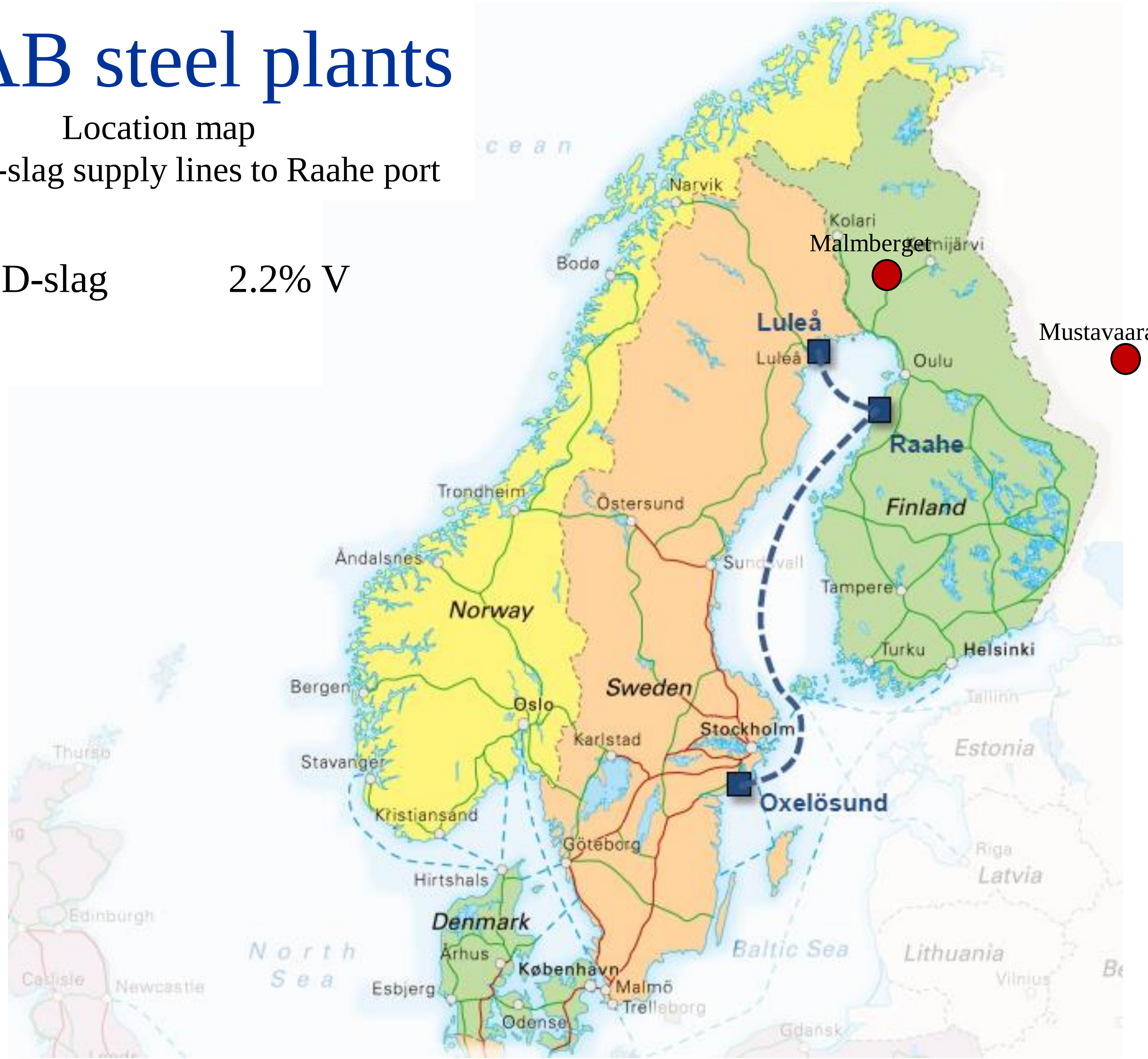
Phosphorus
slag

Ferrovanadium

SSAB steel plants

Location map
with LD-slag supply lines to Raahe port

SSAB LD-slag 2.2% V



Site at Raahe Harbour

Summary of the EXTRAVAN project

- The EXTRAVAN project has demonstrated approaches for efficient recovery of vanadium from primary and secondary raw materials
- By the results from the EXTRAVAN project and previous works, the whole production chain from reduction, oxidation, roasting, leaching/precipitation, VO_x- and FeV-making has been demonstrated
- A novel carbo-chlorination process has also been demonstrated
- The EXTRAN project has also demonstrated the power of cooperation between the EU R&D centers in the field of mineral processing and extractive metallurgy for developing new technologies for the EU mining and metal industry