Circular economy activities at Eramet

Benjamin Ravary, R&D director Mn Alloys (presenter)
Leif Hunsbedt, senior specialist

SisAl Pilot
Clustering meeting 06.10.2022

Eramet

A major player in the **extraction and transformation of metals** (manganese, nickel, ilmenite and zircon)

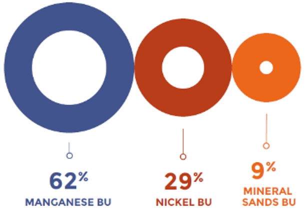
Developments in critical metals for the **energy transition** (lithium, nickel, cobalt)

A CSR commitment that combines the operational performance of our activities with a positive impact on the environment and communities.

Target zero accident

Our ability to perform our activities in complete safety is our absolute priority. We owe it to our employees, to our subcontractors and to all of our partners

Turnover by activity**



Eramet Marketing Services

Mining & Metals Activities

Eramet Ideas
Eramet International

Manganese BU

Steels used for construction and transportation
Batteries, fertilizers, chemicals

Nickel BU

Stainless steel and nickel-based alloys
Batteries

Mineral Sands BU

Pigments and titanium metal
Ceramics, chemicals
Refractory materials, foundry

Lithium BU

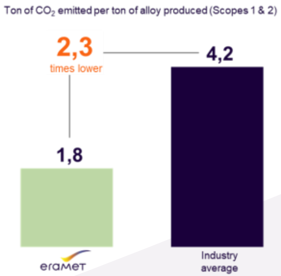
Energy storage for electric vehicles
Portable electronic devices

= mine in Gabon + Mn alloys plants

Eramet CSR roadmap

We are one of the world's cleanest manganese alloys producers

Renewable energy - Efficient production processes - Energy Recycling - Comilog Low Carbon content Ore



Committed to women and men

1. Ensure the **Health** and **Safety** of our employees and subcontractors
2. Enhance **skills**, promote **talent**, and **career** development
3. Strengthen the **commitment** of our employees
4. Integrate and promote the richness of **diversity**
5. Be a respected and contributive partner for our **host communities**

A responsible economic player

6. Be a leader in metals for the **energy transition**
7. Actively contribute to the development of the **circular economy**
8. Set the standard in **human rights** in our field of activity
9. Be an **ethical** business partner of choice
10. Be the go-to **responsible** business in mining and metallurgy

Committed to our planet

11. Reduce our **air emissions**
12. Preserve the **water** resource and accelerate the rehabilitation of our mining sites promoting **biodiversity**
13. Reduce our **energy** and **climate footprint**

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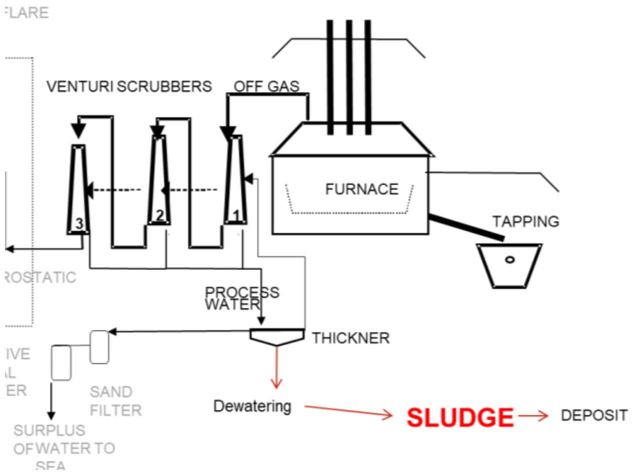
Eramet Norway’s main projects to reduce sludge depositing

Benjamin Ravary, R&D director Mn alloys
05.10.2022

Sludge: from gas cleaning of furnaces

- **Sludge production**
  - Quite constant from year to year
  - 2019: 32 kt
    - ENK: 18 kt
    - ENS: 9 kt
    - ENP: 5 kt
- **20-30% MnO** in sludge → actual for recycling
- **Challenges with sludge**
  - Zn, Pb, K and Na may accumulate under recycling in own furnace →associated with difficult furnace operation, sticking
  - High water content
  - High carbon (present as tar and carbonates)
  - Small particle size
  - Heavy metals
  - Transportability / variations



Mn	27%	P	400 ppm
Fe	1.5%	B	1 000 ppm
Si	4.5%	S	4 000 ppm
Ca	1.7%	As	40 ppm
Al	1.0%	Cd	350 ppm
Mg	1.8%	Hg	20 ppm
Zn	2.2%	Particle size	d50 1-4 µm
Pb	0.35%	Specific area	3-120 m^2/g
K	3.2%	C	9.6%
Na	0.68%		

Average 2007

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Short history: studies over 30 years

Treatment	Zn/Pb returned to SAF	K/Na returned to SAF	Waste to be deposited	% Mn Recovered to process	Product	Technological risk
Landfill	0	0	100	0	None	None
Mountain cavern	0	0	100	0	None	None
Hydrometallurgy	0	0	50	50	Mn_2SO_4	unknown
Briquetting	100	100	0	100	Mn alloy	Poor furnace operation
Direct injection	100	100	0	100	Mn alloy	Poor furnace operation
Sintering	90	90	10	90	Mn alloy	Poor furnace operation
Solid state reduction	1	90	0-5	95	Mn ore substitute	RHF operation not known for Mn
Oxyfines burner	1	10	0-10	90	High Mn slag	Expensive
Melting – slag	1	10	0-5	95	HC FeMn slag	Drying and calcining
Melting – alloy	0	0	0-5	95	Mn alloy	Alloy specification

• 2011: techn… …ling involving removal of problematic elements – in particular alkalis: **prohibitively expensive**

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Current strategy and main projects

- Strategy
  - Modular and limited recycling
  - Partial treatment
    - Agglomeration for transport relevant for most applications → first step
    - Partial recycling – test acceptable limits
  - Open to cooperation

- Main projects
  - NewERA program
    - Energy and resource efficiency
    - Circular part: fine by-products, including sludge in briquettes
  - Pelletising
    - Sludge and dusts
    - Piloting on Kvinesdal sludge

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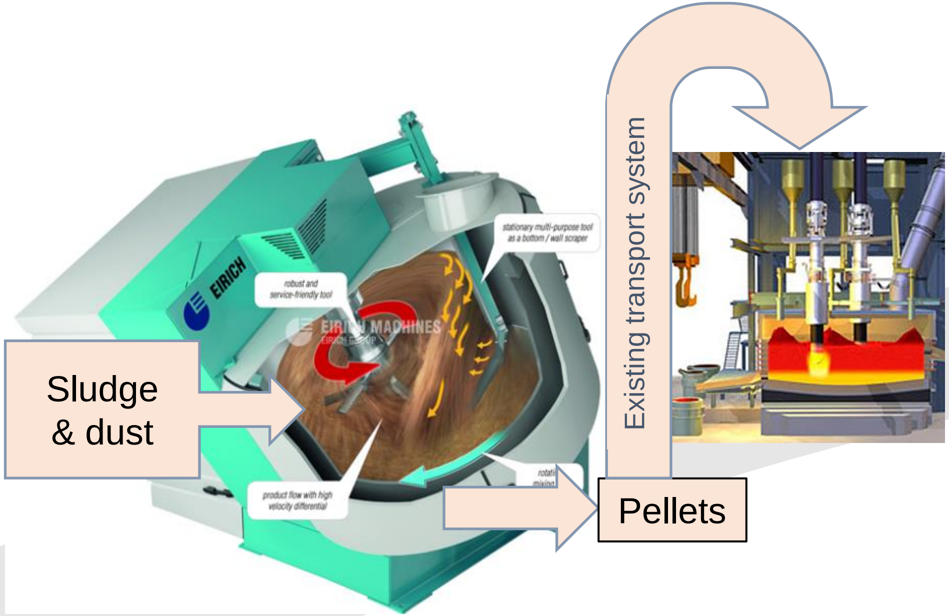
NewERA summary and concept [focus sludge]

- **Main objective:** improve energy and resource efficiency, building on R&D work on pre-reduction in the furnace
- Overall NewERA program
  - Burn furnace off-gas to produce electricity and heat – gas engine
  - Use heat to dry the ore
  - Screen the ore
  - **Circular:** agglomerate ore fines with **sludge,** dusts and metal fines
- Technology for agglomeration: **roll press briquetting**
- Project organization
  - Project manager: Kåre Bjarte Bjelland
  - Steerco

Sludge pelletizing – summary and concept

- Objective: **cost-effective agglomeration** of sludge for **recycling in furnace**
  - Modular: can be the first step of a more complete process involving heat treatment to remove volatiles
  - Can use other waste dust as a filler
    - Internal dusts e.g. filter dusts – too low tonnage for industrial need
    - Dust from FeSi/Si producers
- Technology: **high-intensity mixer** (Eirich type)
  - Same mixers might be use in NewERA – experience may be useful
- Successfull industrial tests in 2016 and 2022
- No economy without reasonable price and good supply of external dust → iniative terminated



Silica Green Stone

An ENO project for actively contribute to development of the circular economy and to reduce energy- and climate footprint

SisAl Pilot

Clustering meeting 06.10.2022

Leif Hunsbedt (presented by Benjamin Ravary)

Outline – Silica Green Stone (SiGS) project

- Production of SiGS (Slag form SiMn production)
- Project objective
- Short summary of work performed, results and work ahead

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Eramet production of Silica Green Stone - Europe

- **Eramet Norway**
  - **Production of approx. 300 kt SiGS/y**
- **Eramet Dunkirk**
  - **Production of 60 kt SiGS/y**

Production of FeMn slag ~ 220 kt

Eramet Norway Sauda

Production of FeMn slag ~ 100 kt
Production of SiGS ~ 90 kt, layer casting

Eramet Norway Porsgrunn

Production of SiGS slag ~ 220 kt
Layer casting

Eramet Norway Kvinesdal

Production of SiGS, ~ 60 kt
Granulation / casting

Eramet Comilog Dunkerque

- **Present production of SiGS is not utilized in an optimal way**
- **Sales / disposal of SiGS is presently a challenge**
- **SiGS is classified as a by-product and not put into landfill**
- **Mainly used as raw material for roads, filling purposes and substitute for quartz and limestone in cement clinker production – low value products**
- **(FeMn slag from Sauda, 220 kt/y, used as raw material for SiMn production)**

SiGS - characteristics

- SiGS is an oxide slag from silico manganese production
- Comparable with natural rock, but higher in manganese oxide
- Recent work has showed that SiGS:
  - Has pozzolanic properties that can be utilized in cement and concrete
  - Contains free silica (mono silicic acid) that can be utilized in agriculture

- By-product from SiMn production, 1 – 1,5 t slag/t alloy
- Composition, %, major oxides:
- MnO: 4 – 8; SiO2: 42 – 45; Al2O3: 13 – 17; CaO: 22 – 24; MgO: 6 - 10
- Minor elements, dependent on raw material mix. Low in heavy metals, no organic compounds
- Density, approx 2,8 t/m3; bulk density approx. 1,7 t/m3
- Melting point approx 1400 deg C. Vickers hardness, approx 6
- Inert to leaching in water or reactions in air
- Physical properties are dependent on solidifying
- Cooling in air with water spraying gives an 90% amorphous, hard, glassy surface, sharp edges.
- Rapid cooling in water (water granulation) gives a fined grained, '100%' amorphous and porous slag.

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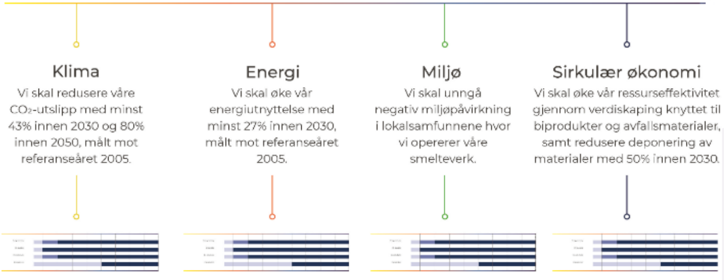
Project objective

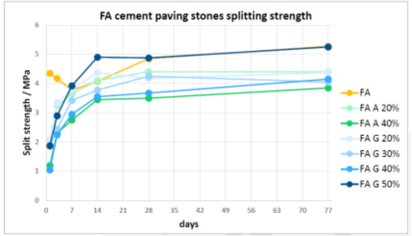
- **Better utilization of SiGS in new markets both with regard to economy and sustainability**
- **Maintain and strengthen existing market until new markets are established**

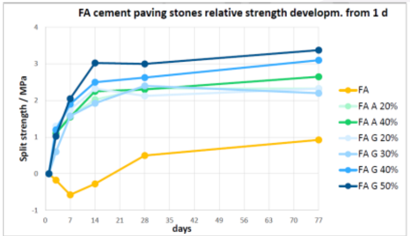


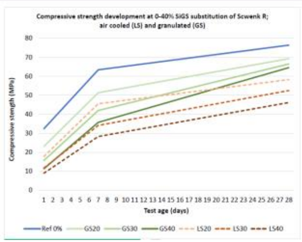
CSR: Corporate Social Responsibility

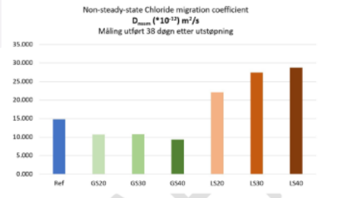
SiGS in cement and concrete

- SiGS contain free silica – SiO_2 that is amorphous – not crystalline
  - ➔ SiGS can act as pozzolanic substance in cement reaction
  - ➔ SiGS contributes to cement reaction
  - ➔ SiGS can be used as a SCM, Supplementary Cementitious Material, thus substituting clinker in cement production, or substituting cement in concrete
- SiGS has similar properties as fly ash and ground blast furnace slag
- SiGS can contribute to lower the CO_2 footprint in cement and concrete production
- SiGS properties have been examined; and will be examined further to demonstrate compliance with standards









Chloride migration in 38 days cured mortar. Granulated SiGS performs consistently better, and air cooled SiGS worse, than the reference.

SiGS in cement and concrete – upcoming work

- Continue / finalize work on compliance to standards
- Establish a business model for SiGS in cement or concrete – or both
- Contract with partners – start of production

IT WILL PROBABLY BE A LONG AND WINDING ROAD,

BUT WE BELIEVE IT IS POSSIBLE ☺

SiGS as soil amendment

- Although silicon in the form as SiO_2 is one of the most abundant elements in the earth crust, some plants suffer from a deficit of this element. Plants can only utilize Si when it is present as free silica or mono silicic acid ($Si(OH)_4$)
- SiGS has been tested in laboratory, green house and field tests.
- Results show that for specific plants crops can be increased when SiGS is added as fine powder
- Tests are presently being performed in Poland on sugar beets

SiGS as soil amendment – upcoming work

- Finalize smaller field test 2022 and continue in 2023
- Perform bigger field tests in 2023
- Start work on approval according to legislation
- Building of partnership to enter market
- Contract with partners

AGAIN, IT WILL PROBABLY BE A LONG AND WINDING ROAD,

BUT WE BELIEVE IT IS POSSIBLE ☺

Concluding remarks

- The human mind is like a parachute
- – works best when it is open

- And now:
- **Questions**