CIC energi GUNE
energy cooperative research centre

REslag
Turning waste into value

Founded by the European Union's H2020 Programme

INFODAY HORIZONTE 2020
Acción por el Clima, Medio Ambiente, Eficiencia de los Recursos y Materias Primas - 18/12/2017 , Bilbao (España)

Turning waste from steel industry into valuable low cost feedstock for energy intensive industry

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CIC Energigune

December 18th, 2017

Turning waste from steel industry into valuable low cost feedstock for energy intensive industry

Call: H2020-WASTE-2014-two-stage / WASTE-1-2014.

Contract number: 642067.

Maximum EC budget: 8,022,006.68 €.

Private budget: 800,946.43 €.

TRL: 5-7.

Duration: 42 months (01/09/2015 – 28/02/2019).

www.reslag.eu

Consortium - 19 partners

(7 companies, 8 research institutes and 3 universities).

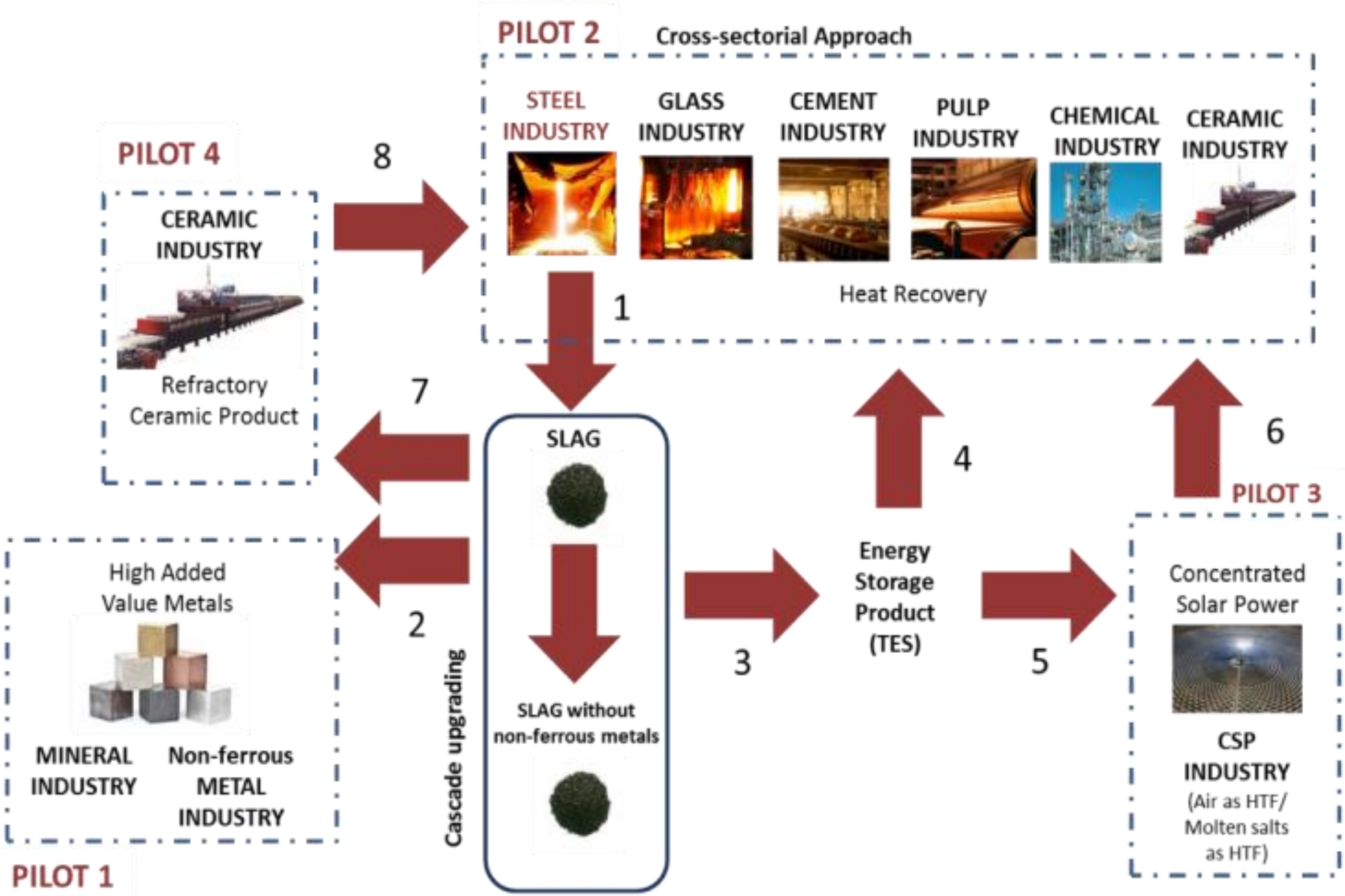
OBJECTIVES of RESLag

In 2010, the European steel industry generated, as waste, about 21.8 Mt of steel slag. 76 % of the slag was recycled in applications such as aggregates for construction or road materials, but these sectors were unable to absorb the total amount of produced slag. The remaining 24 % was landfilled (2.9 Mt) or self-stored (2.3 Mt). The landfilled slag represents a severe environmental problem.

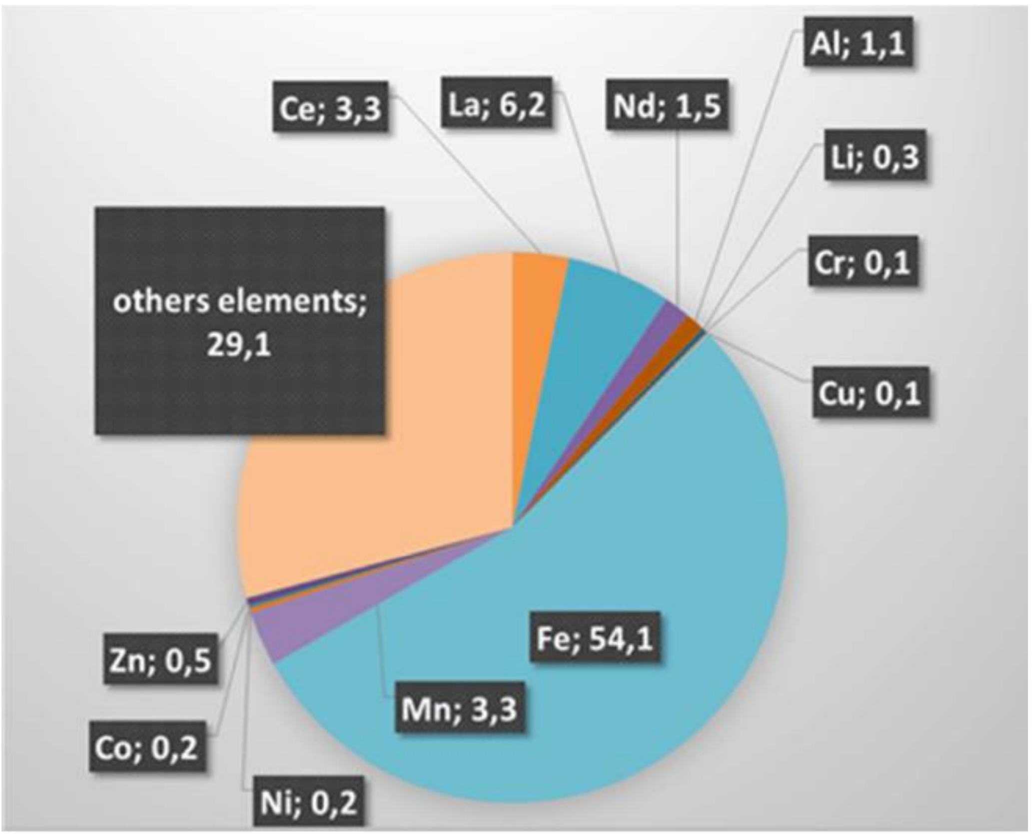
OVERALL OBJECTIVE

To valorize the steel slag that is currently not being recycled and reuse it as a valuable raw material for 4 innovative applications that contribute to a circular economy in the steel sector with an additional cross-sectorial approach

Specific objectives -> 4 innovative applications



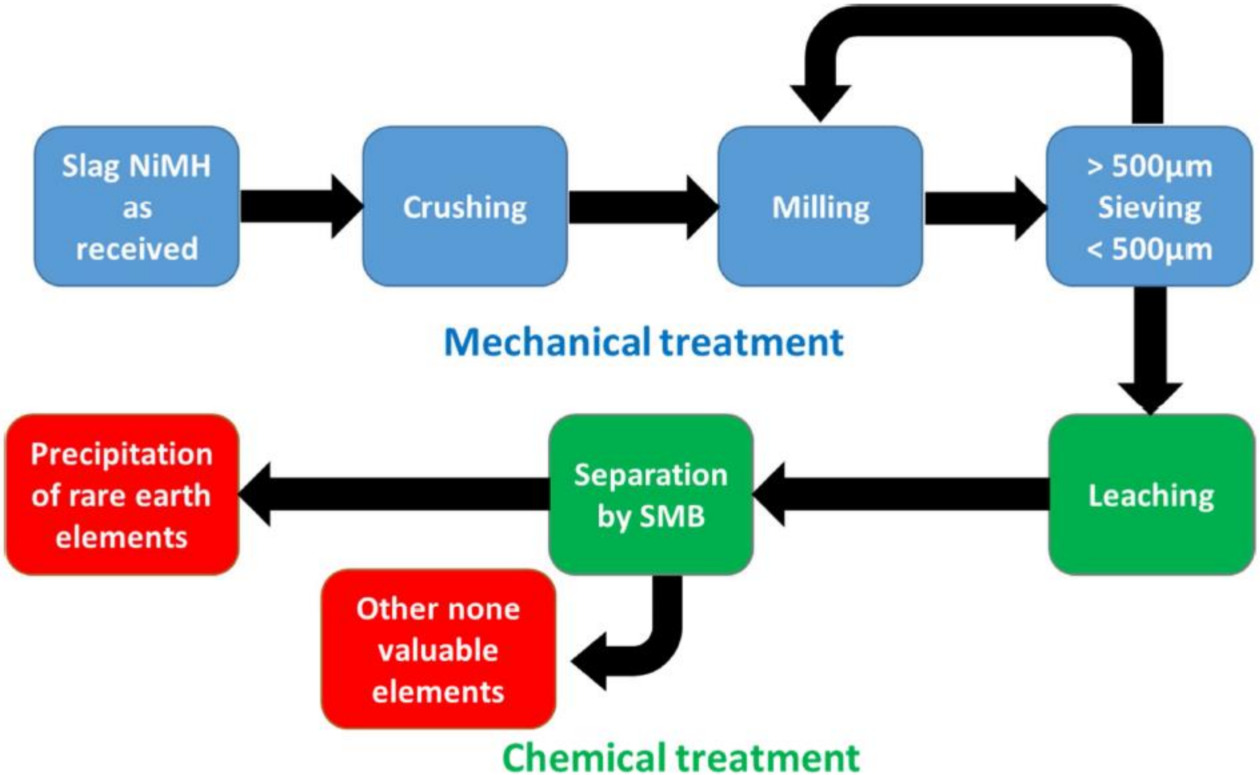
Valorization route #1
High added value metals recovery



Several options of slags were considered

Selection of the richer in critical elements

Batteries recycling slags (6-12 %wt of rare elements)

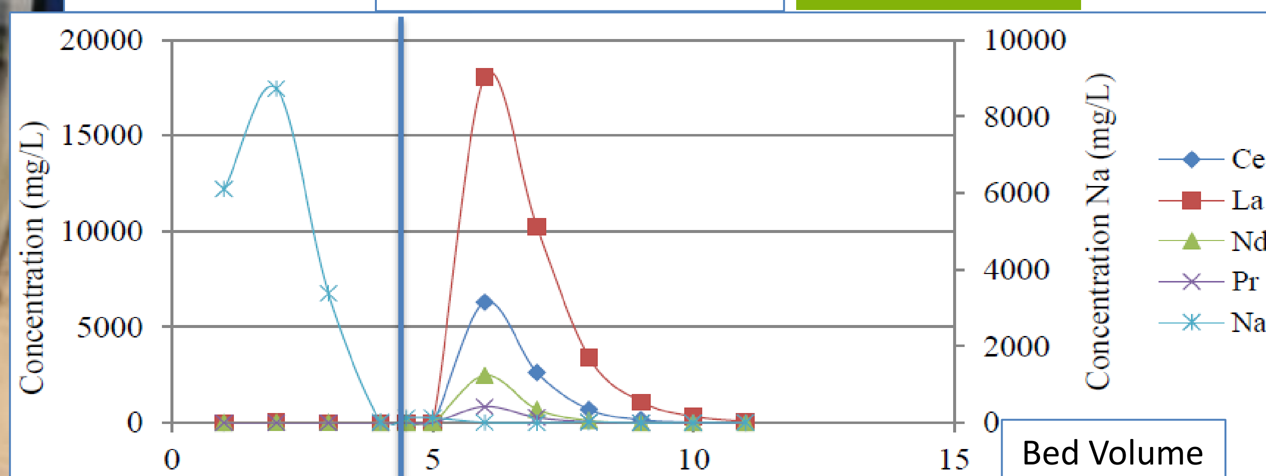


Slag NiMH as received
Crushing
Milling
> 500µm Sieving < 500µm
Mechanical treatment
Leaching
Separation by SMB
Precipitation of rare earth elements
Other none valuable elements
Chemical treatment

PILOT n°1 – Rare elements recovery
CEA (France)

HNO3 0,5M | HNO3 4M

In operation



ECHT	POSITION	La	Ce	Nd	Na	K	Mn	Ni
C6	0	557	197	98	1	0	0	0
C1	1	664	238	143	32	2	7	8
C2	2	937	348	202	190	7	60	61
C3	3	952	356	205	209	7	57	58
C4	4	344	131	79	157	4	46	39
Raff1	4,5	262	97	67	154	5	65	55
C5	5	254	95	58	153	7	87	82
Raff2	5,5	38	12	7	74	0	9	8
C6	6	557	197	98	1	0	0	0
ALIM		305	111	63	140	3	41	33

- It is possible to have a pure fraction of REE's together (C6)
- A complete fractionating of REE's is hard to achieve
- Advanced optimization needed

Valorization route #2
Slags as TES materials

Raw slags → TES materials

- → Waste heat recovery in the steel industry
- → CSP with air as HTF
- → CSP with solar salt as HTF

Raw slags processing routes

Task 3.1. Characterization of SLAG as received

As-received slag from Arcelor Mittal

Properties measured:
- Chemical composition
- SEM/EDS
- Mineralogical composition
- Compression strength (MPa)
- Apparent and skeletal Density (g/cm3)
- Porosity (open and real)
- Cp= Heat capacity (JK^{-1}/kg)
- α= linear thermal expansion coefficient (K^{-1})
- k=Thermal conductivity ($W^{-1}K^{-1}$)
- Thermal stability
- Liquid Viscosity (Pa.s)

Task.3.2. Manufacturing of the PEBBLES

Sub-task 3.2.1. Production of the pebbles by melting process. Alternatively, mechanical conformation

IK4 AZTERLAN

Melted and Poured PEBBLES

Mechanically conformed PEBBLES

Sub-task 3.2.2: Production of the pebbles by sintering process.

OPTIMUMCEMENT ready-mix solutions

Sintered PEBBLES

Comparison between the 3 type of pebbles

Task 3.3. Characterization of the 3 type of PEBBLES.

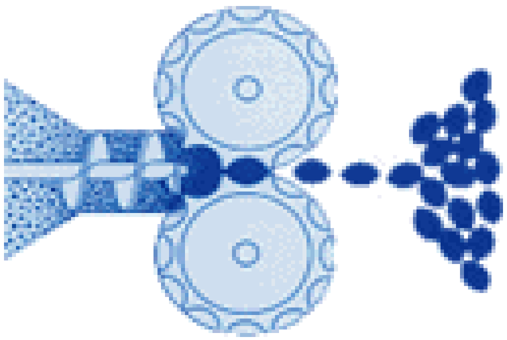
Properties measured:
- Chemical composition
- SEM/EDS
- Mineralogical composition
- Compression strength (MPa)
- Bending test (MPa)
- Apparent and skeletal Density (g/cm3)
- Porosity (open and real)
- Cp= Heat capacity (JK-1/ kg)
- α= linear thermal expansion coefficient (K-1)
- k=Thermal conductivity (W-1K-1)
- Thermal stability

Comparison between the raw SLAG and manufactures PEBBLES

---------------- Mechanically conformed slag (IK4 Azterlan – Spain)

~ 2.5 cm

-------------- Sintered slag (Optimum Cement – France)



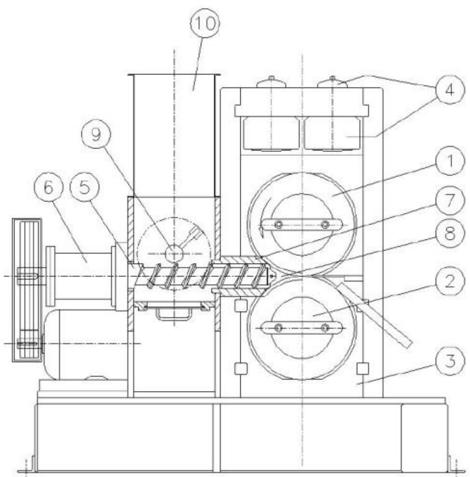


FIG 1 - Roll press assembly - Cross section of pressing system
1 - Roll, 2 - Roll shaft, 3- Bearing block, 4 - Supporting hydraulic system,
5 - Screw feeder, 6 - Screw feeder bearing block, 7 - Feed adapter, 8 - Cheek plate
9 - Paddle mixer, 10 - Feed hopper

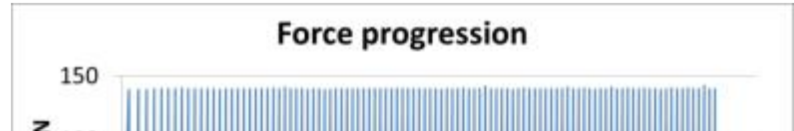
1st Batch

2nd Batch

Thermo-mechanical properties summary

THERMOPHYSICAL PROPIERTIES		Units	AS-RECEIVED SLAG AM SESTAO	MECHANICALLY CONFORMED	SINTERED PEBBLES		
					PEB (01-35)	E3 (24-41), E4 (24-42)	E3 (49-54), E4 (49-54)
Density	**Bulk density**	Kg/m3	**4099** ± 30	**3980** ± 40	**2960** ± 80	E3_28: **3371** E4_28: **3390**	E3_53: **3112** E4_53: **2993**
	Sketal density		**3740**	_	**3460**	E3_28: 3791 E4_28: 3771	E3_53: 3772 E4_53: 3772
Porosity, average		%	**8.7**	**9**	**16.1**	E3_28: **11 %** E4_28: **10 %**	E3_53: **17 %** E4_53: **21 %**
Specific heat capacity (Cp). RT-1100ºC		J/Kg.K	**840-1000**	**670-975** min (700ºC): 780	**760-950** (FAU) **760-1050** (ETHZ)		
Thermal expansion rate (α). RT-1100ºC		K-1	$10\text{-}30*10^{-6}$	αRT-650=$15.37*10^{-6}$ α750-1000=**$156.38*10^{-6}$**	$11.86*10^{-6}\,K^{-1}$		
Thermal **conductivity** (λ). RT-1000ºC		W/K	**1.7-1.3**	**1.2-1.2** (FAU) max (200ºC): 1.4 min (700ºC): 0.87	**1.5-1.0** (FAU) **1.9-1.3** (ETHZ)		
Thermal **diffusivity** (α). RT-800ºC		mm2/s	0.7-05	0.55-0.37	0.75-0.5		
Compression test		Mpa	**100-288**. After 16 TC, decrease to 50 Mpa	**270** ± 80	**42,7** ± 3,9	E3: **310** ± 55	
Flexural strength		Mpa	_	**51** ± 25	**17.6** ± 8,6	**58** ± 22	
Thermal stability			Stable after oxidation process.740 min at 800 ºc				
Thermal Cycling (heating & cooling cycles test)			16 THERMAL CYCLES (heating 800ºC- cooling 300ºC)	DONE. Pending subsequent compression test			
Compatibility with molten salt							

Thermo-mechanical stability of slag



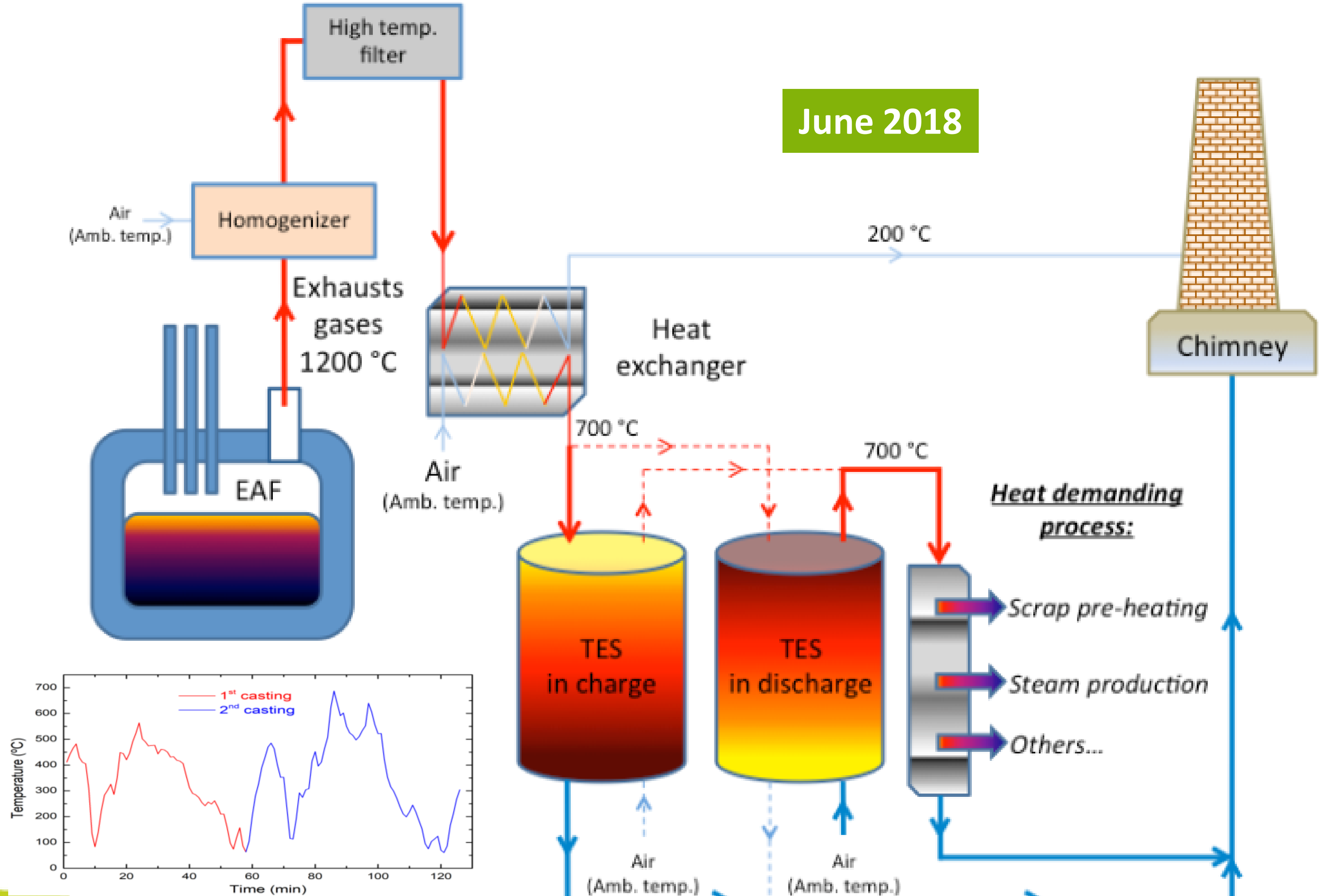
No significant damage

Slag as received thermo-mechanically suitable for full scale TES in CSP with air as HTF

- **Facility specifications:**
  - D x H: 0.5 m x 0.5 m
  - 160 t
  - Max. Temperature: 600 °C
- **Experimental program:** 500 compression cycles from 20 to 140 kN.

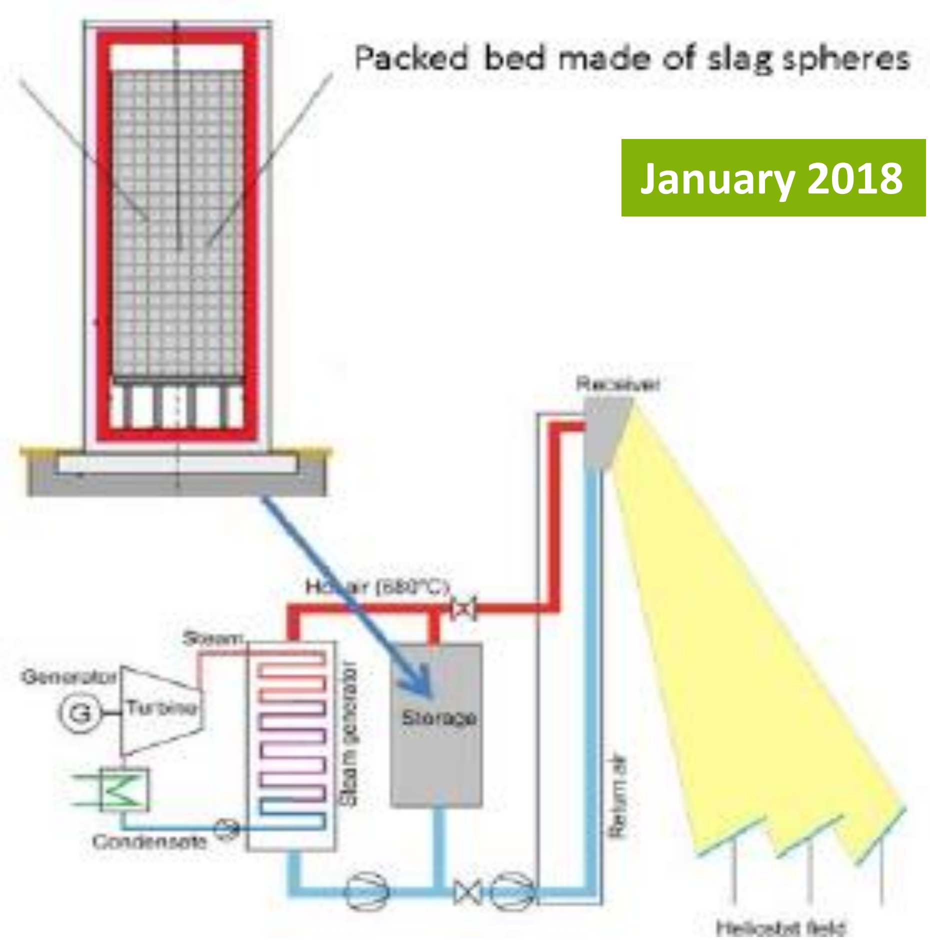
PILOT n°2 - Waste Heat Recovery in steelmaking industry

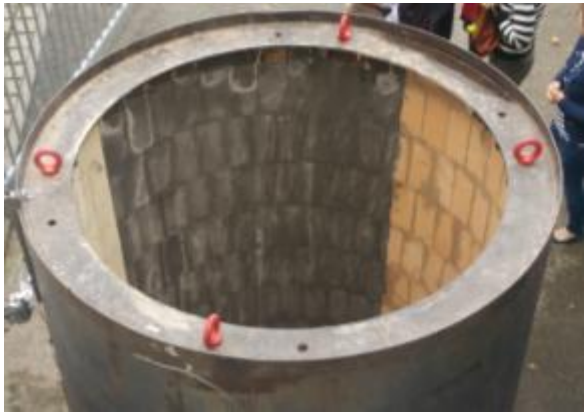
ArcelorMittal Sestao – Novargi – CIC Energigune



PILOT n°3a – CSP with air as HTF
DLR (Germany)

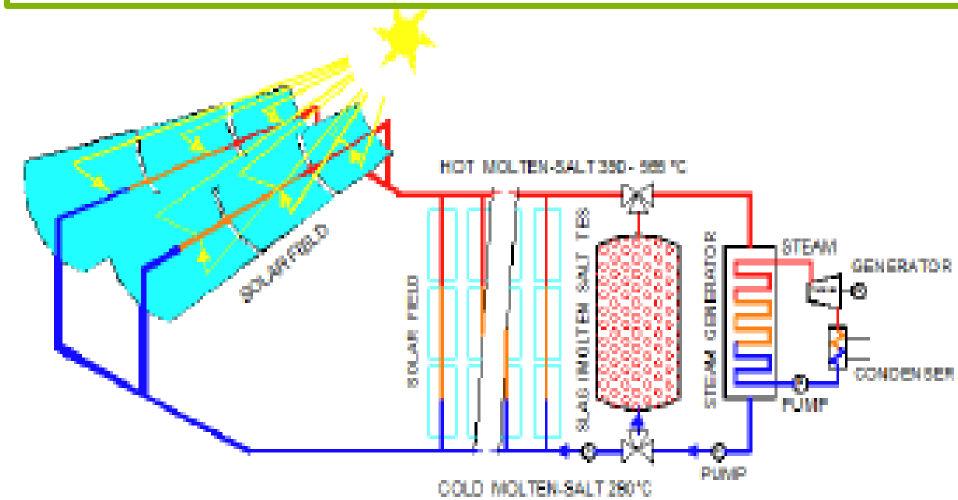
January 2018



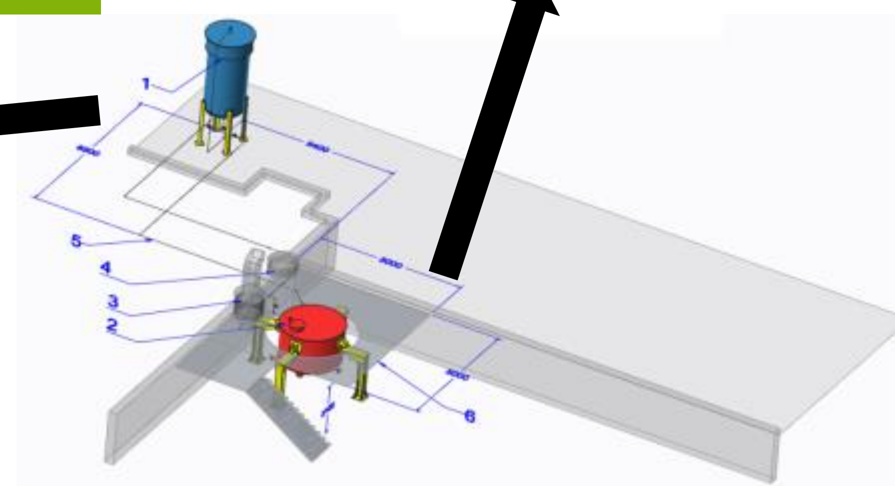


PILOT n°3b – CSP with solar salt as HTF

ENEA (Italy)



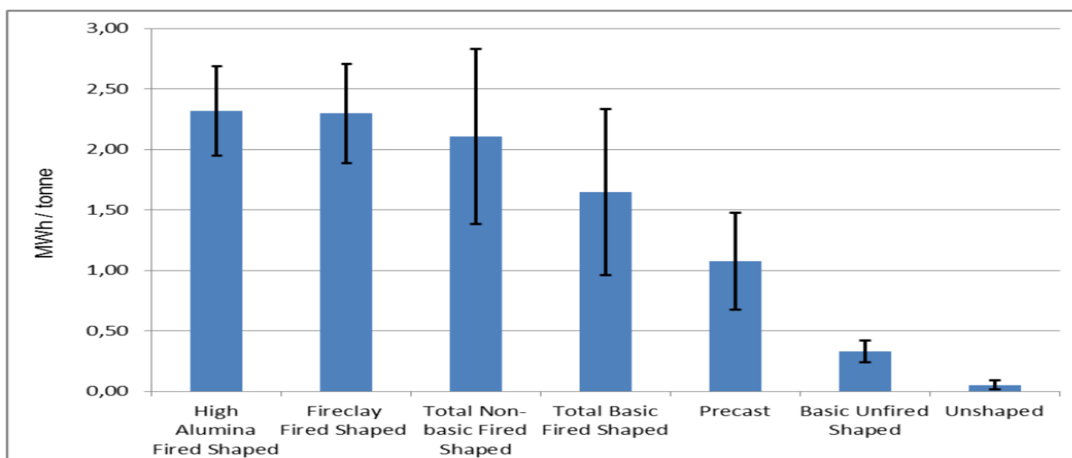
June 2018

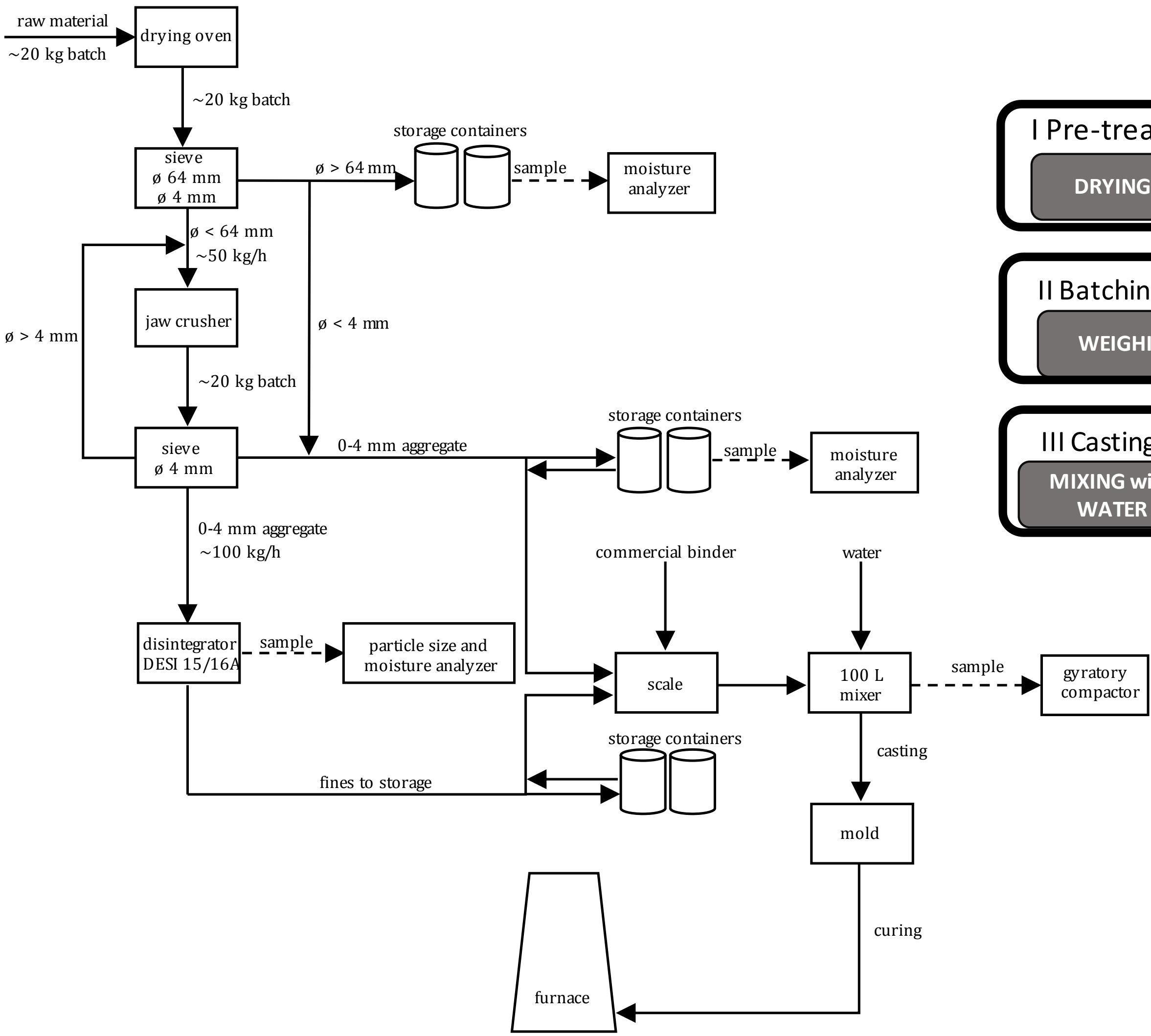


Valorization route #3
Refractory materials

- Slag will avoid the use of virgin raw materials for refractories

- Slag will avoid energy consuming sintering/firing process by using in-situ sintering of combustion chamber insulating linings.





I Pre-treatment

- DRYING
- CRUSHING
- SCREENING
- GRINDING

II Batching

- WEIGHING
- DRY MIXING
- PACKING

III Casting and curing

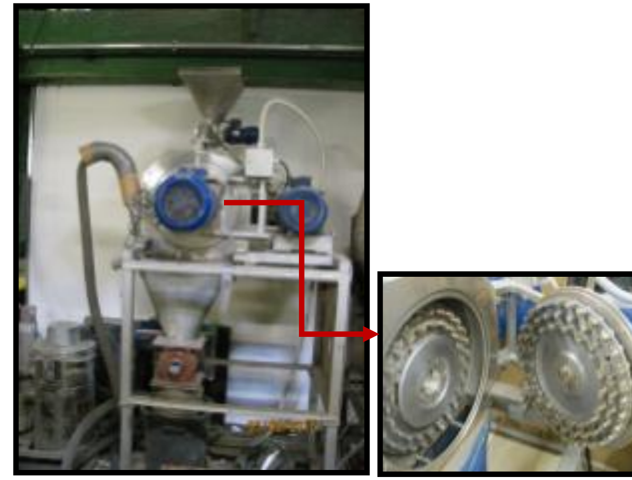
- MIXING with WATER
- CASTING
- CURING
- PRE-FIRING

PILOT n°4 – Refractory materials

VTT & Renotech Oy (Finland)

Jaw crusher

20 kg batch sieves



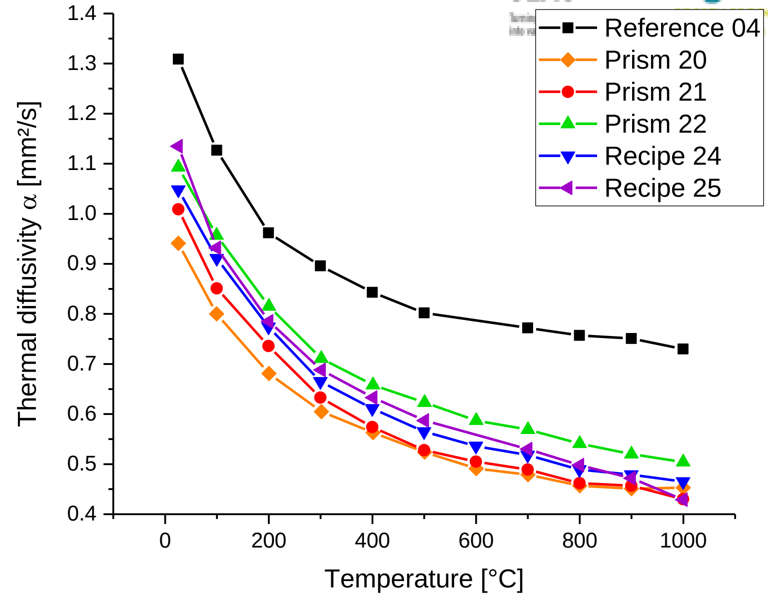
Disintegrator

100 L mixer

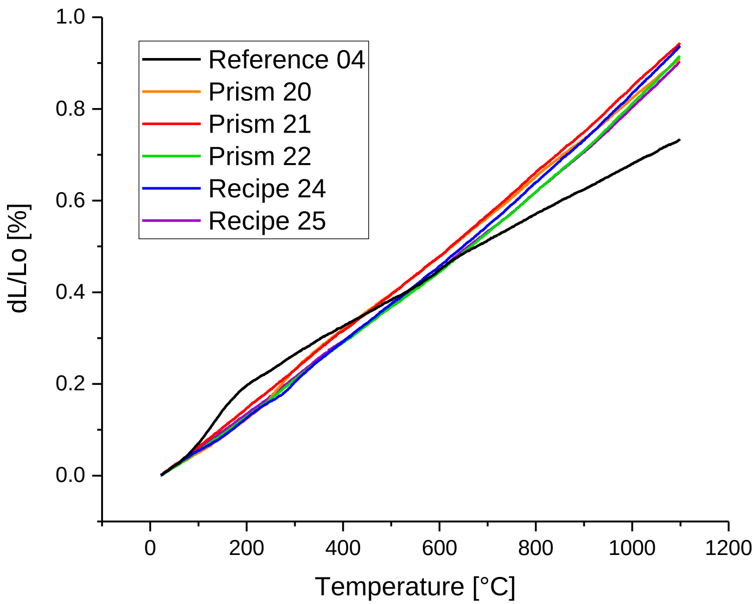
40 mm x 40 mm x 160 mm mould

Drying oven

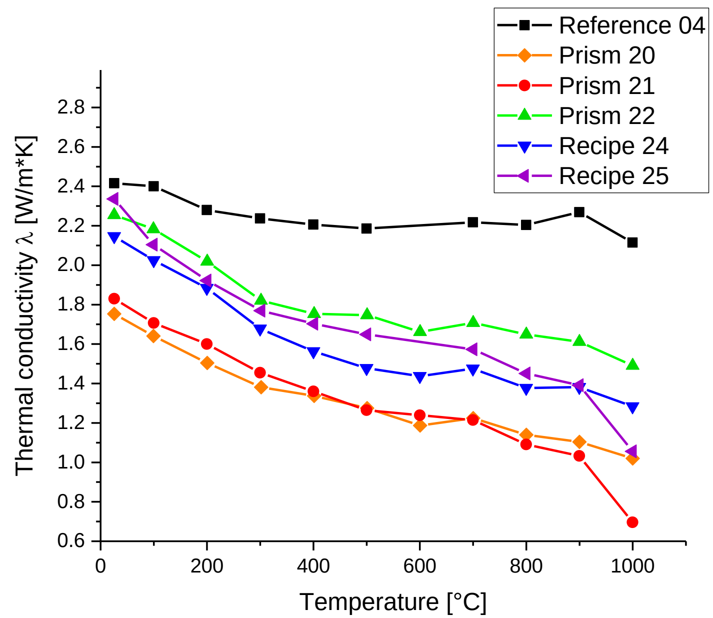
VTT - Reslag
Recipe 25
VTT - Reslag
Reference 04
Renotech
Renotech
Prism 25
Renotech
Prism 26
Renotech
VTT recipe 27



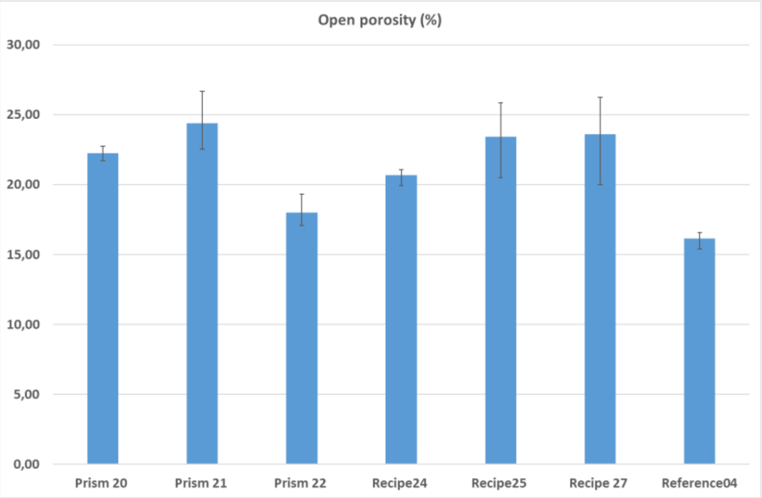
Thermal diffusivity α [mm²/s]
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0
200
400
600
800
1000
Temperature [°C]
Reference 04
Prism 20
Prism 21
Prism 22
Recipe 24
Recipe 25

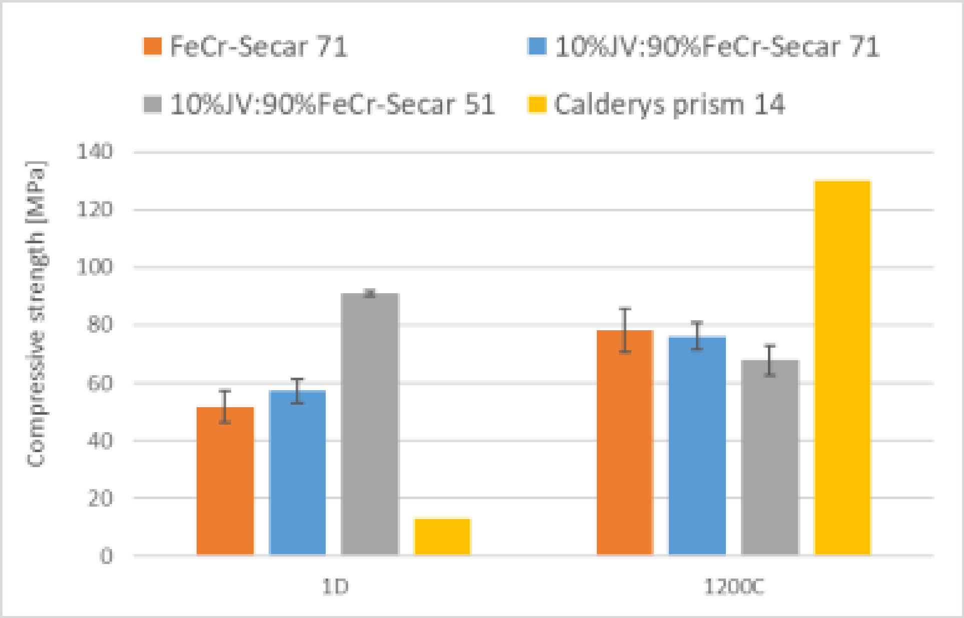


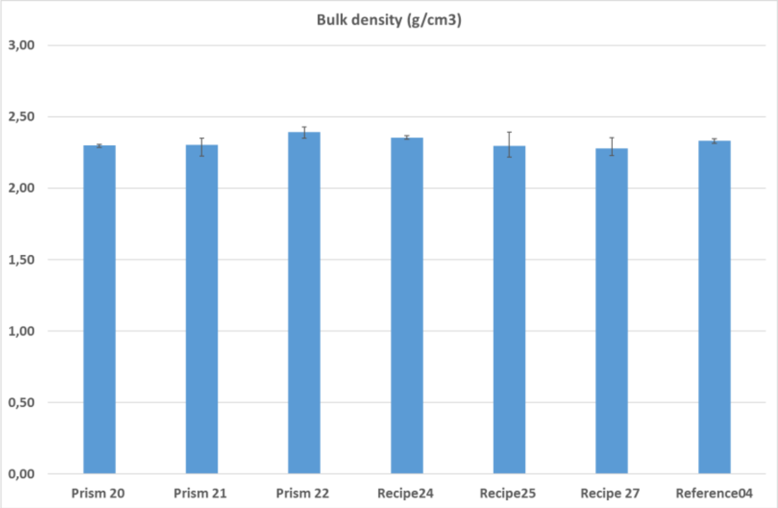
dL/Lo [%]
1.0
0.8
0.6
0.4
0.2
0.0
0
200
400
600
800
1000
1200
Temperature [°C]
Reference 04
Prism 20
Prism 21
Prism 22
Recipe 24
Recipe 25



Thermal conductivity λ [W/m*K]
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0
200
400
600
800
1000
Temperature [°C]
Reference 04
Prism 20
Prism 21
Prism 22
Recipe 24
Recipe 25





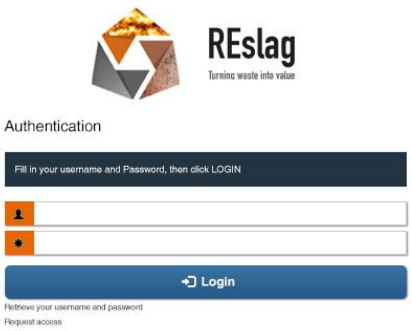



1200 °C


1270 °C


1290 °C

Other RESLag project results



LCA Webtool

http://5.249.152.171/_tstresla/public/usrlogin.php

ICT-Tool (REslag Market)

https://reslag.einszuzwei.de/

CONTACT
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Thank you very much