NEW-MINE

EU TRAINING NETWORK FOR RESOURCE RECOVERY THROUGH ENHANCED LANDFILL MINING

Hugo Lucas, G. Flesoura, G. Ascencão & P. Rabelo Monich

Advanced upcycling of thermal treatment residues

NEW-MINE project has received funding from the European Union's EU Framework Programme for Research and Innovation Horizon 2020 under Grant Agreement No 721185

www.new-mine.eu

Outline

- Overview
  - Advanced upcycling
- Bottom ash conditioning
  - Submerged arc furnace
  - Microwave
  - Chemical stability
- Upcycling
  - Inorganic polymers
  - Glass ceramics
- Conclusions

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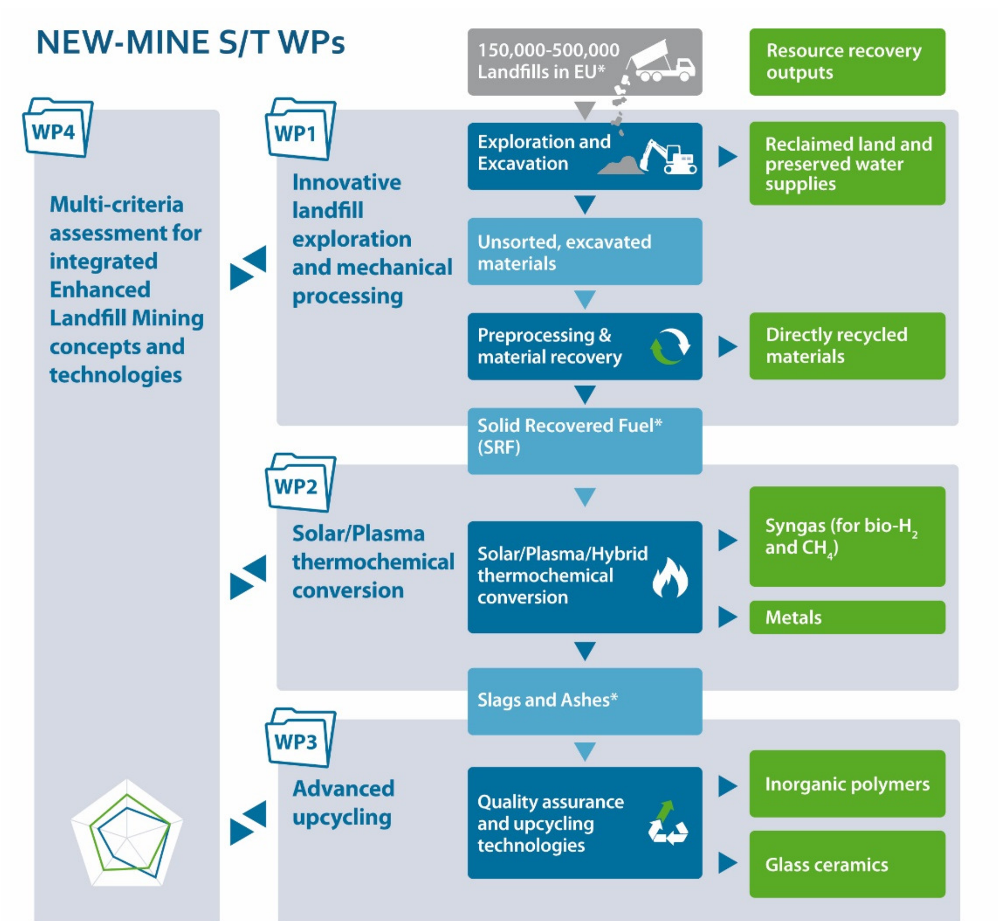
Overview



* **NEW-MINE access to landfill and intermediate research materials:**

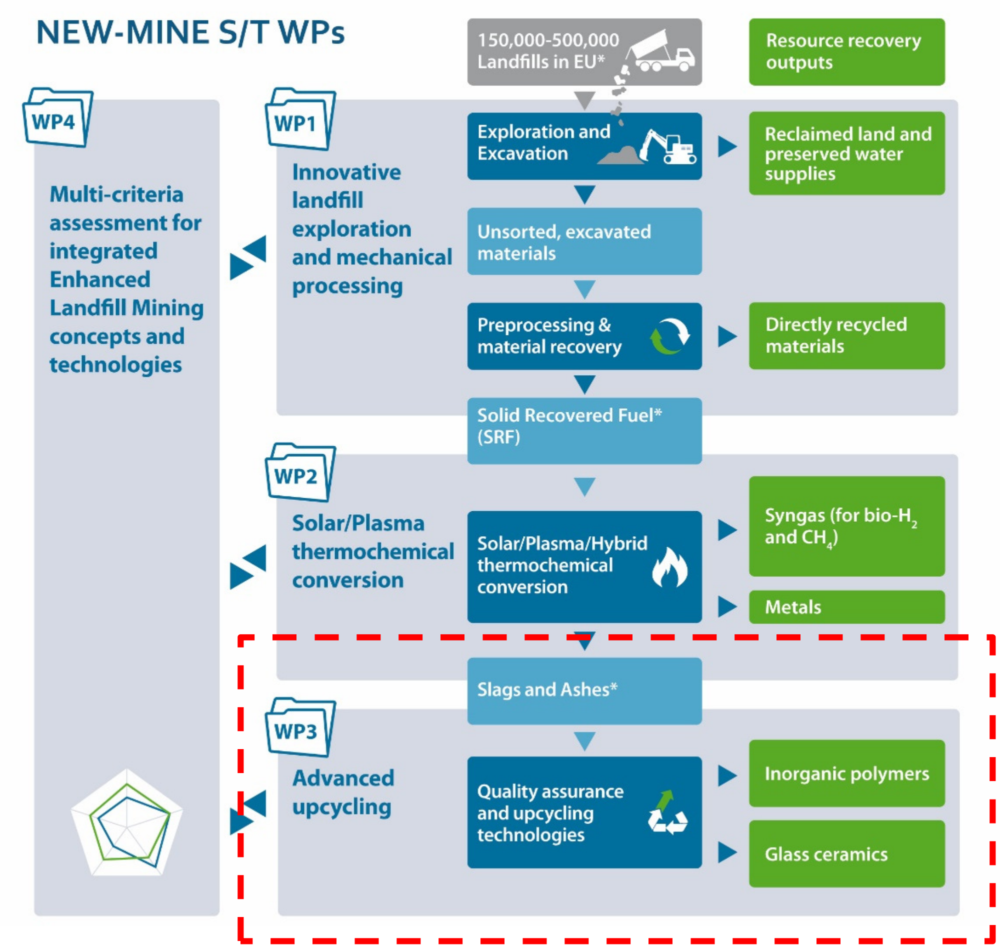
- 5 landfill case-studies: Remo landfill (BE, owned by JMR), Mont-Saint-Guibert landfill (BE, owned by Shanks), Allerheiligen landfill (AT), Leppe landfill (DE, owned by BAV), Gärstad landfill (SE).
- SRF from WP1 and on-going landfill mining R&D projects: CTC/PLASMAT (Remo, JMR), MINERVE (Mont-Saint-Guibert, Shanks), LAMIS (Allerheiligen, ASA)
- Slags and Ashes from WP2 and on-going landfill mining R&D projects: CTC/PLASMAT (Remo, JMR), LAMIS (Allerheiligen, ASA)

WP5 Training

WP6 Dissemination & exploitation

WP7 Management

Overview



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Advanced upcycling
Who does what?

ESR9
RWTH

- Consolidating slags from WtE plants through the use of submerged arc furnaces (SAF)

ESR10
KU Leuven

- Consolidating slags from WtE plants through the use of Microwave technology

ESR11
Italcementi

- Upcycling WtE slags into alkali activated construction materials (inorganic polymers)

ESR12
UNIPD

- Upcycling WtE slags into waste-derived glass-ceramic products with novel functionalities

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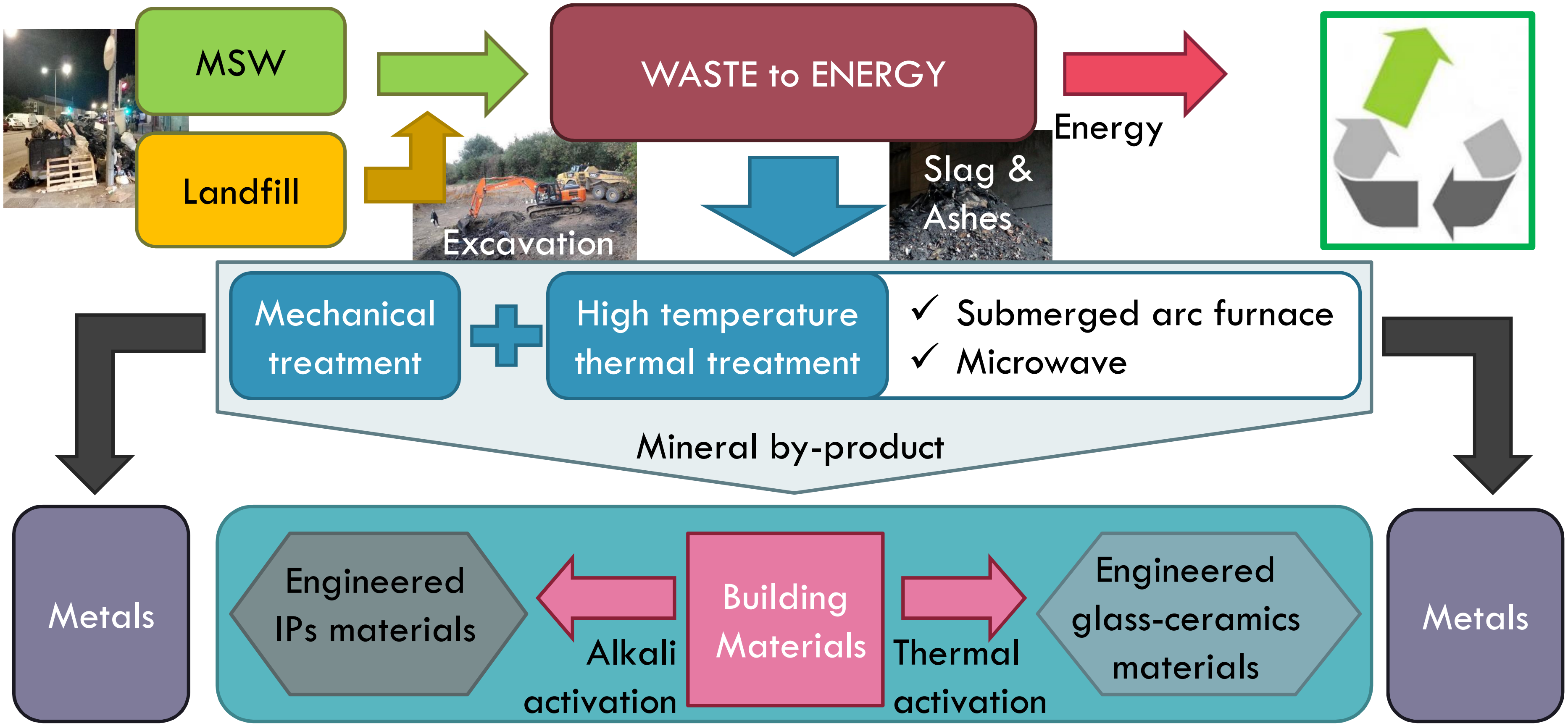
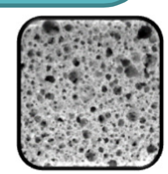
Advanced upcycling

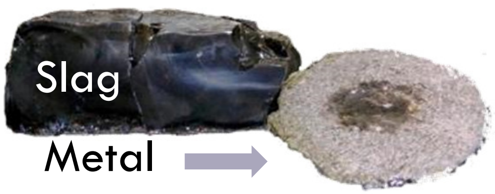



Transformation into useful products, for building applications (especially thermal insulation)



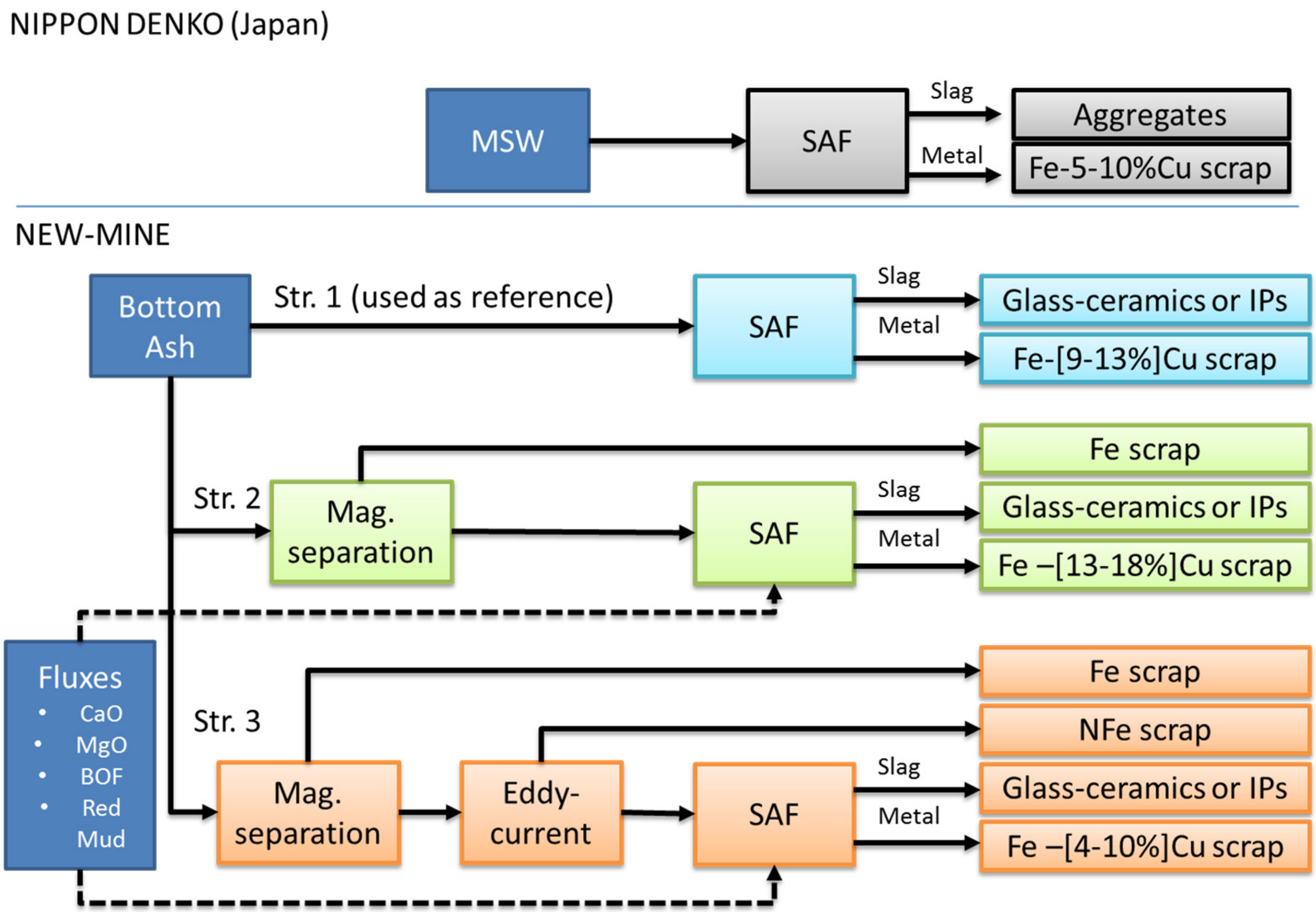

Bottom ash conditioning

Submerged arc furnace (SAF)



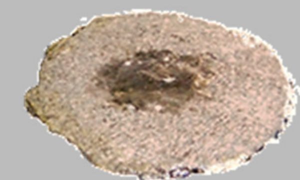
Microwave

Bottom ash conditioning: Submerged arc furnace (SAF)



SAF: the metal tapped out contains a few ppm of Ag and Au
Fluxes: are used not only to adjust the melting point or viscosity but also for novel functionalities in the glass-ceramics

Metal tapped out



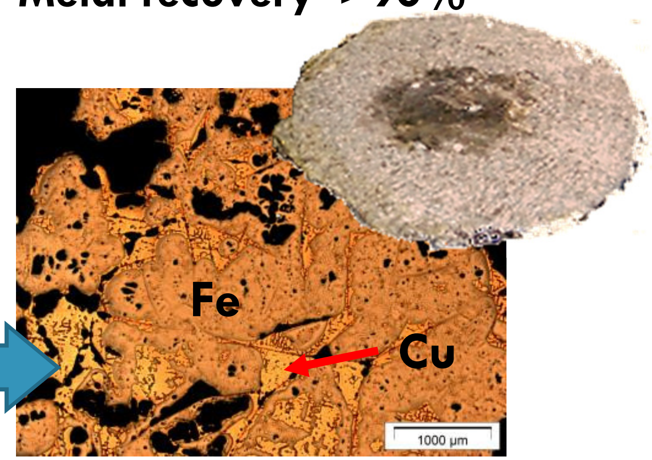
Fe-Cu(4-18%)

Minor metals [ppm]	
Cr	10.000-4.000
Ni	6.400-4.500
Co	6.500-2.500
Sn	2.000-1.000
Mo	1.550-250
Sb	1.200-700
Zn	490-100
Bi	350-170
Nb	90-5
Ag	80-25
Nd	20-15
Cd	9-5
Au	<5
Pt	<5

Bottom ash conditioning: Submerged arc furnace (SAF)

Smelting

Metal recovery >90%

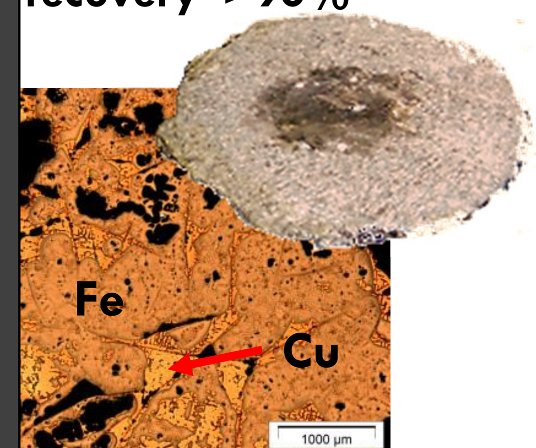


VIBA [%]		Metal tapped [%]		Fly ash [%]	
SiO_2	48,8	Fe	83,4	Cl	26,1
Al_2O_3	17,2	Cu	10,5	Na_2O	13,9
CaO	22,7	Si	1,4	K_2O	12,8
Na_2O	3,8	P	1,4	ZnO	9,2
MgO	2,4	Cr	1,0	CaO	8,1
K_2O	0,8	Ni	0,6	SiO_2	3,2
Fe_2O_3	0,8	Co	0,4	Fe_2O_3	2,6
TiO_2	1,2	Sn	0,2	Al_2O_3	1,9
MnO	0,1	S	0,1	PbO	1,3

Bottom ash conditioning: Submerged arc furnace (SAF)

Smelting

recovery >90%



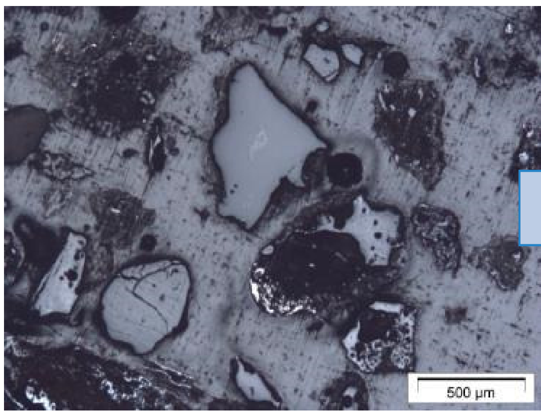
VIBA [%]		Metal tappe [%]	
SiO_2	48,8	Fe	83,4
Al_2O_3	17,2	Cu	10,
CaO	22,7	Si	1,4
Na_2O	3,8	P	1,4
MgO	2,4	Cr	1,0
K_2O	0,8	Ni	0,6
Fe_2O_3	0,8	Co	0,4
TiO_2	1,2	Sn	0,2
MnO	0,1	S	0,1

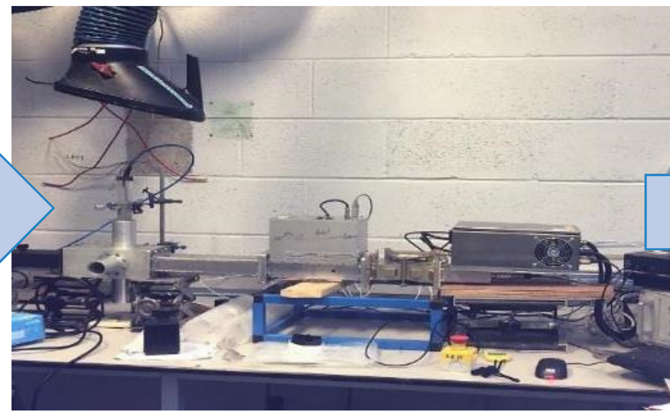
Lessons learnt

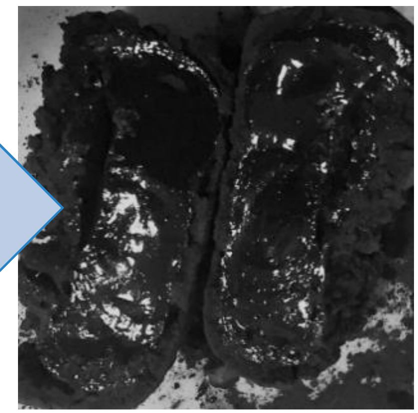
- ✓ Turning waste into raw-material is possible
- ✓ Metal recovery is enhanced

Bottom ash conditioning: Microwave

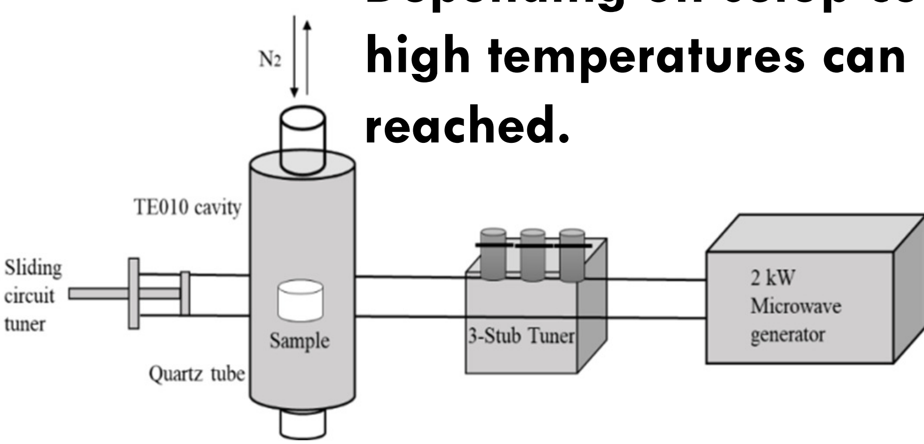
IBA **Microwave** **vitrified IBA.**

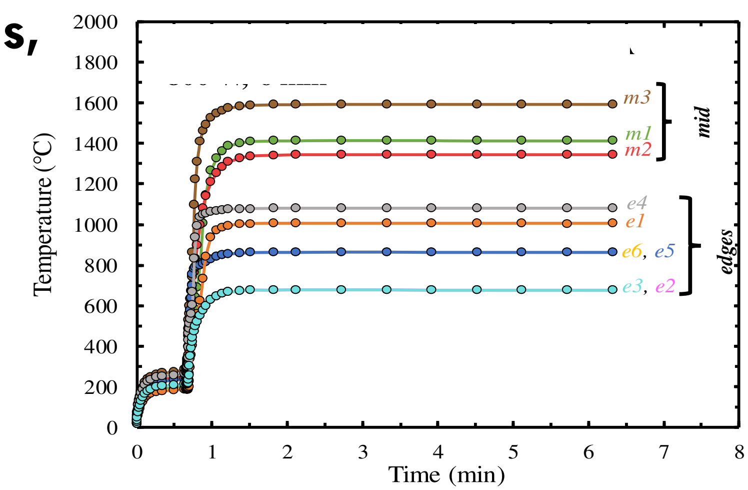






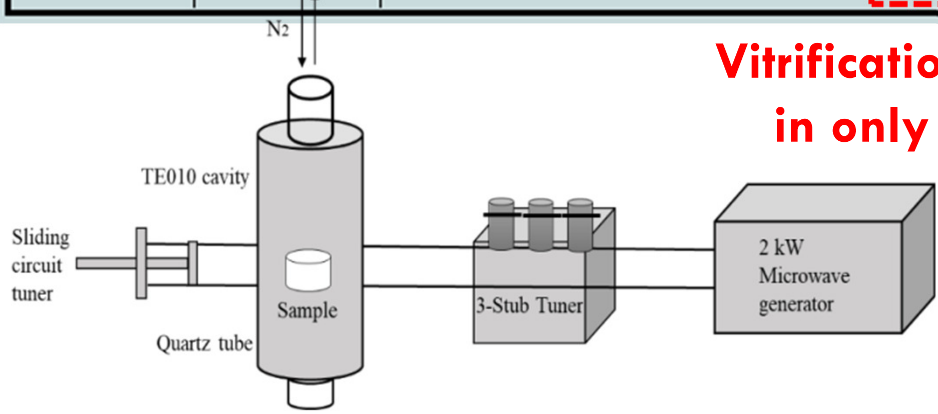
Depending on setup conditions, high temperatures can be reached.



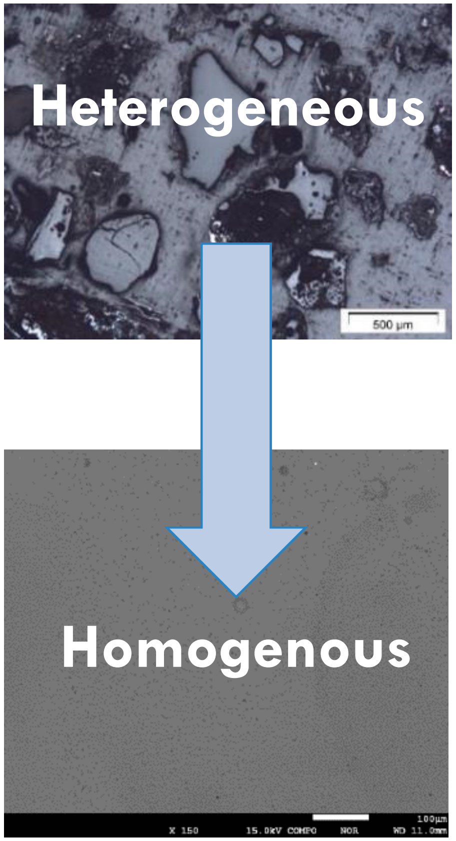


Bottom ash conditioning: Microwave

Theoretical Energy Input (kJ/kg)	Specific Energy Input (kJ/kg)	Experimental parameters: Reflected Power (W)	Power Input (W)	Treatment time (min)	Output: Glass yield (%)
2400	783	159	200	6	0±0
2400	1501	121	400	3	0±0
2400	1087	309	800	1.5	4±0
4800	3405	60	200	12	38±7
4800	3373	67	400	6	51±3
4800	3268	49	800	3	65±4
9600	8269	24	200	24	64±2
9600	7998	38	400	12	69±3
9600	8578	35	800	6	86±0

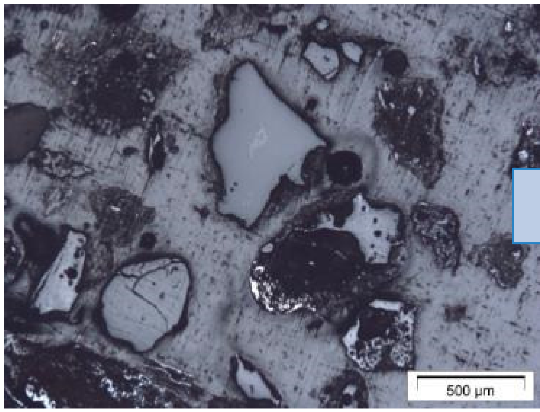


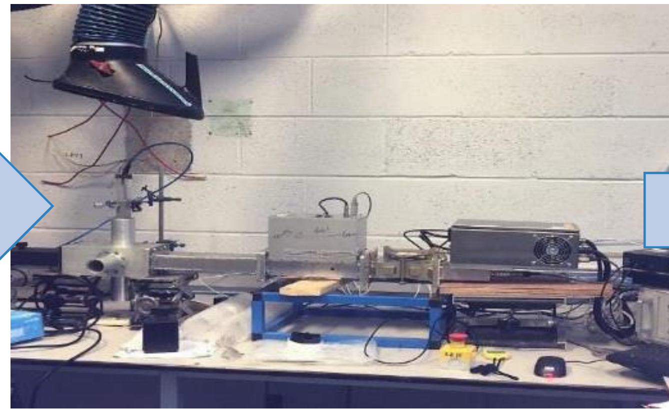
Vitrification yield 86% in only 6 minutes

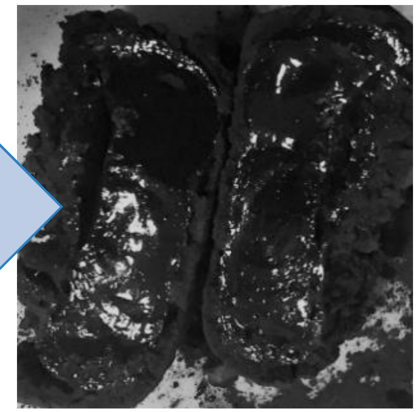


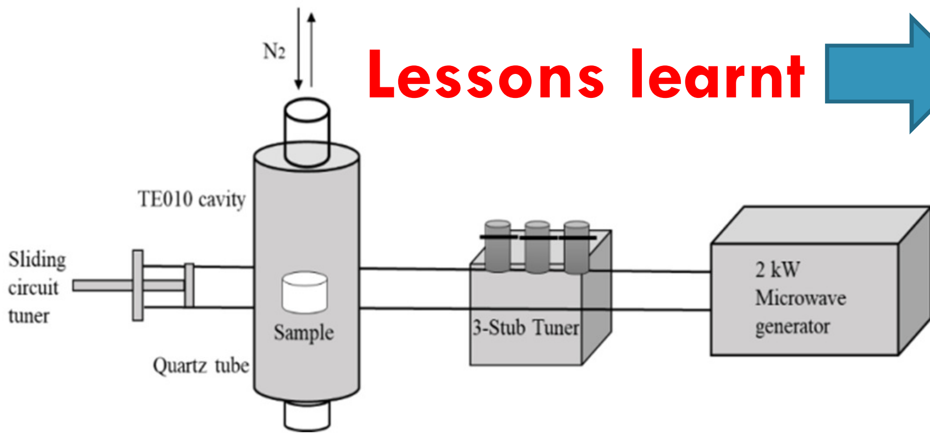
Bottom ash conditioning: Microwave

IBA **Microwave** **vitrified IBA.**









Lessons learnt

SAF… needs hours
Microwave … minutes

Microwave favours a flash vitrification and conditioning of WtE ashes

Bottom ash conditioning: Chemical stability [EN 12457-4]

Leaching [mg/Kg]	MSW			Landfill waste		
	IBA	IFA	VIBA	RDF	IRDF	VIRDF
As	0,03	0,01	0,01	0,05	<0,01	0,12
Ba	1,42	5,22	0,24	0,95	5,24	0,17
Cd	<0,01	0,06	<0,01	0,01	0,01	<0,01
Cu	3,64	0,19	0,08	0,82	0,03	0,13
Mo	1,14	6,83	0,40	0,31	0,56	0,43
Ni	0,16	0,12	<0,01	0,33	0,13	<0,01
Hg	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
Sb	1,00	0,02	0,17	0,19	0,83	0,46
Pb	<0,01	0,25	0,14	0,03	<0,01	0,20
Se	0,02	0,31	<0,01	0,01	0,01	0,03
V	0,01	0,03	0,04	0,06	0,02	0,05
Zn	<0,01	2,77	0,05	0,92	<0,01	0,11
Cr	0,02	14,88	0,07	0,03	<0,01	0,07
F	9,08	6,05	<0,01	3,70	7,00	1,83
Cl	3.252,77	126.061,67	13,97	305,12	18.335,91	34,27
Br	110,05	1.725,86	<0,01	<0,01	206,70	<0,01
NO3	62,33	1,35	0,33	229,09	<0,01	1,00
SO4	4.343,40	10,56	16,60	3.601,44	4.237,01	105,10
Type	NHW	HW	Raw material	NHW	HW	Raw material

RDF: refused derived fuel, IRDF: incineration RDF & VIRDF: Vitrified IRDF

Non-hazardous waste (NHW)	Hazardous waste (HW)	Fulfil most EU standards

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MSW or Landfill waste to Energy

- Concentrates hazardous in the mineral phase

Bottom ash conditioning: Chemical stability [EN 12457-4]

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Non-hazardous waste (NHW)	Hazardous waste (HW)	Fulfil most EU standards

MSW or Landfill waste to Energy
- Concentrates hazardous in the mineral phase

WtE outputs to SAF/Microwave vitrification
- Eliminates hazardous and produces amorphous slags
- Slags have to be fluxed to fulfil all EU standards

Bottom ash conditioning: Chemical stability [EN 12457-4]

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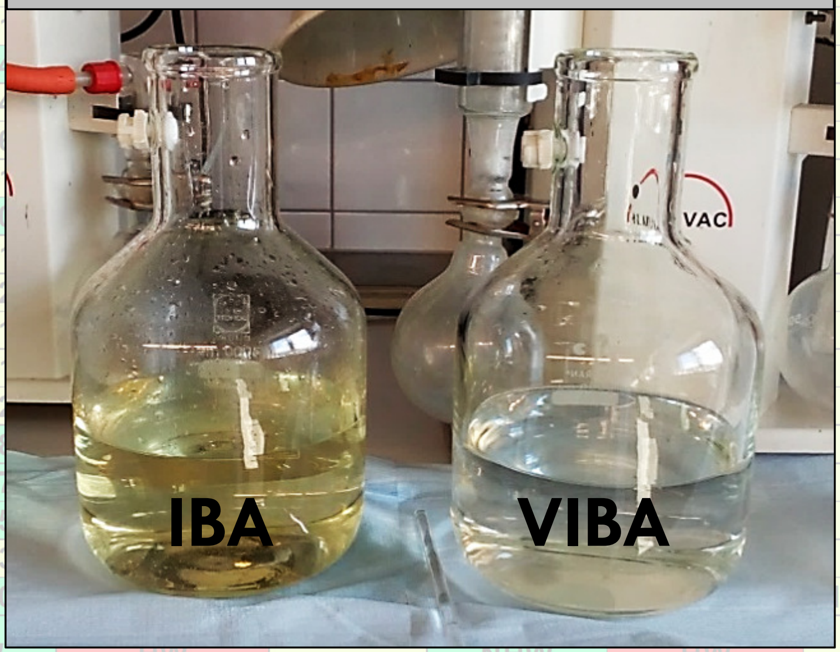
Cr	0,0	0,07
F	9,0	1,83
Cl	3.252,7	34,27
Br	110,0	<0,01
NO3	62,3	1,00
SO4	4.343,4	05,10
Type	NHW	Raw

Before → After

Thermal treatment



How effective are the thermal treatments for conditioning mineral waste?

MSW or Landfill waste to Energy
- Concentrates hazardous in the mineral phase

WtE outputs to SAF/Microwave vitrification
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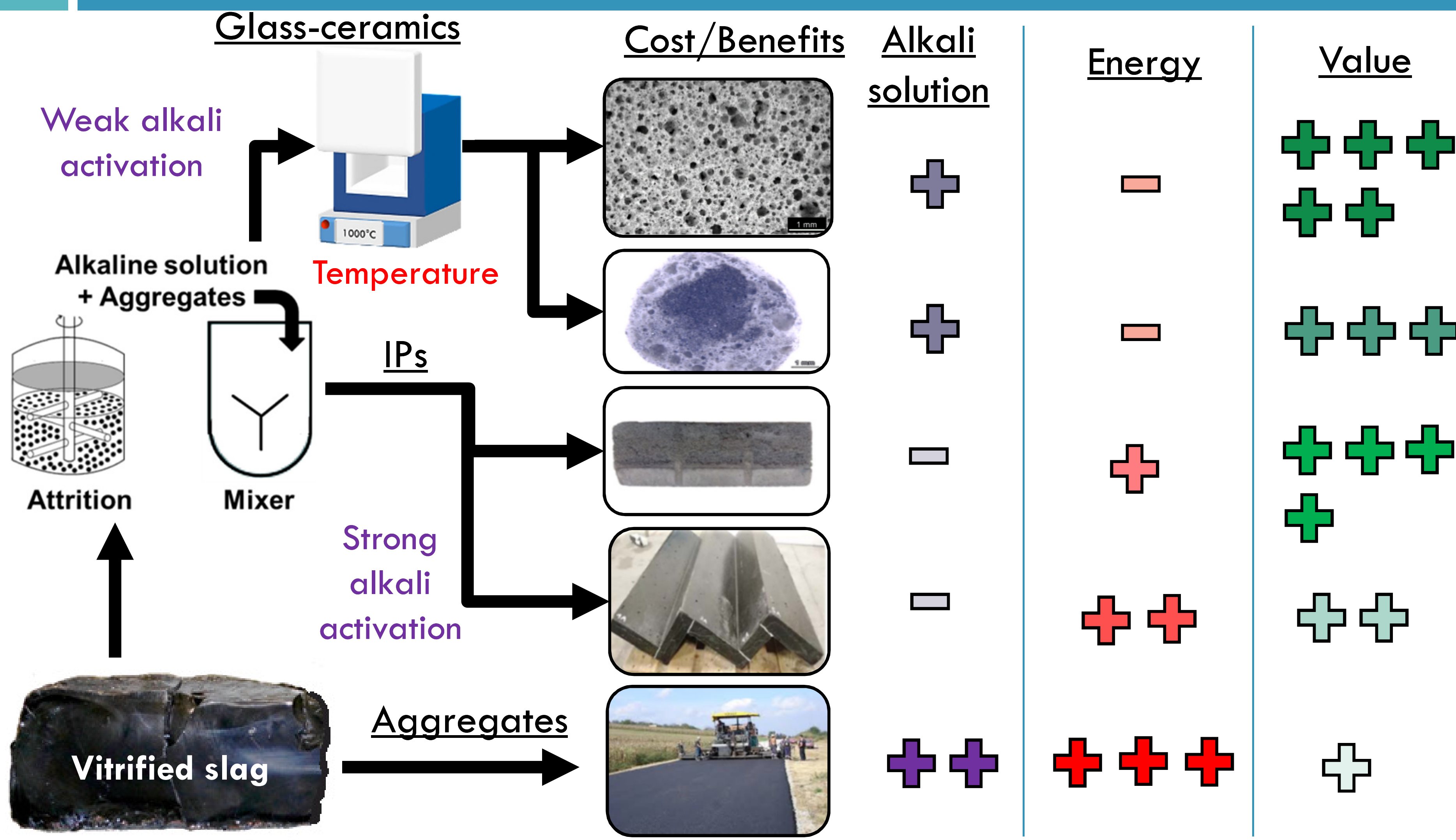
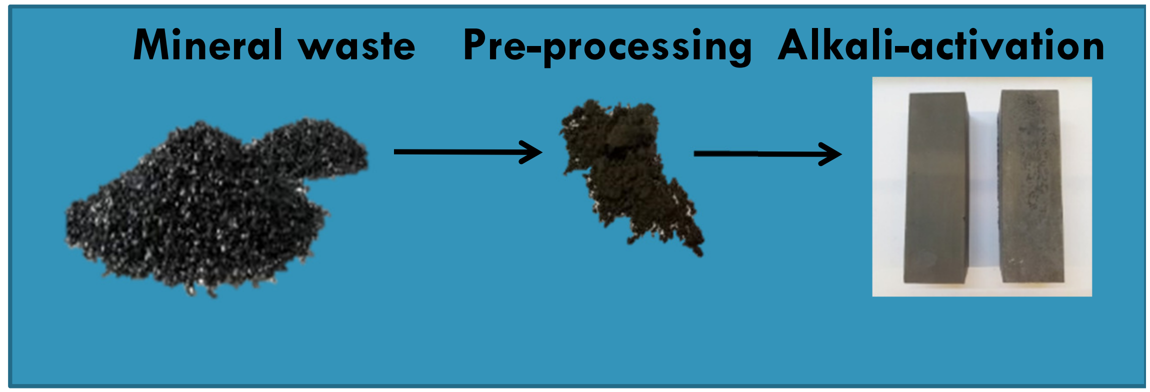
Upcycling

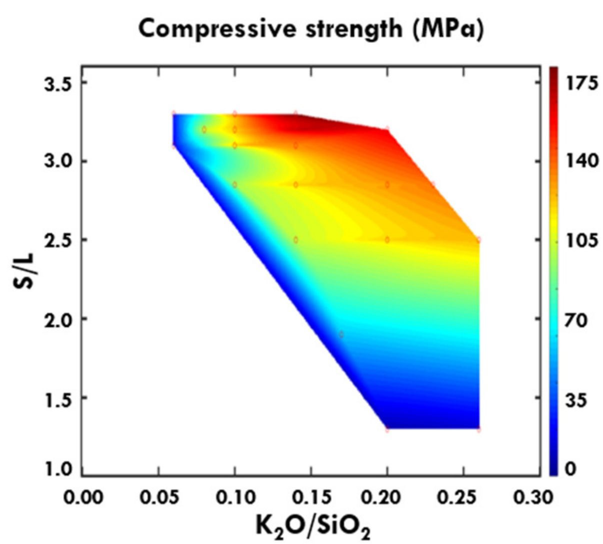

Glass-ceramics
Weak alkali activation
1000°C
Temperature
Alkaline solution + Aggregates
Attrition
Mixer
IPs
Strong alkali activation
Vitrified slag
Aggregates
Cost/Benefits
Alkali solution
Energy
Value

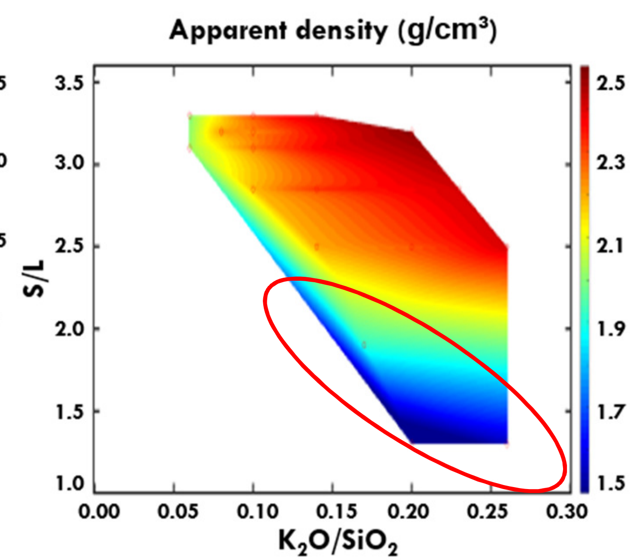
Upcycling: IPs building materials

Screening tests, sequential optimization and DoE



- Solid/Liquid ratio
- $SiO_2/(Al_2O_3+Fe_2O_3)$ molar ratio
- Type of activator
- Initial curing conditions (temp. and RH)
- Activating solution molarity
- K-silicate in the activating sol



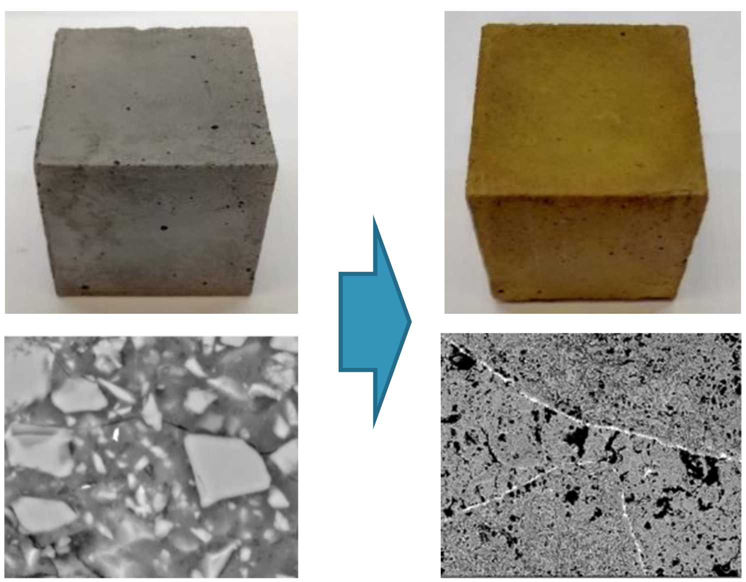


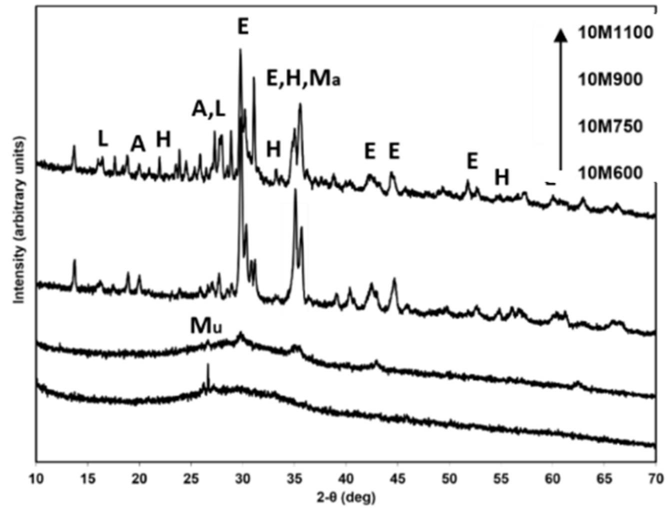
Upcycling: IPs building materials

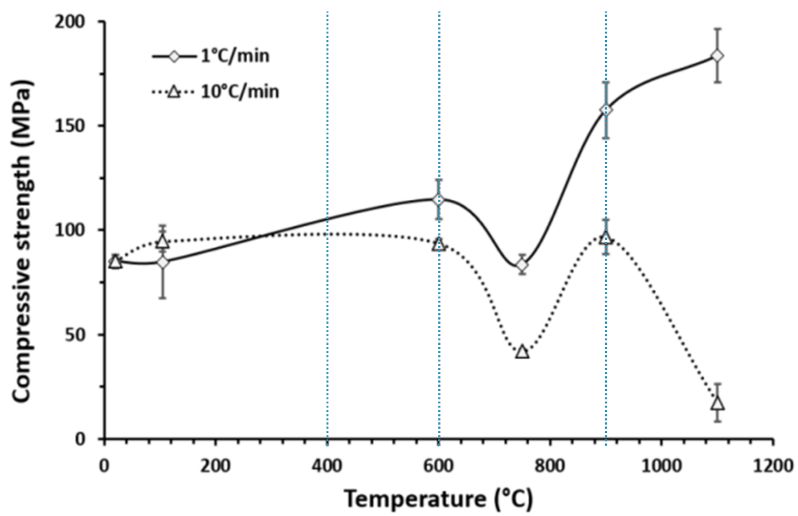
High temperature resistance

- Temperature up to 1100 °C
- Heating rate (1 and 10 °C)
- No shrinkage reducing agents or PCM

Room temperature 1100 °C_1 °C/min







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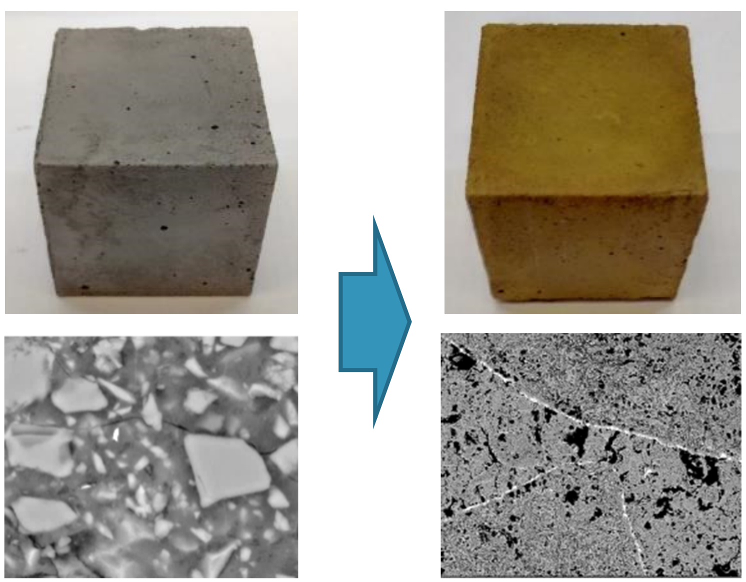
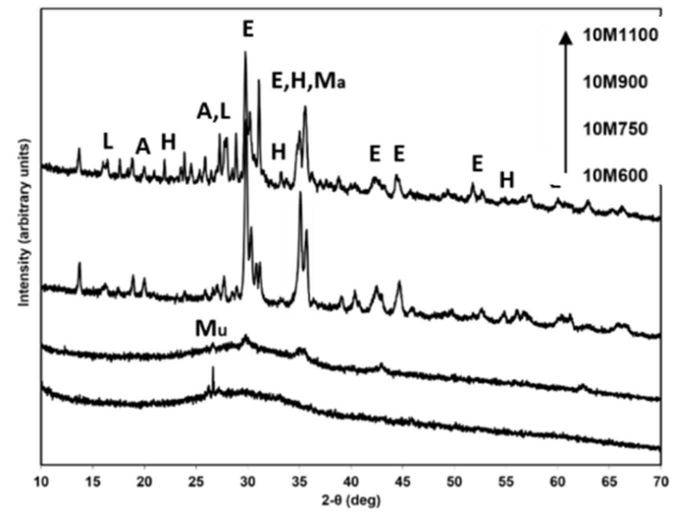
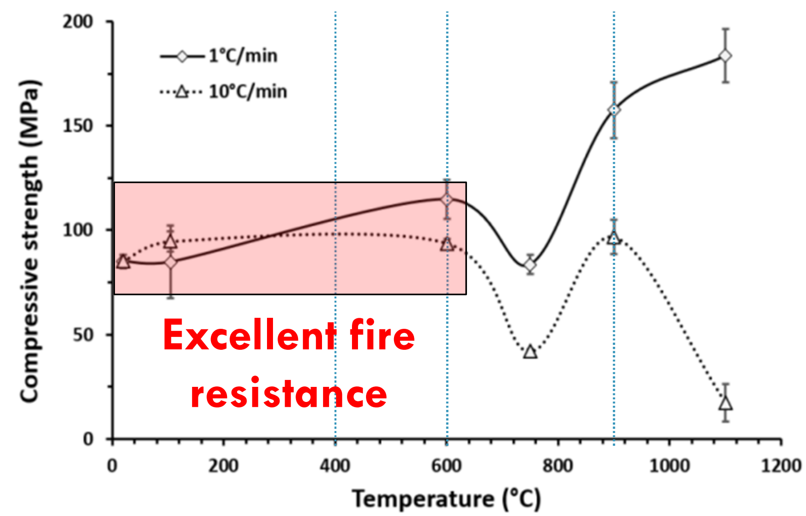






Upcycling: IPs building materials

Multifunctional building elements

Upscaling stage

External layer:

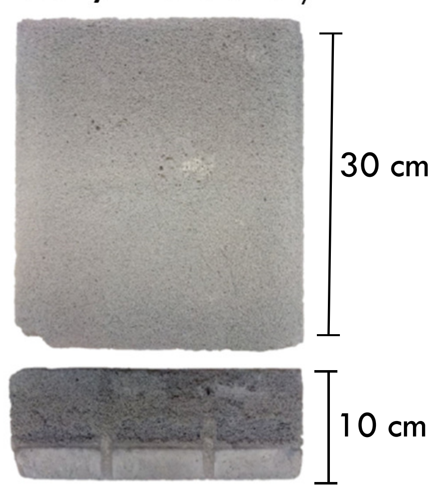
- ❑RSA+ 10 wt% PCM
- ❑ρ≈ 2400 kg/m³
- ❑λdry≈ 0.8 W/m°K

Foamed layer:

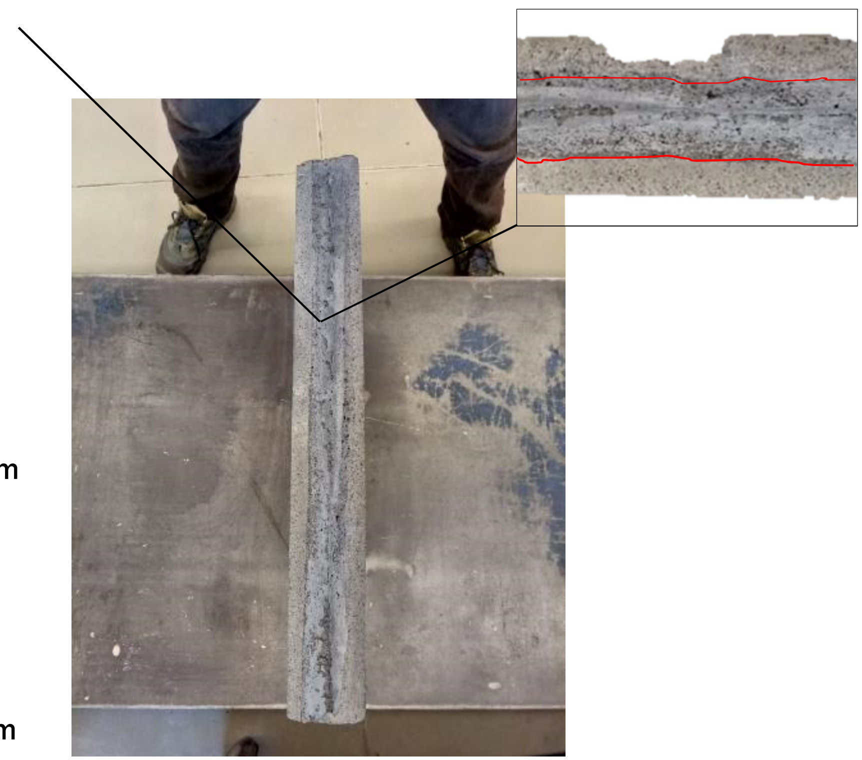
- ❑ρ≈ 620 kg/m³
- ❑λdry≈ 0.08 W/m°K

Predicted properties:

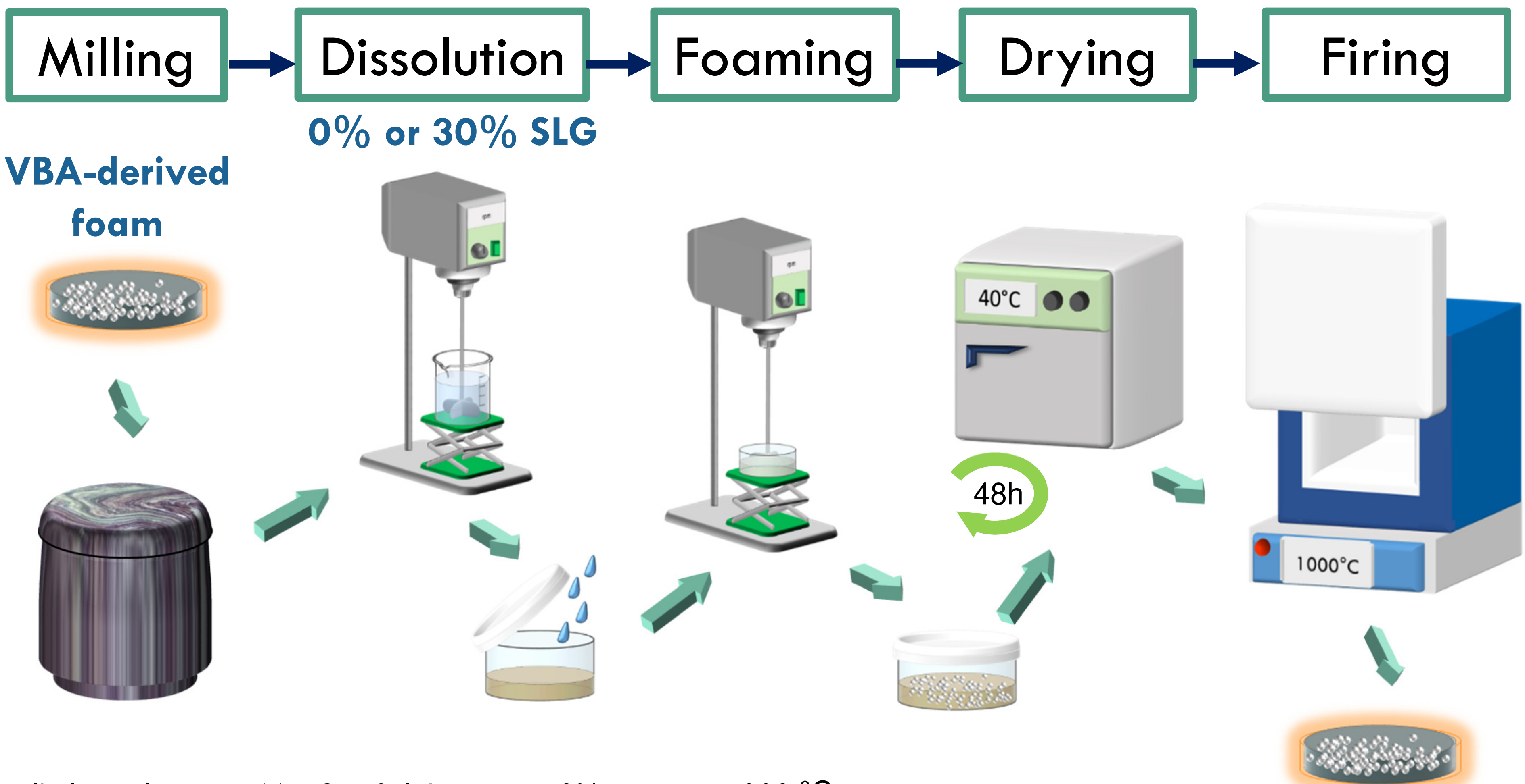
- ❑σ ≈ 35MPa
- ❑ρ≈ 710 kg/m³
- ❑λdry≈ 0.08 w./mK



Multilayer panels

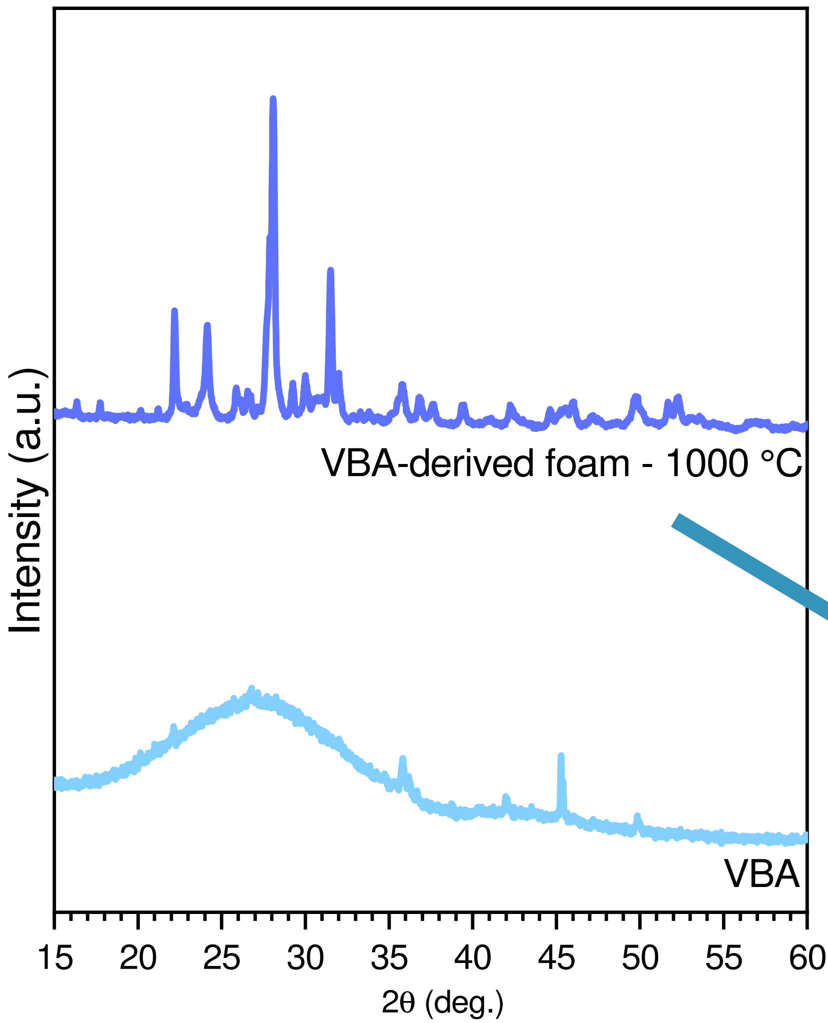


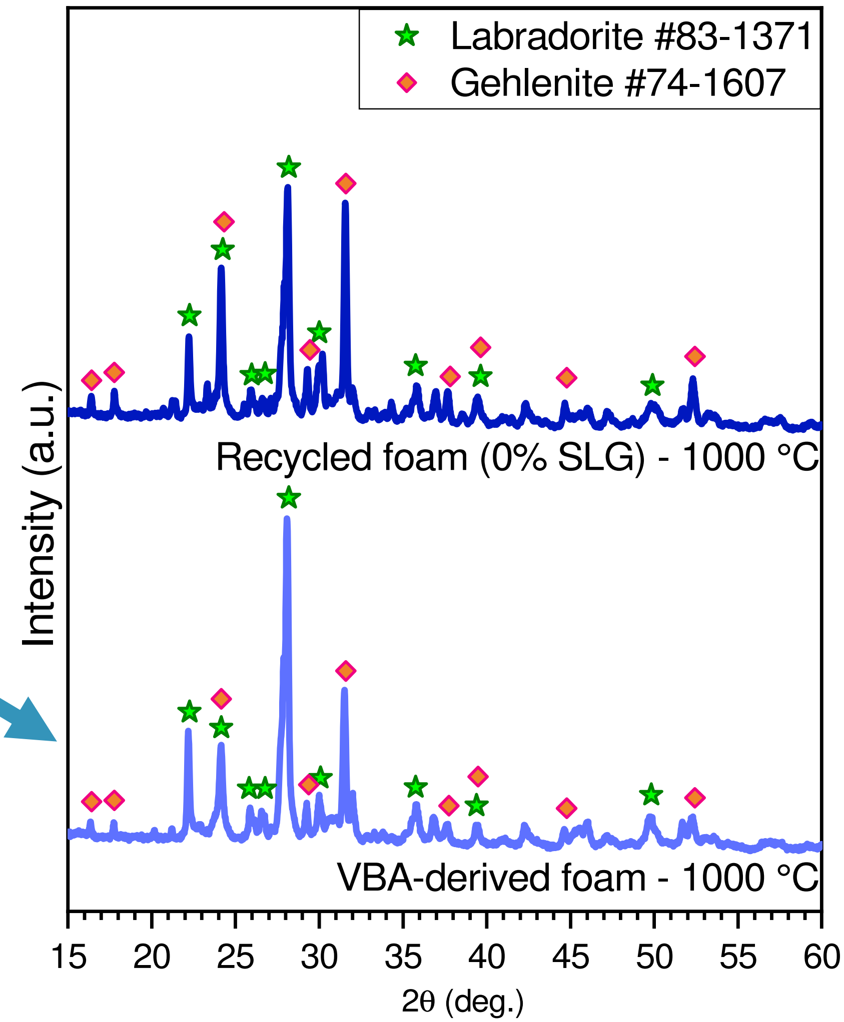
Upcycling: glass-ceramic building materials



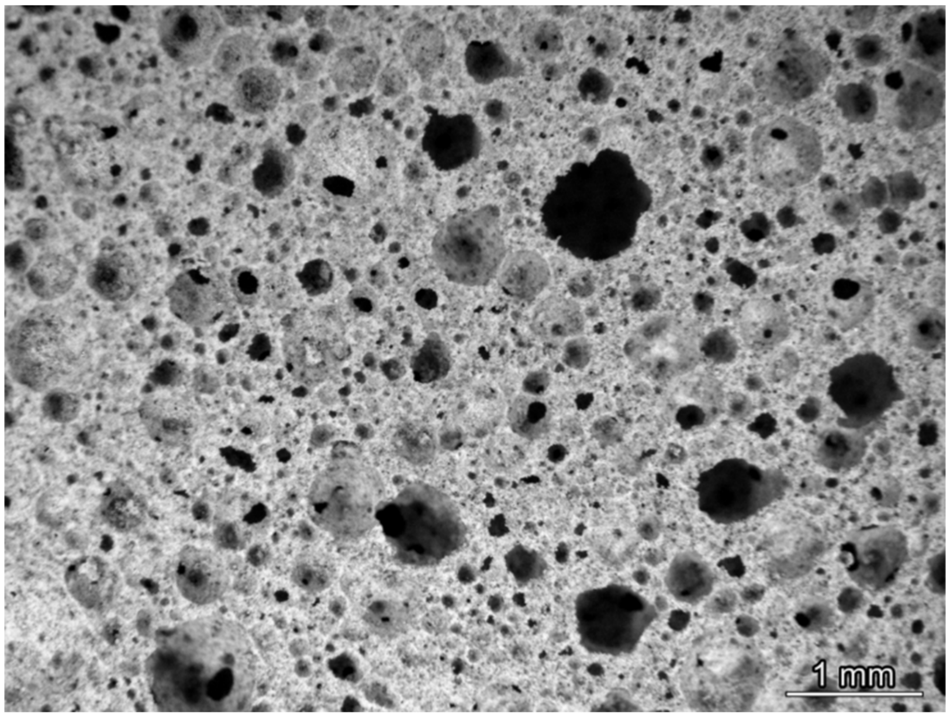
Alkaline soluiton: 1 M NaOH; Solid content: 70%; Firing at 1000 °C

Upcycling: glass-ceramic building materials





Upcycling: glass-ceramic building materials



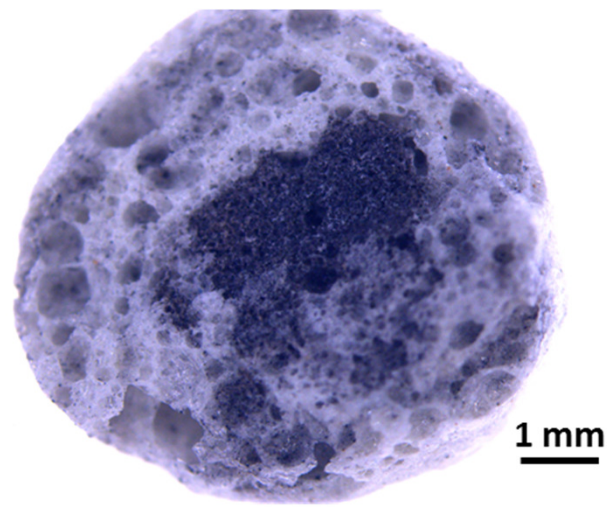
Group of samples	VBA-derived foams	Recycled VBA-derived foams
P_{total}	80.7%	75.0%
P_{open}	79.9%	74.4%
P_{closed}	0.8%	0.6%
σ_c (MPa)	3.03 ± 0.49	1.06 ± 0.14
σ_{bend} (MPa)*	179	42
Inert waste	Yes	Yes

*Calculated by using Gibson and Ashby model for open-celled foams: $\sigma_c \approx 0.2\ \sigma_{bend} \cdot (\rho_{rel})^{3/2}$

Upcycling: glass-ceramic building materials

Lightweight aggregates

Firing temperature	800 °C
ρ_a (g/cm^3)	0.847
ρ_{rd} (g/cm^3)	0.779
ρ_{ssd} (g/cm^3)	0.859
Water absorption (%)	10.26
Inert waste	Yes



Core-shell structure 70% SLG / 30% Plasmastone mixture inside SLG coating.

Conclusions

- Thermal treatment residues from WtE plants can be turned into raw-materials
- Studies carried out can be used to scale up the thermal processing
- Submerged arc furnaces provide a robust technique for conditioning large amounts of mineral waste
- Microwave is a promising technique to reduce time and energy for treating waste
- IPs and glass-ceramics are two methods that can successfully upcycle mineral by-products into valuable eco-friendly construction materials

THANK YOU FOR YOUR ATTENTION

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